County of Ventura

Board of Supervisors Hearing

September 15, 2020

Case No. PL17-0141

Exhibit 19.k

Final EIR, Attachment 1 (Part 2 of 4)

Simmons, Carrie

From:	Curtis, Susan
Sent:	Thursday, February 27, 2020 2:00 PM
To:	Simmons, Carrie
Subject:	FW: 2020 general plan EIR comment letter
Attachments:	2020 General Plan letter to Supervisors.docx
Follow Up Flag:	Follow up
Flag Status:	Flagged

Susan Curtis l Manager
General Plan Update Section
susan.curtis@ventura.org

Ventura County Resource Management Agency | Planning Division
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Visit the Planning Division website at **vcrma.org/planning**
Ventura County General Plan Update. Join the conversation at **VC2040.org**
For online permits and property information, visit **VC Citizen Access**

From: Elaine CAVALETTO <elainesomis@msn.com>
Sent: Thursday, February 27, 2020 1:59 PM
To: Curtis, Susan <Susan.Curtis@ventura.org>
Cc: chris@rinconstrategies.com; Louise Lampara <llampara@colabvc.org>
Subject: 2020 general plan EIR comment letter

H ELAINE CAVALETTO
4031 PRICE ROAD, SOMIS, CA 93066
elainesomis@msn.com 805-479-1422

February 27, 2020

Ventura County Board of Supervisors:
Susan.Curtis@ventura.org

Re: 2040 General Plan Draft EIR Comment

I have some concerns about the 2040 General Plan Report (EIR) that has recently been released. With 700+ policies and implementation programs how can you say you have finished this plan in 6 weeks? 12-18 + months is, what I am understanding, what it takes to adequately complete all the analysis and their impacts.

As an 85 year old farmer, in this county since 1957, it appears that more and more you are not looking what is best for individuals nor long/short term solutions to many issues.

As with a recent issue, a few people stood up talking about "their rights" and to heck with other's rights. Maybe the initial decision, to approve the crop, was made in haste. As well as extending the ban to plant the crop to 10 ½ months. Why not go for another 45 days? You have just taken income from those that farm and taken the side of those who "yell" the loudest.

Wildfire Corridor is another issue – restrictions on brush removal leads to increased fuel load and increased wildfire risk. Did your decisions make things better or worse?

Why would you require small development projects to purchase farmland to preserve in perpetuity? Where are small pieces of farmland available and who will manage these small ag preservation parcels. Again, as I see it, take away from those in agriculture to give to others who have not put in any dollars, sweat or tears in the land. Again, increasing regulatory demands on agriculture.

How current was the background information that was used to understand and evaluate the County's impact analysis. My understanding is that it was older than 2015.

What does the analysis show on these indirect impacts that affect landowners? Such as: theft and vandalism, complaints by those who know nothing about agriculture, water competition, speeding cars in rural areas without regard for farm machinery, etc.

There are many other areas that I feel were not considered and most certainly will continue to increase farming operational costs such as: converting ag equipment to electric, requiring all electric water pumps, water supply increases.

Sincerely,
H Elaine Cavaletto

cc: chris@rinconstrategies.com and llampara@colabvc.org

Simmons, Carrie

From: Curtis, Susan
Sent: Thursday, February 27, 2020 2:19 PM
To: Simmons, Carrie
Subject: FW: Comments on General Plan/EIR

Follow Up Flag: Follow up
Flag Status: Flagged

Susan Curtis l Manager
General Plan Update Section
susan.curtis@ventura.org

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From: Meghan McMonigle <meghancmcmonigle@gmail.com>
Sent: Thursday, February 27, 2020 2:12 PM
To: Curtis, Susan <Susan.Curtis@ventura.org>
Cc: Bev Denicola <de.nicola@cox.net>
Subject: Comments on General Plan/EIR

Ventura County Resource Management Agency, Planning Division
Attn: Susan Curtis, Manager, General Plan Update Section
800 S. Victoria Ave., L #1740
Ventura, CA 93009-1740

GeneralPlanUpdate@ventura.org

Dear Ms. Curtis:

I am writing to call your attention to significant flaws in the process, data, and conclusions of the Ventura County General Plan, Draft EIR, and supplemental documents.

My great great grandfather, Mark McLoughlin (1843-1914), was a true Ventura County pioneer, purchasing his first 318 acres of undeveloped land in Ventura County in 1875. He was a hard-working visionary, revered by his community. With his son—my great grandfather, James Patrick McLoughlin—he raised livestock and farmed the land, providing jobs and feeding the growing towns of Oxnard and Ventura.

Our land, in a vitally important location on Olivas Park Drive across from the Ventura Marina, has been in the family, and part of the economic fabric of the community, for 100 years. And we want it to be part of the future of this community, with a flourishing economy, a thriving job market, and unsurpassed quality of life for its residents.

But the General Plan and DEIR do not describe a viable path for us as landowners going forward.

I will begin with some specific issues regarding language in the Coastal Area Plan, 4-82-83 and 4-94-95. Part of our land is located in the Central Coastal Zone, adjacent to the Ventura Marina, on Olivas Park Drive at Harbor Blvd. The only conclusion the Plan draws about our land is the statement that, "unlike the Preble area, services are not readily available to the Olivas lands." This is false. Our property has access to all utilities, water, main roads, and the freeway. Indeed, easements on our property serve surrounding areas with utilities.

The Plan also claims that our property is "not included in the City's sanitation district because of problems with water pressure." This language is irrelevant and incorrect. There is no evidence that there are water pressure issues, and the sanitation district's pipelines actually traverse our property.

While we do not know the original source of these misstatements, such misrepresentations—now repeated in the Plan—threaten to diminish the value of our land in relation to the Preble property. And, of course, they undermine the goal and the value of the Plan itself.

The General Plan also speaks of the widening of Olivas Park Drive, our southern boundary. This would have a direct impact on our property. But the Plan does not address how this would happen or how it would affect our land.

Damaging misstatements about our property also appear In the DEIR. Contrary to the portrayal in the DEIR, our property has significant infrastructure in place, as well as prime accessibility to the highway and the harbor. In fact, with easy access to the marina and beach community, and with the railroad as part of our eastern boundary, our land is uniquely suited to be an important part of future economic development in the area. We are entitled to have all these matters corrected.

I would also like to raise some additional concerns:

1. The General Plan and DEIR continue to ignore the 28% increase in the homeless population in our community.

2. According to the General Plan, if we were to build an acre of low income / worker housing we would need to buy two replacement acres of same Ag land to be placed into perpetual agricultural preservation. This is unrealistic and infeasible, and certainly not in line with the State government's housing policies.

3. The EIR does not adequately address the enormous “indirect impacts” that will occur as a result of implementing the General Plan, calling them “less than significant.”

4. The General Plan contains policies that will increase the costs of normal farming operations, making it difficult for farming to remain profitable.

5. The Plan does not adequately evaluate the impacts of increased competition for water in our community.

The EIR is a flawed document, full of errors, that does not disclose all impacts, direct and indirect, caused by the General Plan. It was obviously rushed—completed in six weeks. It is inaccurate and incomplete, and fails to provide members of the community with the information that they are legally entitled to. This EIR should be corrected and reconsidered, and a reasonable time period should be allowed for meaningful and thoughtful community input.

Sincerely,

Meghan Elizabeth McMonigle

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Meghan McMonigle
KTLA 5 Technology Segment Producer
5800 Sunset Blvd. Los Angeles, CA 90028 | *Office: 323-460-5520* | *Cell: 323-371-4042*

Simmons, Carrie

From:	Curtis, Susan
Sent:	Thursday, February 27, 2020 2:19 PM
To:	Simmons, Carrie
Subject:	FW: Ventura County GPU EIR - SoCalGas Comments
Attachments:	Ventura GPU EIR Comment Letter_2.27.2020_Final.docx; Ventura County GPU&CAP Comment Letter.docx
Follow Up Flag:	Follow up
Flag Status:	Flagged

Susan Curtis l Manager
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From: Pezda, Jennifer <JPezda@socalgas.com>
Sent: Thursday, February 27, 2020 2:16 PM
To: Curtis, Susan <Susan.Curtis@ventura.org>
Cc: Ventura, Maria M <MVentura@socalgas.com>
Subject: Ventura County GPU EIR - SoCalGas Comments

Hi Susan,

Please find attached SoCalGas' comment letter for the County's General Plan Update EIR. I've also attached our prior comment letter on the General Plan Update and Climate Action Plan, for reference.

Let me know if you have difficulty accessing any of the documents. Our regional public affairs representative is also hand-delivering our comments to County Staff.

Thank you!

Sincerely,
Jenny Pezda

Jenny Pezda, MESM | Environmental Policy Advisor | **SoCalGas**
Office: 213-244-4570
Cell: 213-321-8443

SoCalGas
A Sempra Energy utility

Jennifer Pezda, MESM
Environmental Policy Advisor

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6/21/2019
Susan Curtis
RMA Planning Division, General Plan Update
800 South Victoria Avenue., L #1740
Ventura, CA 93009-1740

RE: Ventura County 2040 General Plan Update and Climate Action Plan

Dear Ms. Curtis,

SoCalGas appreciates the opportunity to submit comments on County's Preliminary Public Review Draft General Plan (Draft Plan). We have been continually engaged in the development of the Draft Plan and further appreciate the opportunities to attend public workshops, planning commission meetings, and participate in online surveys as means to submit feedback throughout the planning process. We believe this document will provide valuable direction for the County to pursue effective, long-term sustainable planning goals. SoCalGas especially supports the County's direction to pursue policies that promote furtherance of renewable energy development and expansion while also contributing to regional and local resiliency. We support many of the policies currently included in the Draft Plan and look forward to partnering with the County to achieve these ambitious strategies and actions. We do believe the Draft Plan could benefit from active identification and incorporation of the following takeaways:

- **The Draft Plan can be greatly enhanced by pursuing significant synergies between production and use of renewable natural gas (RNG) and the County's renewable energy goals, waste reduction/diversion targets, and emission reduction strategies.**
- **Because the pipeline system that delivers RNG is inherently resilient to aboveground climate events, it can greatly help increase the resiliency of County infrastructure and operations to climate hazards and impacts.**

Most prominently, we are excited at the potential opportunities that exist between the county's waste reduction and diversion targets, as stated in the Draft Plan, and development and use of RNG resources that can drive and incentivize their attainment. RNG can be produced from existing waste streams within the County, including organic waste, green waste, and agricultural waste. This aligns with the goals of Strategy PFS-5.5 – "support the beneficial reuse of agricultural wastes…such as energy generation" and PFS-5.6 – "promote value-added alternatives to solid waste management, such as…energy." Further, the organic waste diversion incentives generated by RNG production would also help the County achieve the organic waste diversion targets mandated under SB 1383. Similarly, use of existing waste resources to produce RNG aligns with the County's emphasis to increase the use of renewable energy as stated in Policy COS-8 and its supporting strategies that advocate promoting development and use of renewable energy resources (including bioenergy) and transitioning to zero net energy buildings (Strategies COS-8.1 and 8.5, respectively). We are ecstatic to see that such synergies are acknowledged in the GHG Mitigation and Climate Adaptation Measures in the County's Draft Climate Action Plan, Appendix B of the Draft Plan, such as in Policy AG-L which prompts the County to develop a program to coordinate public-private local investment in biogas control systems.

Because RNG is produced from existing methane sources that are otherwise being emitted into the air, unabated, capturing these emissions to produce RNG helps reduce both regional and local methane and GHG emissions. As a short-lived climate pollutant, methane has a greater global warming potential than carbon dioxide—specifically, methane is approximately 28 times more potent than carbon dioxide in the atmosphere[1,2]. From a lifecycle perspective, because RNG production removes a greater quantity of more potent GHG emissions from the air than what it produces at end uses, its production is a **carbon negative process**, and can be used to offset other uses that cannot achieve carbon neutrality. As the County is aware, SoCalGas recently filed a request with the California Public Utilities Commission seeking to offer RNG to all customers, which would have significant potential to significantly reduce both local and regional GHG emissions. In fact, replacing only 20% of existing natural gas supply with RNG achieves the same emissions reductions as electrifying the entire building sector by 2030, but at one-third of the cost.[3] For these reasons, we recommend that the Draft Plan include additional policies and supportive strategies to promote both production and use of RNG as an incentive mechanism to enhance organic waste reduction/diversion, in addition to use as a renewable fuel option for decarbonizing the building and transportation sectors.

The underground natural gas system is more resilient than the aboveground electric system

Use of RNG as a renewable energy source also has synergies with County resilience goals and targets. As stated at the recent Planning Commission General Plan Update Workshop on June 13th, 2019, County staff directly acknowledged the dual importance of decarbonizing energy supplies but while also keeping in mind the critical importance of energy reliability. As we know, the impacts of global climate change are set to continually increase in severity, which will result in more severe wildfires, storms, and floods. Wildfire risk, specifically, is one of the most prominent climate change hazards facing the County, especially as just over the past two years Southern California has experienced two of the largest wildfires in the State's history that burned millions of acres and destroyed thousands of homes and property, a significant portion of which occurred within Ventura County. To this end, SoCalGas supports the draft policies

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[1] IPCC. Global Warming Potential Vallueshttps://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

[2] California Air Resources Board (CARB). Understanding Global Warming Potentials. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

[3] PR Newswire. New Study Advises Policymakers to Consider Renewable Natural Gas for Low-Carbon Buildings Strategy. August 8, 2018. https://www.prnewswire.com/news-releases/new-study-advises-policymakers-to-consider-renewable-natural-gas-for-low-carbon-buildings-strategy-300691318.html

aimed at enhancing local adaptative capacity such as Policy HAZ-11.4, which supports education and outreach efforts to inform local communities about climate change impacts, and Policy HAZ-P, which aims to identify critical infrastructure vulnerable to extreme heat.

As seen in the recent wildfires and mudslides that ravaged Southern California, energy system vulnerability is a significant factor that affects local resilience to such hazards. As the electric system is almost entirely aboveground, it is significantly more exposed to threats and, when impacted, can not only leave hundreds to thousands of residents without power at their homes, but also affect operation of critical facilities. For example, in 2017 the Thomas Fire damaged electric power lines throughout the City of Ventura. Because the City's water pumps to supply water to firefighters ran on electricity without any other form of backup power, firefighters were unable to get water from the pumps to put out burning residences[4]. If the water pumps had been connected to a backup power system, such as a natural gas generator, firefighters would have been able to access the water.

In contrast, as the natural gas system is mostly underground, it is very resilient to extreme weather events. For example, in 2012, after Superstorm Sandy, the entire natural gas system in the Northeast was essentially intact, allowing residents to support back-up generators, cook, and keep warm. Businesses with natural gas-powered fuel cells were able to operate and compressed natural gas (CNG) buses in New Jersey were used to shuttle residents to safety[5]. Further, when Hurricane Harvey temporarily disabled almost 30% of the nation's refining capacity, CNG shuttles were able to continue operating, and hospitals that had on-site combined heat and power systems were able to provide urgently needed medical attention, despite flooding. These examples demonstrate the critical role natural gas infrastructure can play in supporting local and regional energy supply resilience in the face of extreme climate events and use of renewable natural gas can achieve additional co-benefits in reducing GHG emissions.

SoCalGas has been engaging with stakeholders and consultants to conduct case studies and risk assessments of the natural gas system with the intent to demonstrate the security and resilience of our system. SoCalGas intends to use this information to help local and regional cities and counties undertake similar efforts to identify system and infrastructure vulnerability. We also offer our annual Climate Adaptation and Resilience Grant[6] to local cities and counties to help fund efforts to update and develop local adaptation and resilience plans. We greatly appreciate recognition of our grant in the Draft Climate Action Plan and encourage the County to apply during this year's application period.

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[4] ICF. Case Studies of Natural Gas Sector Resilience Following Four Climate-Related Disasters in 2017. https://www.socalgas.com/1443742022576/SoCalGas-Case-Studies.pdf

[5] https://www.energy.gov/eere/articles/5-ways-alternative-fuels-aid-response-hurricanes-and-natural-disasters?utm_source=EERE+Weekly+Digest+of+Clean+Energy+News&utm_campaign=f048cbec65-EMAIL_CAMPAIGN_2017_09_25&utm_medium=email&utm_term=0_96dffafa2f-f048cbec65-34678197

[6] SoCalGas Climate Adaptation and Resiliency Planning Grant Program. https://www.socalgas.com/smart-energy/sustainability-at-socalgas/climate-grant

Looking forward, we believe renewable natural gas will play an important role in the County's renewable energy plans and help it achieve State GHG emission reduction goals, organic waste diversion goals, as well as climate resiliency goals. Decarbonizing our natural gas delivery system keeps intact the inherent energy efficiencies of direct uses of natural gas, at lower carbon-content, while also demonstrating synergies with County waste reduction goals by boosting efforts to enhance organic waste management and recycling. SoCalGas appreciates the opportunities provided by the County to engage throughout the formation of this Draft Plan and hopes to continue communication for the duration of the planning process. If you have any questions, please do not hesitate to reach out via telephone or email. Thank you!

Sincerely,

Jennifer Pezda, MESM
Environmental Policy Advisor
Southern California Gas Company

Deanna Haines
Director of Policy, Strategy and Environment

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Manager, General Plan Update Section
Ventura County Resource Management Agency, Planning Division
800 South Victoria Avenue, L #1740
Ventura, CA 93009-1740

RE: County of Ventura – Draft 2040 General Plan Update EIR

Dear Ms. Curtis,

Southern California Gas Company appreciates the opportunity to submit comments on the Draft 2040 General Plan EIR ("DEIR") and believes the document will provide valuable direction for the County to pursue effective, long-term development goals, as well as enhance local sustainability objectives. In particular, we support proposed policies that encourage beneficial reuse of County-generated waste for energy generation. Such policies have great potential to help reduce County GHG emissions, especially from agriculture and human waste streams.

However, SoCalGas is concerned by one of the County's proposed mitigation measures: MM GHG-1: New Implementation HAZ-X: Prohibit Natural Gas Infrastructure in New Residential Development:

> **Implementation Program HAZ-X: Prohibit Natural Gas Infrastructure in New Residential Development** – To support the proposed reach codes under COS-S, the 2040 General Plan shall include a new program in the Hazards and Safety element that prohibits the installation of new natural gas infrastructure in new residential construction through amendments to the Ventura County Building Code. This program shall also be extended to include commercial building types such as offices, retail buildings, and hotels where the use of natural gas is not critical to business operations and contain appliances that can be feasibility substituted with electricity powered equivalents." (pg. 4.8-45-46).

While we support the County's attempt to reduce emissions associated with buildings, this mitigation measure is technology-restrictive, may actually increase emissions and will limit the County's ability to explore other innovative approaches to achieve emissions reductions in the future without deleveraging residents and businesses to hedge themselves against climate risks such as wildfires and household rising energy costs.

This type of ban would contravene California state law and policy as it relates to the availability of natural gas as a resource for residents and to the provision of a reliable and resilient energy supply. In addition, such a ban raises concerns under federal law.

Further, the DEIR's analysis and treatment of MM GHG-1 is legally flawed under the California Environmental Quality Act ("CEQA"). First, the DEIR fails to consider, discuss or analyze the environmental effects of implementing MM GHG-1. Second, the County cannot rely on MM GHG-1 to mitigate GHG impacts caused by the 2040 General Plan because MM GHG-1 is "infeasible" under CEQA. Lastly, by finding that climate change impacts would remain significant and unavoidable even with implementation of MMs GHG-1 through GHG-3, the County has neglected to consider other GHG emission reduction strategies as potential mitigation in the DEIR.

1. **The DEIR Fails to Analyze the Environmental Impacts Associated with MM GHG-1**

CEQA Guidelines section 15126.4(a)(1)(D) provides that, if a mitigation measure would itself cause significant environmental impacts, those impacts must be discussed in the EIR.[1] Here, the DEIR discusses what MM GHG-1 would consist of (*i.e*., implementation of programs to prohibit natural gas infrastructure in new residential development, otherwise known as "Reach Codes"), notes that MM GHG-1 would implement Policy COS-8.6, which "will encourage zero net carbon emissions building design, which was assumed for quantifying GHG reduction benefits of the program", and states that implementation of a Reach Code will be predicated on a "cost-effectiveness study" by the California Energy Commission ("CEC").[2] However, the DEIR fails to discuss the potential environmental effects from implementing a Reach Code that bans or restricts natural gas in residential and/or commercial buildings.

Substantial evidence indicates that adopting and implementing MM GHG-1 and Reach Codes could lead to the following significant environmental impacts under CEQA.

- ***Utilities and Service Systems –*** In the CEQA Guidelines Appendix G checklist,[3] section "XIX. Utilities and Service Systems" asks whether proposed projects would "[r]equire or result in the relocation or construction of new or expanded water, wastewater treatment or storage drainage, *electric power*, … facilities, the construction or relocation of which *could* cause significant environmental effects."

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[1] 14 Cal Code Regs. § 15126.4(a)(1)(D); *see also Sacramento Old City Assn. v. City Council* (1991) 229 Cal.App.3d 1011, 1027; *Stevens v. City of Glendale* (1981) 125 Cal.App.3d 986); *Ocean View Estates Homeowners Assn., Inc. v. Montecito Water Dist.* (2004) 116 Cal.App.4th 396, 400 (mitigation measures employed to prevent downstream flooding associated with reservoir project may themselves have a significant environmental impact, but was not analyzed); *Gray v. Cty. of Madera* (2008) 167 Cal.App.4th 1099, 1118 (EIR did not address potentially significant impacts associated with water quality mitigation measures).

[2] DEIR at 4.8-47.

[3] *See* Governor's Office of Planning and Research, Final Adopted Text of Revisions for CEQA Guidelines, http://resources.ca.gov/ceqa/docs/2018_CEQA_FINAL_TEXT_122818.pdf.

Adoption and implementation of a Reach Code would require new buildings to either be all-electric or, if mixed-fuel, likely subject to higher levels of energy efficiency than all-electric buildings. It is reasonably foreseeable that some developers will choose to develop buildings with all-electric energy, which will increase the demand for electricity; however, there is no analysis in the DEIR as to whether (i) the local grid has the generating resources and capacity to meet such increased demand for electricity, or (ii) whether the local public utility or load-serving entity has sufficient distribution or transmission assets to provide increased service in a safe and reliable manner.[4] The DEIR fails to quantify increased electricity demand, how many additional generation, distribution or transmission assets may be needed to facilitate this increased demand, or how the construction or relocation of such assets could impact the environment.[5]

The need to substantially overbuild local power systems when natural gas is not used as a base load means that a much greater amount of land, habitat and related physical resources will be impacted by solar and wind generation facilities. In a scenario where natural gas is banned across the state, new solar arrays and wind farms will need to be fabricated, transported to, and installed throughout California at more than five times the historical rate of deployment every year for the next 25 years.[6] This deployment will significantly impact the physical environment across California. The fabrication, transportation and construction of the required generation facilities will also generate GHG emissions that would have cumulative climate change impacts.

In addition, as more electric energy is utilized new transmission capacity must be fabricated, transported to and installed throughout the state to connect with thousands of miles of new nationwide transmission lines. Additional transmission facilities will have significant impacts to the physical environment and result in aesthetic and potentially cultural impacts. The fabrication, transportation, and construction of new transmission equipment and capacity will also generate GHG emissions.

Because renewable generation is intermittent, California will also be required to increase power storage capacity to unprecedented levels if natural gas is banned. This could equate to over 300 Tesla Powerwall 2 systems per household, which each cost about $7,800 for hardware and equipment.[7] Alternatively, California would need to

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[4] *See, e.g.*, Pub. Res. Code § 451 ("Every public utility shall furnish and maintain such adequate, efficient, just, and reasonable service, instrumentalities, equipment, and facilities, including telephone facilities, as defined in Section 54.1 of the Civil Code , as are necessary to promote the safety, health, comfort, and convenience of its patrons, employees, and the public.").

[5] *Cf. California Clean Energy Comm. v. City of Woodland* (2014) 225 Cal.App.4th 173, 208 (EIR for shopping center lacked required energy analysis despite stating, among other things, that existing facilities were sufficient to serve the project: "In addition, a substation, multiple utility lines (60 kV, 115 kV, and 230 kV), and gas transmission lines exist in the area to serve the buildout of the proposed project.").

[6] Clean Air Task Force, Comments On SB 100 Joint Agency Report - Charting a Path to a 100% Clean Energy Future, September 19, 2019, https://efiling.energy.ca.gov/GetDocument.aspx?tn=229800&DocumentContentId=61244 (CATF 2019).

[7] See, J. Jenkins et al., Deep decarbonization of the electric power sector insights from recent literature, Energy Innovation Reform Project (Mar. 2017), https://www.innovationreform.org/wp-content/uploads/2018/02/EIRP-

dramatically increase hydropower capacity by increasing the size of state reservoirs by as much as 100 times above current levels. Battery storage on this scale would have significant hazardous materials, human health, fire, fire suppression, and policing services, GHG emissions, and physical impacts. The construction of new hydropower storage would similarly have significant air quality, aquatic plant, animal and habitat, land, GHG emissions, water and hydrology, public safety, and other impacts.

CEQA caselaw holds that EIRs must consider the effects of changes to the environment that can result from an expansion of facilities, services, or utilities to serve the project.[8] Here, DEIR Chapter 4.17 does not cross-reference MM GHG-1 and fails to discuss how implementation of MM GHG-1 may lead to expanded facilities, services or utilities that would be necessary in the future when a Reach Code is adopted.

- ***Greenhouse Gas (GHG) Impacts –*** Implementation of a Reach Code under MM GHG-1 is predicated on the assumption that 100% electrified buildings are more energy-efficient and have a smaller carbon footprint than buildings with gas-powered appliances. Yet, multiple, independent studies demonstrate that such an assumption is not accurate.
  - In May 2019, the U.S. Department of Commerce, National Institute of Standards and Technology ("NIST") published a study of the energy use, environmental impacts, and economic performance of residential buildings using either electricity or natural gas for space and domestic water heating. The analysis was based on a single-family home meeting all applicable building code requirements in Maryland. The NIST research concluded that a natural gas-heated home is more economical, results in "lower environmental impacts across numerous impact categories," including lower GHG emissions, has a faster heating response time and generates a greater level of indoor comfort than an all-electric residence. In particular, GHG emissions were found to be higher because of the greater amount of fuels required to produce electricity for home use compared with the use of natural gas equipment in a residence.[9]
  - Although California has a larger proportion of renewable utility-scale energy than Maryland, consistent with the NIST study the CEC has also shown that, on average, natural gas generates substantially lower GHG emissions than electrical building use in California. As shown below, in 2018 the CEC estimated that electricity use in buildings produces a greater level of GHG emissions than

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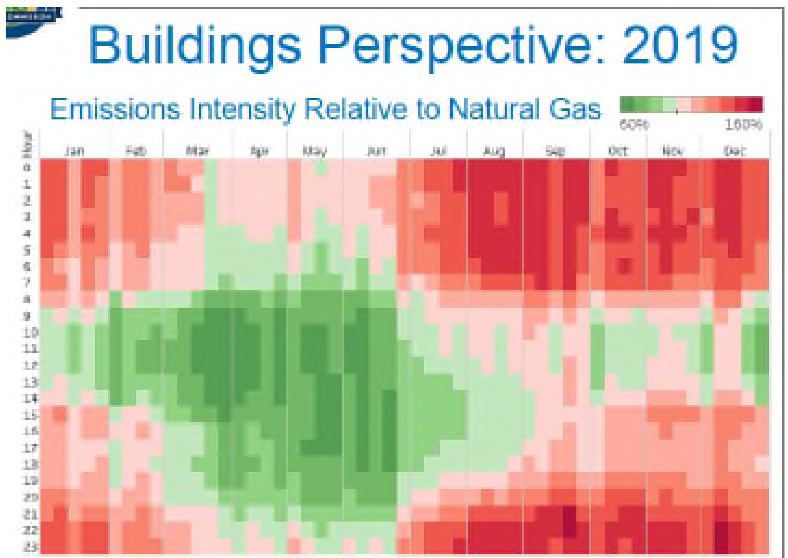
Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf at 5 ("Battery storage is infeasible for such long duration seasonal storage. For comparison, the total storage capacity envisioned by Jacobson et al. is equivalent to 37.8 billion Tesla Power Wall 2.0 home energy storage systems—320 Power Walls per U.S. household").

[8] *Goleta Union Sch. Dist. v. Regents of Univ. of Cal*. (1995) 37 Cal.App.4th 1025; *El Dorado Union High Sch. Dist. v. City of Placerville* (1983) 144 Cal.App.3d 123.

[9] E. O'Rear, D. Webb, J. Kneifel and C. O'Fallon. *Gas vs electric: Heating system fuel source implications on low-energy single-family dwelling sustainability performance*. Journal of Building Engineering. September 2019 issue. Full text available at https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=926046.

natural gas about 60 percent of the year in California.[10] Natural gas results in lower GHG emissions during a significant majority of all morning and evening hours in all months, the periods of highest residential energy demand. The significantly lower GHG emissions from natural gas use in California buildings reflects the fact that, except during daytime hours from about March to June, intermittent solar and wind is insufficient to meet in-state building energy demand. When intermittent renewable energy is not available, electrical generation is less efficient and produces a greater level of GHG emissions than natural gas use in California buildings.



- Other researchers have also questioned whether requiring all electric buildings might, however unintentionally, result in higher GHG emissions. Household energy demand tends to peak in the morning and evening hours, when residents are preparing to leave for or returning from work, school or other activities and when intermittent renewable power, particularly solar, is unavailable. At these times, electric supplies must be produced from other sources, including natural gas-fired power plants. Converting fuels, such as natural gas, to electricity to meet home demands is less efficient than directly using natural gas. As a result, a Stanford University researcher has estimated that when renewable power is unavailable, such as during the evening hours, residential electricity consumption produces *three times* more GHG emissions than natural gas.[11]

- The County cannot assume that, over time, GHG emissions from electrical generation will be reduced during peak morning and evening periods when

[10] CEC, Building Decarbonization, 2018 Update – Integrated Energy Policy Report, Presentation by M. Brook at June 14 2018 IEPR Workshop at 16, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223817.
[11] *See* Anthony R. Kovscek, *Is a natural gas ban an 'antidote to climate change'?*, San Jose Mercury News (Nov. 12, 2019), https://mercurynews-ca.newsmemory.com/?publink=754c8d2e3_13411ac. Professor Kovscek is a member of the Energy Resources Engineering faculty at Stanford University.

natural gas is currently a lower emission energy source in the state. Recent studies indicate that even if additional intermittent wind and solar generation capacity is deployed, gas-fired electrical facilities will almost certainly remain essential to stabilize the state's power grid. The gas-fired generators serving the state, however, may be forced to increasingly operate as short-term inefficient "peaker plants" which are known to emit more GHG emissions.[12] Thus, it is far from clear that an all-electric building mandate will reduce GHG emissions.

The DEIR must disclose and acknowledge potential GHG impacts that could occur from shifting building energy use from natural gas to electric power given reasonably foreseeable conditions in which electrical energy consumption would produce more GHG emissions than natural gas building use.

- ***Energy Impacts*** – Under the CEQA Appendix G Checklist, a project may involve a significant environmental impact if it would result in "wasteful" or "inefficient" energy consumption. MM GHG-1 seeks to prohibit the installation of new natural gas infrastructure in new residential construction. But nowhere does the DEIR discuss how that may result in either (i) a failure to use already captured natural gas, or (ii) the expenditure of additional energy to transport or divert natural gas elsewhere. Studies have shown that low carbon natural gas may continue to be a viable resource in assisting the state with reaching its climate goals, and should continue to be utilized in typically hard to electrify thermal applications in residential, commercial and industrial uses.[13] Specifically, Renewable Natural Gas ("RNG"), or biomethane, can be produced from biomass wastes (e.g. forest, agriculture, waste water and food and green waste) and then processed to inject into existing pipelines. Because its production removes more potent greenhouse gas from the air (methane) compared to what is produced when used (carbon dioxide), RNG production can be carbon negative from a lifecycle perspective. The County cannot determine whether full electrification policies will have unintended consequences of "wasteful" or "inefficient" energy use, without first analyzing these impacts in the DEIR.

- ***Public Health and Safety*** – In an era of increasingly dry and warm climates, and increased population in the wildfire urban interface along with build out of electrical infrastructure that could be an ignition source to serve population growth, California wildfires are occurring at increased frequencies and severities. Each of the three California investor-owned utilities adhere to wildfire mitigation plans ("WMP") submitted to and approved by the California Public Utilities Commission ("CPUC") —

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[12] *See, e.g.,* Mark Thurber, *Gas-fired generation in a high- renewables world,* Stanford University School of Earth, Energy & Environmental Sciences and Precourt Institute for Energy Natural Gas Initiative, NGI Research Brief (June 2018), https://ngi.stanford.edu/sites/g/files/sbiybj14406/f/NGI_Brief_2018-06_R3_Thurber.pdf.

[13] Energy + Environmental Economics, *Decarbonizing Pipeline Gas to Help Meet California's 2050 Greenhouse Gas Reduction Goal* (Jan. 2005), https://www.ethree.com/wp-content/uploads/2017/02/E3_Decarbonizing_Pipeline_01-27-2015.pdf.

which establish internal mechanisms and protocols for de-energization events, also known as Public Service Power Shutoffs ("PSPS"). PG&E's most recent PSPS event (occurring on October 6, 2019) impacted over 728,980 customers in 35 counties across the Sacramento Valley, Sierra Foothills, North Bay, South Bay, East Bay, Central Coast, and parts of Southern California.[14] Southern California Edison ("SCE")— the investor-owned utility whose service territory includes the County — is likewise obligated to implement PSPS protocols in certain circumstances giving risk to wildfires and has done so on numerous occasions in 2019 and 2020. For example, on November 15-17, 2019, SCE instituted a PSPS event that was initially estimated to impact 31,975 customers on 48 circuits across four counties (including the County), although had a much smaller impact than originally considered.

It is evident that increasing the amount of power needed from the electrical grid, such as by reducing the use of natural gas and increasing the use of electricity, will only exacerbate these problems. Until that time, however, PSPS events will be the "new norm," both in Northern and Southern California. In addition to the large-scale economic losses that customers suffer as a result of a PSPS event, public safety issues can also arise due to several factors. These include loss of power at critical medical facilities, added strain on first responder services (such as local police departments and EMTs), loss of school days, and disruption of critical city infrastructure during emergency responses (such as traffic lights). Although MM GHG-1 will contribute to an overloaded grid and exacerbate the economic and safety implications from future, likely PSPS events; the DEIR mentions none of these issues.

The County should consider how increased deployment of other technologies, such as microgrids and energy storage projects, can help achieve decarbonization and resiliency goals. A 2018 CEC report found that microgrid projects offer a number of "value propositions," including renewable energy integration, grid resiliency, and carbon reductions.[15] The CEC report concluded that microgrid projects align with the state's Renewables Portfolio Standard and GHG reduction mandates.[16] The County should analyze the effectiveness of these mitigation options instead of a ban on natural gas.

- ***Impacts on Biological Resources, Water Quality and Noise Stemming From Additional Renewable Generating Resources*** – As stated above, the County has not demonstrated how adopting and implementing MM GHG-1 will impact existing electricity demand. In other words, no evidence exists to support the notion that existing or future electricity load could meet energy demands if natural gas infrastructure is banned for all future

[14] PG&E, "Public Safety Power Shutoff (PSPS) Report to the CPUC Oct. 9-12, 2019 De-Energization Event" (Oct. 25, 2019), at https://www.pge.com/pge_global/common/pdfs/safety/emergency-preparedness/natural-disaster/wildfires/PSPS-Report-Letter-10.09.19.pdf.

[15] Asmus, Peter, Adam Forni, and Laura Vogel. Navigant Consulting, Inc. 2017. *Microgrid Analysis and Case Study Report. California Energy Commission*. Publication Number: CEC-500-2018-022, https://ww2.energy.ca.gov/2018publications/CEC-500-2018-022/CEC-500-2018-022.pdf

[16] *Id*. at ii.

residential construction. Rather, it is reasonably foreseeable that new renewable energy resources will be needed, in addition to those required under the California Renewables Portfolio Standard ("RPS"), to meet new building electrification policies. The CEC's 2019 *California Energy Efficiency Action Plan Staff Report* acknowledges that statewide building electrification efforts "will seek to increase the share of renewable generation on the electricity grid…."[17]

The DEIR does not analyze how development of foreseeable additional renewable generating resources will impact the environment. Because it is likely that the County can determine with particularity the amount of MW or MWh that will be needed to fully implement MM GHG-1 in years to come, an accompanying analysis of generating resources and their potential environmental impacts must be provided. These renewable resource facilities are known to have their own environmental impacts associated with construction and operation, including but not limited to, impacts on federal and California sensitive species, water quality and quantity, nearby noise receptors, and project-related air quality impacts.

Because such commercial-scale facilities might be located outside the County does not insulate the County from its obligation to consider the indirect environmental impacts from MM GHG-1. Indeed, "the purpose of CEQA would be undermined if the appropriate governmental agencies went forward without an awareness of the effects a project will have on areas outside of the boundaries of the project area."[18] It is well-settled that "the project area does not define the relevant environment for purposes of CEQA when a project's environmental effects will be felt outside the project area."[19]

- ***Environmental Justice*** – "Environmental justice" is defined as "the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies." Gov. Code § 65040.12(e). An Attorney General report defines "fairness" in this context to mean that "the benefits of a healthy environment should be available to everyone, and the burdens of pollution should not be focused on sensitive populations or on communities that already are experiencing its adverse effects." "In addition, though CEQA's main purpose is to evaluate whether a project may have a significant effect on the physical environment, "human beings are an integral part of the environment."

  The CEQA Guidelines state that "[e]conomic or social effects of a project may be used to determine the significance of physical changes caused by the project. For example, if the construction of a new freeway or rail line divides an existing community, the construction would be the physical change, but the social effect on the community would be the basis for determining that the effect would be significant." Here, MM

[17] California Energy Commission, *2019 Energy Efficiency Action Plan Draft Staff Report*, https://efiling.energy.ca.gov/getdocument.aspx?tn=229496.
[18] *Napa Citizens for Honest Government v. Napa County Bd. of Supervisors* (2001) 91 Cal.App.4th 342, 369.
[19] *County Sanitation Dist. No. 2 of Los Angeles County v. County of Kern* (2005) 127 Cal.App.4th 1544, 1582–1583.

GHG-1 would require the construction of new electric infrastructure, including within the County, to supply the electricity necessary to support a natural gas ban. This physical change to the environment will lead to cost increases for ratepayers, an economic impact which must be considered under CEQA.

Before the County can adopt MM GHG-1, the DEIR must consider the impact it will have on customer affordability and ratepayers. About 90 percent of residential energy consumers in Southern California use natural gas for space and water heating, and ratepayers prefer a choice in how they heat their homes and cook their food. Further, according to a 2018 study produced by Navigant Consulting on behalf of the California Building Industry Association, switching to all-electric appliances could cost single-family homeowners in Southern California "over $7,200 and increase energy costs by up to $388 per year." Low-income customers would be the most burdened by the costs of building electrification.

Thus, as a resulting of adopting MM GHG-1, the County will have effectively established an unnecessary energy policy that will disproportionately impact its disadvantaged communities. Under CEQA, the County cannot gloss over this potential impact.

Given the substantial evidence that adopting and implementing MM GHG-1 will result in potential significant environmental impacts, the County is required to undertake proper CEQA review of such impacts, including both the direct and indirect environmental impacts stemming therefrom.

2. <u>MM GHG-1 is Not "Feasible" under CEQA</u>

Pursuant to CEQA Guidelines section 15126.4(a)(1), an EIR must "describe feasible measures which could minimize significant adverse impacts, including where relevant, inefficient and unnecessary consumption of energy." "Feasible" means "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors."[20] Courts do not defer to an agency's determination that mitigation measures will work when their efficacy is not apparent and there is no evidence in the record showing they will be effective.[21] Here, there is no evidence that MM GHG-1 is feasible as a means to mitigate GHG-related impacts associated with the 2040 General Plan. In fact, evidence demonstrates that natural gas bans are environmentally, economically and technologically infeasible.

Intermittent Renewable Generation Inhibits Feasibility of a Natural Gas Ban

Since 2015, several studies have evaluated the results of multiple assessments of national and California decarbonization strategies and options.[22] Other studies have considered the power

[20] CEQA Guidelines § 15364.
[21] *See, e.g.*, *Sierra Club v. County of San Diego* (2014) 231 Cal.App.4th 1152, 1168; *Communities for a Better Env't v. City of Richmond* (2010) 184 Cal.App.4th 70, 95; *Gray v. County of Madera* (2008) 167 Cal.App.4th 1099, 1116-17.
[22] *See, e.g.*, P. Loftus et al., A critical review of global decarbonization scenarios: what

system and costs associated with relying solely on intermittent renewable power for decarbonization, in contrast with approaches that also utilize fossil fuels with CCS or renewable natural gas ("RNG").[23] These studies consistently conclude that renewable generation without a reliable baseload power source cannot achieve deep carbonization, will require installing massive amounts of additional generation and distribution facilities, and will be unaffordable.

- Relying on variable renewable sources such as wind, hydroelectric and solar to decarbonize will require the fabrication, installation and operation of approximately 3 to 10 times the level of solar and wind facilities that would be required if a reliable lower-carbon energy source was also utilized.[24] This overbuilding is required as intermittent power cannot achieve its nominal nameplate capacity—100 megawatts of solar or wind power will produce approximately 20-40 percent of capacity per year compared with approximately 90 percent capacity rates for natural gas. Thus, a much larger power system must be built to produce enough energy.

- As the percentage of intermittent renewable power serving a community increases, the amount of energy that is "curtailed" or wasted because it is not produced when needed can approach 40 percent of total generation.[25] Due to the timing mismatch between demand and the availability of solar and wind power, wind and solar would

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do they tell us about feasibility?, WIRES Climate Change, January/February 2015, https://www.researchgate.net/publication/267875650_A_critical_review_of_global_decarbonization_scenarios_what_do_they_tell_us_about_feasibility_A_critical_review_of_global_decarbonization_scenarios (analysis of 17 decarbonization studies); J. Jenkins et al., Deep decarbonization of the electric power sector: insights from recent literature, Energy Innovation Reform Project, March 2017, https://www.innovationreform.org/wp-content/uploads/2018/02/EIRP-Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf (analysis of 30 decarbonization studies); S. Brick, Renewables and decarbonization: studies of California, Wisconsin and Germany, The Electricity Journal, 2016, https://www.researchgate.net/publication/299380869_Renewables_and_decarbonization_Studies_of_California_Wisconsin_and_Germany/fulltext/57dc15a408ae4e6f18469f9d/299380869_Renewables_and_decarbonization_Studies_of_California_Wisconsin_and_Germany.pdf?origin=publication_detail (analysis of California, Wisconsin and German studies); and J. Jenkins et al, Getting to zero-carbon emissions in the electric power sector, Joule, 2018, https://www.sciencedirect.com/science/article/pii/S2542435118305622 (analysis of 40 studies).

[23] *See, e.g.*, N. Sepulveda et al, The role of firm low-carbon electricity resources in deep decarbonization of power generation, Joule, November 2018, https://www.sciencedirect.com/science/article/pii/S2542435118303866?via%3Dihub and B. Frew at al., Flexibility mechanisms and pathways to a highly renewable US electricity future, Energy, 2016, https://web.stanford.edu/group/efmh/jacobson/Articles/Others/16-Frew-Energy.pdf.

[24] *See, e.g.*, P. Loftus et al., A critical review of global decarbonization scenarios: what do they tell us about feasibility?, WIRES Climate Change, January/February 2015, https://www.researchgate.net/publication/267875650_A_critical_review_of_global_decarbonization_scenarios_what_do_they_tell_us_about_feasibility_A_critical_review_of_global_decarbonization_scenarios and J. Jenkins et al., Deep decarbonization of the electric power sector insights from recent literature, Energy Innovation Reform Project, March 2017, https://www.innovationreform.org/wp-content/uploads/2018/02/EIRP-Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf.

[25] J. Jenkins et al, Getting to zero-carbon emissions in the electric power sector, Joule, 2018, https://www.sciencedirect.com/science/article/pii/S2542435118305622 based on

be unable to meet about 30 percent of California's annual energy demand.[26] As a result, massive electrical power storage must be constructed, installed and operated to capture a community's surplus intermittent power generation. In California alone, storing surplus generation would require batteries with an instantaneous capacity "larger than the generating capacity of the entire US electric grid." Even assuming battery storage costs fall dramatically to $80 per megawatt, California communities would be required to pay about $2.9 trillion to secure the necessary power storage.[27]

- To increase the reliability of intermittent renewable energy, significant new large-scale transmission will be required to "knit together diverse wind, sun and hydro resources" including as much as "a twenty-fold increase in US transmission capacity and interties for very high renewable energy scenarios, according to the National Renewable Energy Laboratory." [28]

- Due to the need for overbuilding, energy storage increases, and new transmission capacity, decarbonization using intermittent renewables without reliable low-carbon power sources would be unattainably expensive. The cost of electricity generation in California has been estimated to rise from about $58 per megawatt hour with 60 percent renewable generation to $389 using 80 percent renewable power, and an astonishing $1,402 per megawatt hour at 100 percent renewable levels even assuming that the cost of wind, solar and storage falls substantially.[29] Other studies have estimated that California communities would pay more than $1,600 per megawatt hour using 100 percent renewable power.[30]

A Natural Gas Ban is Economically Infeasible for Customers

According to 2019 survey data published by the U.S. Energy Information Agency, the average household in California currently consumes about 7 megawatt hours of energy at a cost of approximately $1,000 ($0.14 per kilowatt hour). Published estimates indicate that California electrical generation costs could rise by 8 to 24 times current levels with 60 percent renewable power, higher utilization of renewables than at present. California households would also use more electrical power over time for transportation and other needs under a 100 percent renewable power scenario. Assuming that the average household electrical demand increases

[26] CATF 2019.
[27] CATF 2019.
[28] CATF 2019.
[29] CATF 2019.
[30] J. Temple, The $2.5 trillion reason we can't rely on batteries to clean up the grid, MIT Technology Review, July 27, 2018, https://www.technologyreview.com/s/611683/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/.

to 10 megawatt hours per year,[31] and that prices do not significantly increase until renewable use reaches 80 to 100 percent of total generation, the average California household electric bill would increase to about $8,000 per year at 80 percent renewable use, and to about $24,000 per year with 100 percent renewable use.

Annual cost increases of this magnitude could be expected to stimulate significant population relocation to lower cost communities. Physical relocation, including the use of larger, high emission vehicles, could have significant impacts on air quality, population and housing. High household energy costs would also have significant health and safety impacts, including higher mortality and illness rates for vulnerable populations due to the inability to heat or cool homes. Direct relocation GHG emissions, and additional emissions that could occur from the movement of large amounts of households to lower cost communities with higher average household emission rates could also generate significant cumulative climate change impacts.

Higher electrical power costs could also result in the relocation, or failure to open and operate businesses in the state and the relocation of these activities to lower cost, higher-emission communities. As discussed in a January 2020 report by the California Legislative Analyst's Office, California communities already have disproportionately higher energy costs than most of the U.S. compared with marginal generation expenses. Consequently, higher costs associated with 100 percent renewable energy could generate significant GHG impacts.

3. The DEIR Finds that GHG Impact 4.8-1 Will Remain Significant and Unavoidable, but Does So Without Considering Other Feasible and Effective GHG Mitigation

Under CEQA, a lead agency may not adopt a project unless it has eliminated or substantially lessened all significant effects on the environment, or determined that remaining significant effects are acceptable due to overriding considerations.[32] Here, the County concluded that, with the implementation of all identified GHG mitigation measures, Impact 4.8-1 would remain significant and unavoidable.[33] However, the County cannot adopt this finding without implementation all feasible mitigation measures.[34] While it is true than "an EIR need not analyze 'every imaginable alternative or mitigation measure' …," it "must respond to specific suggestions for mitigating a significant environmental impact unless the suggested mitigation is facially infeasible."[35]

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[31] EIA, *How much electricity does an American home use?* (Oct. 2, 2019), https://www.eia.gov/tools/faqs/faq.php?id=97&t=3 (explaining that in 2018, the average annual electricity consumption for a U.S. residential utility customer was 10,972 kWh).
[32] Pub. Res. Code. § 15092(b).
[33] DEIR at 4.8-49.
[34] Guidelines §§ 15043(a), 15092(b).
[35] *Los Angeles Unified Sch. Dist. v. City of Los Angeles* (1997) 58 Cal. App. 4th 1019, 1029; citing San Francisco *Ecology Center v. City and County of San Francisco* (1975) 48 Cal.App.3d 584, 596 (EIR did not respond to School District's suggestion that air conditioning and filtering might prove feasible means of reducing air quality impacts under proposed plan).

SoCalGas urges the County to consider other GHG emission-reduction strategies that are scalable and easier to implement, more resilient and more affordable. Specifically, the use of renewable gases such as hydrogen and renewable natural gas (RNG), are low carbon to negative fuels that can dramatically reduce county greenhouse gas emissions and provide optionality and flexibility for the energy system.

As stated in our prior comment letter for the General Plan Update (attached), RNG, or biomethane, can be produced from a variety of waste resources (e.g. agricultural waste, forest biomass, waste water, and landfills) and then processed to meet pipeline specifications. Further, green hydrogen can be produced from excess solar and wind power generated when demand is low. The hydrogen can then be stored for later use in hydrogen fueling stations, be used for electric generation in fuel cells, and/or blended into the gas pipeline system to decarbonize gas supply which benefits all sectors. This technology, called Power-to-Gas, has been demonstrated in numerous pilot projects, including UC Irvine.[36]

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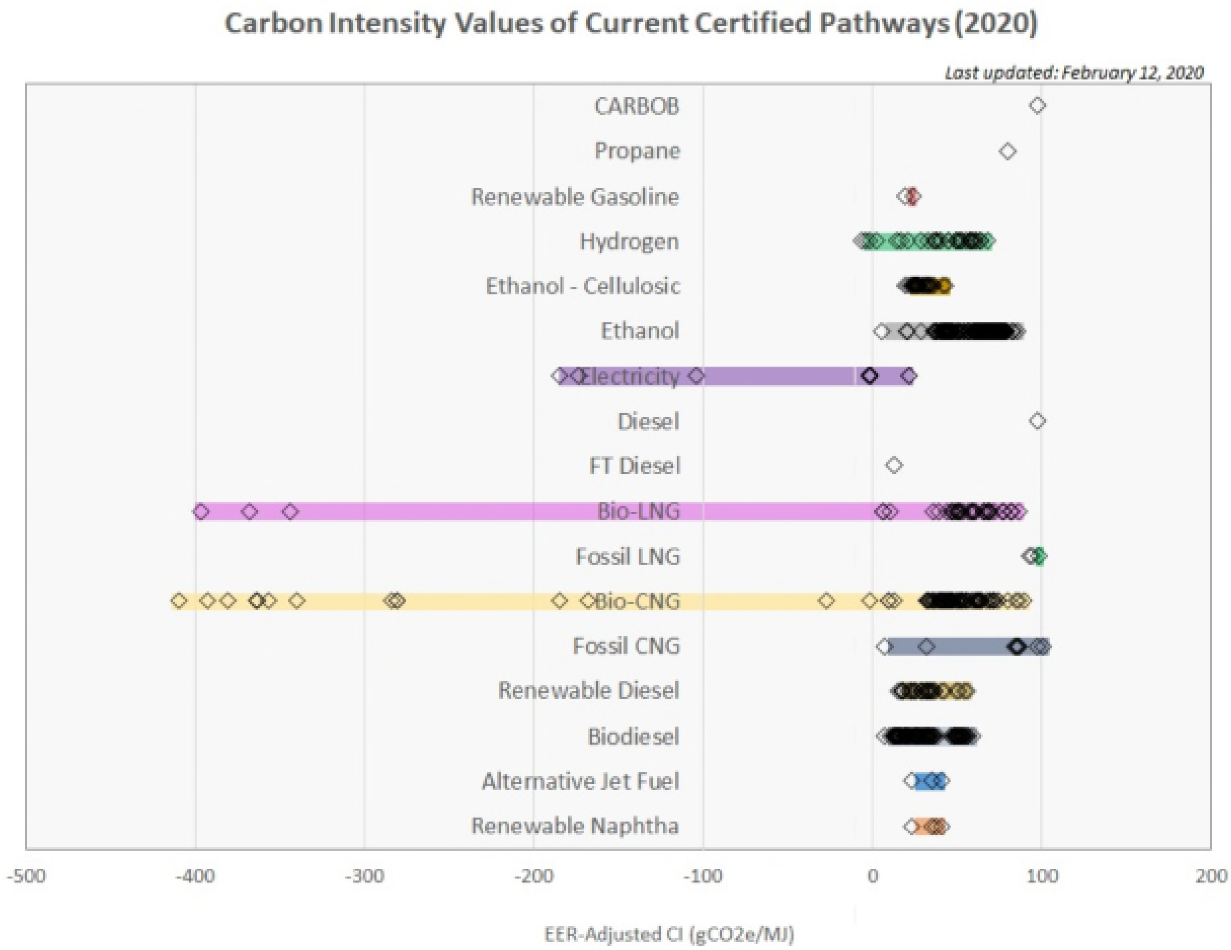
[36] UCI Samueli School of Engineering. UCI and SoCalGas Partner to Design "Advanced Energy Community." December 2017. Available at: https://engineering.uci.edu/news/2017/12/uci-and-socalgas-partner-design-advanced-energy-community



[37]

Because most production of renewable natural gas removes methane from the air and converts it to carbon dioxide when used, RNG production can be significantly carbon negative from a lifecycle perspective. Renewable gases can also achieve co-benefits by helping the energy system be more flexible and work across sectors. For example, conversion of dead trees and forest waste to renewable gases can dramatically reduce wildfire risks. The Power to Gas concept that can convert excess renewable electricity to hydrogen that can store energy in the for months at a time instead of hours as in the case with batteries enables extension of the renewable energy for long durations to meet peak demands. Finally, renewable gases can support decarbonizing difficult sectors such as the agriculture and other industries which form the economic engine of California and the associated jobs. As the County is aware, SoCalGas is working towards the goal of replacing 5% of our natural gas supply with RNG by 2022, and 20% by 2030.

[37] California Air Resources Board. LCFS Certified Pathway Carbon Intensities. February 2020. Available at: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities

The CPUC is also evaluating the levels of hydrogen that can be blended in to the natural gas system as we speak. Furthermore, just last month, Lawrence Livermore National Labs issued a study of how California can get to carbon neutrality by leveraging the gas pipelines and their rights-of-way to convey hydrogen and carbon dioxide.[38] In fact, the most cost-effective carbon negative solution is to convert biomass waste to hydrogen and sequestering the carbon via pipelines using the rights-of-ways of the natural gas system. In addition, studies show that replacing roughly 16% of SoCalGas throughput with RNG achieves the same emissions reductions as electrifying the entire building sector by 2030.[39]

Inclusion of RNG as a mitigation strategy also aligns with policies already included in the Draft General Plan. In particular, policies PFS-5.4, PFS-5.5, PFS-5.6, and COS-8.1 all support reuse of waste resources for energy generation as well as replacement of fossil fuels with renewable energy resources, including bioenergy. Accordingly, the use of renewable gases as a mitigation measure seems a natural complement to these policies, whereas a ban on gas infrastructure seems counterproductive. Therefore, we encourage the County to replace Mitigation Measure GHG-1: Prohibit Natural Gas in New Residential Construction, with an alternative mitigation measure that is performance-based, technology neutral and allows for flexibility in use of renewable fuels to help achieve emissions reductions.

We appreciate the opportunity to submit comments on the DEIR and look forward to working with the County as a valuable energy partner to achieve their environmental goals. If you have any questions, please do not hesitate to reach out via telephone or email.

Sincerely,

Deanna Haines
Director Policy, Strategy and Environment

[38] Lawrence Livermore National Laboratory. Getting to Neutral. January 2020. Available at: https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf
[39] Navigant Consulting, Gas Strategies for a Low-Carbon California Future (April 2018).

Simmons, Carrie

From: Sara L. Breckenridge <breckenridge@smwlaw.com>
Sent: Thursday, February 27, 2020 4:02 PM
To: Downing, Clay
Cc: Curtis, Susan; Simmons, Carrie; Carol Holly; Carmen J. Borg; Kevin P. Bundy
Subject: RE: County of Ventura 2040 General Plan and Draft Environmental Impact Report

That is the correct. The second document (Comment Letter) is also included as the first 38 pages of the third document (Comments and Exhibits). Thank you.

From: Downing, Clay <clay.downing@ventura.org>
Sent: Thursday, February 27, 2020 3:43 PM
To: Sara L. Breckenridge <breckenridge@smwlaw.com>
Cc: Curtis, Susan <Susan.Curtis@ventura.org>; Simmons, Carrie <Carrie.Simmons@ventura.org>; Carol Holly <Carol.holly2@gmail.com>; Carmen J. Borg <Borg@smwlaw.com>; Kevin P. Bundy <Bundy@smwlaw.com>
Subject: RE: County of Ventura 2040 General Plan and Draft Environmental Impact Report

Good afternoon Ms. Breckenridge,

Thank you for submitting this public comment. We have downloaded the following materials successfully:

- Email submission (2 pages)
- Comment Letter (38 pages)
- Comments and Exhibits (782 pages)

If these materials do not reflect all of the materials in your submission, please notify us immediately so that we can ensure we have all materials associated with your submission. Best,

Clay Downing, MPPA | Associate Planner
Permit Administration and General Plan Update Sections
Clay.Downing@ventura.org

Ventura County Resource Management Agency | Planning Division
800 S. Victoria Ave., L #1740 | Ventura, CA 93009-1740
Office 805.650.4047
Additional Planning Division information is available at vcrma.org/planning
Ventura County General Plan Update. Join the conversation at VC2040.org
For online permits and property information, visit VC Citizen Access

Pursuant to the California Public Records Act, emails retained by the County of Ventura may constitute public records subject to public disclosure.

From: Curtis, Susan <Susan.Curtis@ventura.org>
Sent: Thursday, February 27, 2020 3:16 PM
To: Downing, Clay <clay.downing@ventura.org>
Cc: Simmons, Carrie <Carrie.Simmons@ventura.org>
Subject: FW: County of Ventura 2040 General Plan and Draft Environmental Impact Report

Susan Curtis l Manager
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Visit the Planning Division website at **vcrma.org/planning**
Ventura County General Plan Update. Join the conversation at **VC2040.org**
For online permits and property information, visit **VC Citizen Access**

From: General Plan Update <GeneralPlanUpdate@ventura.org>
Sent: Thursday, February 27, 2020 3:00 PM
To: Curtis, Susan <Susan.Curtis@ventura.org>
Subject: FW: County of Ventura 2040 General Plan and Draft Environmental Impact Report

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From: Sara L. Breckenridge <breckenridge@smwlaw.com>
Sent: Thursday, February 27, 2020 1:50 PM
To: General Plan Update <GeneralPlanUpdate@ventura.org>
Cc: Kevin P. Bundy <Bundy@smwlaw.com>; Carmen J. Borg <Borg@smwlaw.com>; Carol Holly <Carol.holly2@gmail.com>
Subject: County of Ventura 2040 General Plan and Draft Environmental Impact Report

Ms. Curtis,

Please find attached a letter from Kevin Bundy and Carmen Borg, on behalf of Climate First: Replacing Oil & Gas, regarding the County of Ventura 2040 General Plan Update and Draft Environmental Impact Report. Due to large file size, the exhibits are attached as a Dropbox download link. Please confirm your receipt of this message, and that you were able to download the exhibits. Thank you.

https://www.dropbox.com/s/itvm16fo7c4m8fm/CFROG%202040%20GPU%20DEIR%20Comments%20and%20Exhibits%202-27-2020.pdf?dl=0

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Simmons, Carrie

From: Sara L. Breckenridge <breckenridge@smwlaw.com>
Sent: Thursday, February 27, 2020 1:50 PM
To: General Plan Update
Cc: Kevin P. Bundy; Carmen J. Borg; Carol Holly
Subject: County of Ventura 2040 General Plan and Draft Environmental Impact Report
Attachments: CFROG 2040 GPU DEIR Comment Letter 2-27-2020.pdf

Follow Up Flag: Follow up
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Ms. Curtis,

Please find attached a letter from Kevin Bundy and Carmen Borg, on behalf of Climate First: Replacing Oil & Gas, regarding the County of Ventura 2040 General Plan Update and Draft Environmental Impact Report. Due to large file size, the exhibits are attached as a Dropbox download link. Please confirm your receipt of this message, and that you were able to download the exhibits. Thank you.

https://www.dropbox.com/s/itvm16fo7c4m8fm/CFROG%202040%20GPU%20DEIR%20Comments%20and%20Exhibits%202-27-2020.pdf?dl=0

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Via E-Mail

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Re: County of Ventura 2040 General Plan and Draft Environmental Impact Report – State Clearinghouse No: 2019011026

Dear Ms. Curtis:

This firm represents Climate First: Replacing Oil & Gas ("CFROG") on matters related to the 2040 General Plan ("the Draft Plan") and its draft environmental impact report ("DEIR"). As detailed below, the Draft Plan fails to take meaningful, feasible steps to confront climate change. The DEIR also falls far short of the requirements of the California Environmental Quality Act ("CEQA") (Public Resources Code section 21000 *et seq.*) and CEQA Guidelines (California Code of Regulations, title 14 section 15000 *et seq.*).

As you know, CFROG's primary concerns include the effect of oil and gas development on Ventura County's climate, natural resources, and quality of life. Proximity to oil and gas exploration, extraction, processing, and transportation exposes countless County residents to ongoing harm, exacting a tremendous toll on public health and safety. Moreover, the County is already experiencing severe impacts from climate change, and those impacts are likely to intensify in coming years. As CFROG has pointed out in prior letters, overwhelming scientific evidence shows humanity has only a few years remaining in which to dramatically draw down fossil fuel emissions if we are to preserve a decent chance of avoiding even more severe and lasting disruptions.

Unfortunately, like its predecessor, the Draft Plan does little to promote the policy transitions required to meet this challenge. If anything, the Draft Plan's approach to oil and gas policy largely continues a business-as-usual approach to petroleum extraction. This is so despite the Draft Plan's recognition that the County must reduce greenhouse gas emissions by roughly 60 percent over the next 20 years in order to keep up with reductions demanded by state climate policy.

As explained in CFROG's prior comments,[1] although CFROG recognizes the history and economic importance of the County's oil industry, the time for a transition to cleaner alternative sources of energy and economic sustenance is now. With that principle in mind, CFROG previously submitted recommendations of specific policies and programs to be adopted as part of the General Plan, or if they are not adopted, that they be considered as mitigation measures and/or alternatives in the DEIR for the General Plan. We are disappointed that many of CFROG's recommended policies and programs have neither been included in the Plan nor discussed in the DEIR.

The County's General Plan update process is a critically important planning exercise because so much is at stake. The climate change crisis alone mandates a dramatic refocus away from the business-as-usual approach of facilitating oil and gas extraction in the County. A recent analysis of more than a century of temperature data indicates that temperatures from Santa Barbara southward are warming at double the rate of the continental United States. Washington Post, "California climate change: Fires, floods and a fight over free parking," December 5, 2019, attached as Exhibit 1. Ventura County has suffered an average temperature increase of 4.7 degrees Fahrenheit since preindustrial times and ranks as the fastest-warming county in the lower 48 states. *Id*.

While the Draft Plan contains some laudable policies, it nonetheless fails to demonstrate a serious commitment to tackling this ecological and social crisis. Many of

[1] This firm previously submitted comments on the Preliminary Draft General Plan Update ("Preliminary Draft") dated June 5, 2019. In that letter we described many substantive flaws in the Preliminary Draft, many of which the County disregarded in preparing the Draft Plan. We also recommended numerous new and amended policies and asked that they be considered as mitigation measures and/or alternatives in the DEIR; most of these recommendations, however, are not addressed at all in the DEIR. Consequently, most of the comments in the June 5 letter remain applicable to the current Draft Plan and DEIR. Our June 5, 2019 letter and accompanying exhibits and references are therefore incorporated herein by reference.

the Draft Plan's policies are merely advisory and lack the enforceable detail necessary to achieve real greenhouse gas reductions. The DEIR, for its part, proposes to water down many of the Draft Plan's provisions even further.

The Draft Plan and DEIR are out of touch with both climate science and state policy. The State of California has begun active planning for a managed transition away from fossil fuels. The 2019 Budget Act allocated significant funding for studies outlining a long-term reduction in both demand for and supply of fossil fuels, in service of the state's goal of achieving carbon neutrality by 2045. *See* Stats.2019, ch. 23, Item 0555-001-3228 (Assembly Bill No. 74), attached as Exhibit 2. The state has adopted a scope of work for each study and the planning effort is underway. *See* Carbon Neutrality Studies Scope of Work, Studies 1 and 2, attached as Exhibits 3, 4. The Draft Plan's commitment to expanded oil and gas operations in Ventura County is contrary to these statewide efforts and profoundly counterproductive.

The 2040 General Plan update offers a critical opportunity to support statewide and global efforts by shifting away from dependence on oil and gas production and expanding renewable energy production and consumption. Such a shift would have tremendous benefits, including reduced air pollution and greenhouse gas ("GHG") emissions, lower energy consumption, fewer impacts to public health and safety, and greater water quality protection. In other words, a shift in direction would provide either an alternative or a series of mitigation measures that could further reduce or avoid many of the Draft Plan's significant environmental impacts.

Unfortunately, the Draft Plan and DEIR fail to provide for any such shift, and instead assume continued expansion of oil and gas extraction, even as statewide production continues to decline and the rest of California begins to plan for a post-carbon future. Indeed, the DEIR admits the Draft Plan will not achieve the County's fair share of reductions needed to meet either short-term or longer-term state climate goals. The Draft Plan's business-as-usual approach will create long term environmental damage, affecting residents and future generations throughout the region.

Finally, as detailed below, the DEIR fails to meet CEQA's requirements. For example, the DEIR fundamentally fails to identify or analyze credible, feasible mitigation measures or alternatives that could reduce or avoid the Draft Plan's significant environmental impacts. CEQA requires enforceable, concrete commitments to mitigation and consideration of a range of potentially feasible alternative approaches that could avoid significant impacts. The DEIR, in contrast, primarily offers vague, voluntary, and unenforceable policies, particularly with respect to anticipated greenhouse gas emissions.

As a result, the DEIR fails to describe measures that could avoid or substantially lessen the proposed Plan's numerous significant impacts.

I. The County's Climate Action Plan Is Ineffective At Reducing GHG Emissions.

As acknowledged in the DEIR for the Draft Plan, the County has a considerable number of oil and gas operations in the unincorporated areas. Draft Plan at 6-12. These facilities contribute to climate disruption. Further expanding local oil and gas development will add even more carbon to the atmosphere, undercut California's efforts to reduce emissions, and further limit our ability to avoid the worst effects of climate change. The General Plan Update—and, in particular, the provisions of the Plan comprising the County's Greenhouse Gas Strategy or Climate Action Plan ("CAP")—offers an important opportunity to reduce emissions from oil and gas development.

Unfortunately, the CAP as described in Appendix B to the Draft Plan largely passes up this opportunity. As explained in more detail below, the CAP presents incomplete and inaccurate data regarding anticipated GHG emissions under the proposed Plan. In addition, the CAP lacks specific, enforceable measures necessary to achieve the established targets and goals for emission reductions. As a result, the CAP is ineffective in reducing anticipated GHG emissions, and the DEIR's conclusions regarding the Draft Plan's climate impacts are without support.

A. The Baseline Inventory of GHG Emissions Is Incomplete and Inaccurate.

As we pointed out in our prior letter on the Preliminary Draft, the baseline inventory of County GHG emissions is the foundation of the CAP. Without a complete and accurate inventory, the County cannot accurately project future business-as-usual ("BAU") emissions or measure the effectiveness of reduction measures in meeting identified targets and goals. Effective policies cannot be built on a flawed inventory. Unfortunately, the CAP inventory remains incomplete, internally inconsistent, and inaccurate.

According to the CAP, 2015 stationary source emissions totaled 275,096 $MTCO_2e$. Draft Plan, Appendix B at B-7 (Table B-2), B-8. This estimate purportedly was derived "by scaling the statewide emissions reported for oil and gas production to the local level using the proportion of oil and gas production in the unincorporated area relative to the statewide total." *Id.* at B-8.

The estimate in the CAP is not clearly supported by data in the DEIR. Appendix D to the DEIR appears to take two different approaches to estimation of stationary source emissions. The first approach (in a spreadsheet entitled "Estimating Ventura County Stationary Source Emissions from Oil and Gas") estimates a total of 284,693 $MTCO_2e$. DEIR, Appendix D at 43. The second approach (apparently using two spreadsheets, one entitled "Statewide Stationary Source Emissions from Oil and Gas" and the second entitled "State Report on Well County and Production of Oil, Gas, and Water by County – 2015") arrives at the "scaled" emissions estimate of 275,096 $MTCO_2e$ discussed in the CAP. DEIR, Appendix D at 44-45. Neither the CAP nor the DEIR appears to explain the discrepancy between the two estimates.

Further inconsistencies in the inventory are similarly unexplained. For example, estimates under the first approach described above show zero emissions from natural gas "fuel combustion" in the County. DEIR, Appendix D at 43. Statewide figures supporting the second approach, however, show that natural gas combustion is by far the single greatest source of CO_2 emissions from the oil and gas sector (13,750,201 MTCO2e, or 69.4% of statewide total CO_2e emissions). *Id.* at 44. Neither the CAP nor the DEIR appears to contain any evidence that unlike the rest of the state, not a single oil and gas operation in Ventura County consumes natural gas. As we pointed out in our letter on the Preliminary Draft Plan, cyclic steaming and steam flooding operations—which often burn natural gas to generate steam—are currently occurring in the County, including in the Oxnard oilfield. DOGGR 2017 (annual report) at 22 (attached as Exhibit 5) to comments on Preliminary Draft Plan). In fact, the Ventura County Air Pollution Control District recently issued a permit to California Resources Production Corporation authorizing operation of steam generators "fired on PUC Natural gas, with PUC natural gas mixed with produced gas as secondary fuel." VCAPCD, Part 70 Permit No. 00012, Section No. 2 at 1 (Table No.2) (May 14, 2019), attached as Exhibit 6; *see also* VCAPCD Rule 74.15.B.1(3)(a) (allowing steam generators to use "alternate fuel" only "due to the curtailment of natural gas service to the individual unit by the natural gas supplier" and only during "the period of natural gas curtailment"). Steam generators in Ventura County clearly use natural gas in the production of oil. The inventory's omission of natural gas combustion emissions is thus inaccurate and unsupported.

The "scaled" estimate of emissions from County oil and gas operations also appears unreasonably low. DEIR Appendix D concludes that Ventura County produces 4.2% of the state's oil and 5.1% of the state's associated gas. DEIR, Appendix D at 45. Yet DEIR Appendix D also concludes that Ventura County contributes only about 1.4% of the statewide GHG emissions from oil and gas (275,096 $MTCO_2e$ out of the statewide total of 19,803,975 $MTCO_2e$). Again, neither the CAP nor the DEIR explains why "scaled" Ventura County emissions are so low compared to the volumes of oil and gas produced.

This stark discrepancy further underscores a point we made in our prior comments: the Preliminary Draft Plan failed to explain or provide evidentiary support for the "scaled" estimate, i.e., for calculating Ventura County emissions as a percentage of statewide emissions from the oil and gas sector rather than based on information specific to exploration and production in Ventura County. Neither the CAP nor the DEIR supplies the missing explanation. Local oil and gas operations may or may not be consistent with statewide averages in terms of the energy (and associated emissions) required for extraction. However, additional justification and explanation of this methodological choice, based on information specific to Ventura County, is necessary—particularly in light of the DEIR's apparent conclusion that County oil and gas emissions are significantly lower than anywhere else in the state, even on a "scaled" basis.

The CAP inventory also continues to omit other sources of GHG emissions from oil and gas production. For example, the inventory does not include emissions from the transport of oil and gas production, particularly freight rail and ocean freight emissions. Draft Plan, Appendix B at B-8. Nor does the inventory include any "downstream" emissions from refining or combustion of County-produced oil and gas. As explained in our prior letter, these emissions should have been included because the County controls activities related to exploration and production of oil and gas. Without these activities, emissions from transportation, refining, and combustion of oil and gas produced in the County would not occur. Where, as here, "downstream" emissions are foreseeable and capable of estimation, they should be disclosed. *Cf. Sierra Club v. Federal Energy Regulatory Com.* (D.C. Cir. 2017) 867 F.3d1357; *Mid States Coalition for Progress v. Surface Transportation Bd.* (8th Cir. 2003) 345 F.3d 520. Nor can the County avoid responsibility for disclosing and analyzing rail and ocean freight emissions simply because it may lack authority to prevent or mitigate the effects of these activities directly. See *Association of Irritated Residents v. Kern County Bd. of Supervisors* (2017) 17 Cal.App.5th 708, 750-52 (federal preemption of railroad regulation did not extend to responsibility for disclosure and analysis of environmental effects of railroad operations under CEQA).

It is also unclear whether the emissions inventory includes aviation emissions. The DEIR includes emission factors for aviation gas and jet fuel. DEIR, Appendix D at 47 and 49. However, the inventory does not appear to include any emissions from aircraft. *Id.* at 27 and 28. Moreover, although the inventory appears to include some emissions from vessels, harborcraft, and cargo handling equipment (*id.* at 27), it is not clear that the inventory includes all emissions related to operations at the Port of Hueneme.

Finally, recent data collected by the National Aeronautics and Space Administration ("NASA"), indicates that emissions from a handful of sites (or "super emitters") account for the vast majority of California's methane emissions. *See,* Bloomberg News article, "NASA Flew Gas Detectors Above California, Found 'Super Emitters", November 7, 2019, attached as Exhibit 7; https://climate.nasa.gov/news/2930/a-third-of-california-methane-traced-to-a-few-super-emitters/ news article, attached as Exhibit 8; and https://methane.jpl.nasa.gov/, . Of the "super emitters" identified around the State, oil and gas operations accounted for 26 percent of all source emissions.

Several of these "super emitters" are located in Ventura County. See Ventura County Methane Plume Data, attached as Exhibit 9. They include, but are not limited to, the Ventura Oil Field, Rincon Oil Field, Bardsdale Oil Field, and South Mountain Oil Field, which were all mapped as emitting methane plumes. Methane is a greenhouse gas that is at least 85 times more potent than carbon dioxide at trapping heat and contributing to global warming over the 20-year period covered by the General Plan.[2] Therefore, addressing these emissions is critical for the County to meet emission reduction targets required under State law.

Despite this available data, the County's Draft Plan and DEIR failed to disclose these emissions, analyze their impacts, or identify feasible measures to ensure emission reductions over the life of the Plan. The result is a CAP that presents flawed baseline data of GHG emissions that undermines the entire planning process. Without an accurate baseline inventory, the DEIR's projected future emissions from the oil and gas sector (see

[2] Current scientific evidence concerning the global warming potential of methane over different time scales is discussed in detail in CFROG's comments on the Preliminary Draft Plan. *See* June 5, 2019 Comments at 16-18 and cited references. Specifically, according to the Intergovernmental Panel on Climate Change's most recent Assessment Report, methane is 85-87 times more potent than carbon dioxide over a 20-year time period, accounting for climate-carbon feedbacks and additional warming from methane oxidation. Myhre, G., et al., 2013: Anthropogenic and Natural Radiative Forcing at 714 (Table 8.7). In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf. An excerpt from the IPCC report is attached as Exhibit 10.

DEIR, Appendix D at 45) have no evidentiary basis. Inasmuch as the County permits oil and gas operations in unincorporated lands in the County, the County has an obligation to consider these emissions and take concrete steps to limit them in the future. The failure to do so renders the CAP fatally flawed. A revised CAP must correct this flaw and include a comprehensive inventory of all emissions, including all emissions from oil and gas operations.

B. Emission Forecasts are Inadequately Supported.

Projections of "business as usual" emissions from the oil and gas sector in the CAP and DEIR lack adequate justification and support. The DEIR assumes oil and gas production will increase by more than one million barrels per year between 2015 and 2040. DEIR Appendix D at 45. Stationary sources are projected not only to remain a significant source of emissions in the County, but also to continue increasing, through 2050. Draft Plan at B-10 (Table B-4).

Appendix B appears to use "County-specific demographic" projections—presumably population growth—as the basis for its future emissions projections, although the precise methodology used is not explained. *See* Draft Plan at B-10. The DEIR similarly bases its projections on "growth rates for population, employment and housing" forecast by the Southern California Association of Governments." DEIR at 4.8-5. Yet neither document explains why stationary source emissions from in-County oil and gas development would be expected to increase due to County population growth. As we noted in our prior comments, the document offers no basis for assuming that local oil and gas development is driven by local population growth in the same manner as transportation or residential or commercial development. Put another way, neither the Draft Plan nor the DEIR offer evidence that local *demand* for oil and gas drives local *production* of oil and gas (or, put another way, that local oil and gas production tracks generic projections of County growth in a linear fashion).

Nor do the Draft Plan or DEIR provide any evidence to support the assumption that County oil and gas production will continue to increase through 2050. *See* DEIR, Appendix D at 45. California production has been declining for many years. *See, e.g.*, U.S. Energy Information Administration, California Field Production of Crude Oil 1980-2018 (attached as Exhibit 3 to June 5, 2019 letter); DOGGR 2017 (attached as Exhibit 2 to June 5, 2019 letter) at 5. The DEIR's assumptions thus appear contrary to the evidence. To the extent some other assumptions lie behind the projected increase in emissions—for example, that production might increase as a result of new or expanded enhanced oil recovery technologies—Appendix B fails to explain what they are.

In fact, Appendix B's projected increase in production is contrary to state policy and trends. Statewide efforts to decarbonize the electrical grid, electrify the transportation sector, and increase building energy efficiency should reduce local demand for oil and gas significantly over the next several decades. As discussed above, the state is actively planning to transition away from fossil fuels—including reductions in both demand and supply—by 2045. *See* Exhibits 2, 3, 4 [Budget Act; Carbon Neutrality Studies Scope of Work 1 and 2]. Unfortunately, the discussion of statewide legislation and policy that could reduce fossil fuel demand and emissions in coming years (Draft Plan at B-11) is incomplete; for example, it does not include Zero Net Energy improvements to the Building Code or incentives for electric vehicles. Nor does Appendix B mention the state's Short-Lived Climate Pollutant strategy. In short, Appendix B's forecast increase in stationary source emissions lacks adequate support and analysis.

Finally, planning for continued expansion of Ventura County oil and gas production flies in the face of both overwhelming climate science and clear state policy. Nowhere do the Draft Plan or the DEIR adequately disclose or analyze the consequences of this approach or its blatant inconsistency with statewide GHG reduction plans and programs. *See* CEQA Guidelines, § 15125(d).

C. The Draft Plan Presents Vague Measures That Cannot Produce the Necessary Emission Reductions and Improperly Defers Development of Implementation Programs.

Appendix B's most fundamental weakness may be its failure to identify a set of GHG reduction measures that comes anywhere close to achieving the County's desired targets and goals. The Draft Plan offers only a vague assurance that the "County shall reduce GHG emissions" through "combination of measures included in the GHG Strategy" (Draft Plan at B-15; Policy COS-10.4), but never addresses how that "combination of measures" will reduce emissions by the amounts necessary.

Indeed, many of the "CAP" measures collected in Appendix B from various other elements of the General Plan represent only soft, unquantifiable commitments to "encourage" or "promote" various actions (see section II.B below for specific examples). Although hortatory, qualitative measures of this sort may be appropriate to supplement more concrete requirements, identification of specific, enforceable measures and quantification of resulting emissions reductions are required to demonstrate consistency with quantitative targets and goals. Enforceable, concrete commitments to mitigation also are required under CEQA. Neither the Draft Plan nor the DEIR contains adequate measures of this kind.

D. The CAP and DEIR Fail to Provide Adequate Mitigation to Reduce the Plan's Emissions.

The DEIR acknowledges that GHG emissions under the proposed Plan would be significant, even with proposed mitigation measures. DEIR at 4.8-49. The DEIR also acknowledges that the Draft Plan would result in future GHG emissions that exceed the State's 2030 and post-2030 targets for emission reduction. DEIR at 4.8-52. However, the DEIR fails to identify feasible mitigation measures that will lessen these significant impacts.

Under CEQA, mitigation measures proposed in an EIR must be "fully enforceable" through permit conditions, agreements, or other legally binding instruments. Pub. Res. Code § 21081.6(b); CEQA Guidelines §15126.4(a)(2). As the DEIR itself admits, a substantial number of the programs and policies proposed in the Plan will not result in quantifiable emissions reductions and thus cannot be counted on to mitigate the Plan's significant GHG impacts. DEIR at 4.8-50. As discussed in more detail in section III.B of this letter below, the programs and policies in the General Plan are unlikely to reduce the Project's impacts because of their voluntary, flexible, and unenforceable nature. Here, the proposed policies are vague and include directory terms like "as appropriate," "where feasible" and "support," rather than mandatory terms like "require," "reduce," and "deny."

Moreover, the Draft Plan and DEIR fail to adequately address methane emissions from the oil and gas sector. The Plan includes programs to address methane emissions from the waste (e.g., PFS-L), water (e.g., Program WR-G) and agriculture (e.g., Programs AG-I, AG-J, and AG-K) sectors. DEIR at 4.8-44. The Plan, however, omits policies, programs, or mitigation measures to reduce methane emissions from oil and gas operations. This omission should be corrected through additional mitigation measures that will effectively limit expansion of oil and gas operations in the County and actively transition the County's economy away from fossil fuels. See, sections III B and C of this letter below for specific policy recommendations related to GHG emissions reductions.

Finally, the DEIR improperly attempts to avoid responsibility for proposing mitigation by claiming the County has no authority "to enforce measures that may potentially infringe upon private property rights, reduce the economic competitiveness of local businesses, or inhibit the ability for residents to travel between residences, jobs, and amenities." DEIR at 4.8-49; *see also id.* at 4.8-39, 4.8-52. While the County obviously must operate within constitutional limits, the DEIR's attempt to disclaim any authority to control activities within its jurisdiction is overbroad to the point of abdication. For more than a century, courts have recognized that local governments may exercise their police powers despite resulting impingements upon property rights and economic competitiveness. *See, e.g.*, *Hadacheck v. Sebastian* (1915) 239 U.S. 394, 409-10. Moreover, to the extent the DEIR is claiming that any additional mitigation (particularly with respect to existing land uses) would be legally infeasible, its conclusory statements regarding lack of authority fall far short of CEQA's requirements. *See, e.g.*, *City of San Diego v. Board of Trustees of California State University* (2015) 61 Cal.4th 945, 956 ("An EIR that incorrectly disclaims the power and duty to mitigate identified environmental effects based on erroneous legal assumptions is not sufficient as an informative document.") (internal quotation omitted). "In mitigating the effects of its projects, a public agency has access to all of its discretionary powers . . . includ[ing] such actions as adopting changes to proposed projects, imposing conditions on their approval, adopting plans or ordinances to control a broad class of projects, and choosing alternative projects." *Id.* at 959. The DEIR's attempt to abdicate the County's regulatory and police power authority has no legal basis and cannot support any finding of infeasibility.

The DEIR also appears to conclude that the County may weigh the Draft Plan's asserted economic and other benefits against its environmental consequences without first proposing and adopting all feasible measures to mitigate or avoid significant effects. *See* DEIR at 4.8-49, 4.8-52. This conclusion rests on a misinterpretation of CEQA. An agency must properly find that mitigation and alternatives are infeasible *before* engaging in any balancing of benefits and harms. *See* Pub. Resources Code § 21081(a)(3), (b); CEQA Guidelines § 15092(b)(2). The County may not disclaim its responsibility to develop feasible mitigation by prematurely claiming that the project's benefits outweigh its environmental drawbacks.

E. The Draft Plan's "GHG Strategy" Does Not Satisfy the Requirements for CEQA Streamlining.

As pointed out in our prior comments, the Draft Plan (and the portions of the Draft Plan comprising the "GHG Strategy" or CAP) fails to provide any basis for streamlining analysis of the cumulative climate impacts of subsequent projects based on consistency with the General Plan or CAP. *See* CEQA Guidelines § 15183.5. The DEIR correctly proposes to eliminate one express reference to streamlining based on the CAP. The Draft Plan and the County's Initial Study Assessment Guidelines, however, should be revised to make explicit that neither the General Plan nor the CAP contains sufficient specific, enforceable GHG reduction measures to support streamlined CEQA review of future projects.

Proposed Implementation Program COS-EE (Draft Plan at B-20) would allow streamlined GHG emissions analysis for projects demonstrating that: the project is consistent with current general plan and zoning designations; that the project incorporates all applicable GHG reduction measures in Appendix B to the General Plan; and the project "clearly demonstrates the method, timing, and process for which the project will comply with applicable GHG reduction measures and/or conditions of approval. Draft Plan, Appendix B at B-20 and B-2. As drafted, however, the CAP falls far short of the requirements of CEQA Guidelines section 15183.5. In order to support a determination that CAP consistency eliminates significant climate effects, a CAP must (among other things) clearly demonstrate that its prescribed measures will actually achieve the reductions necessary to attain the CAP's stated goals. CEQA Guidelines § 15183.5(b)(1)(D). As discussed above, the CAP provides no basis for such a conclusion.

The DEIR proposes a mitigation measure that deletes Implementation Program COS-EE, purportedly on the ground that project-specific review may ensure greater emissions reductions over time than compliance with generic measures in the General Plan and CAP. *See* DEIR at 2-34 and 2-35, MM GHG-3. We agree that Implementation Program COS-EE should be removed from the Draft Plan, and that rigorous review of the climate impacts of future discretionary projects should be required. Until such time as the General Plan identifies policies and programs that lead to quantifiable emission reductions adequate to achieve the Plan's stated goals, streamlining environmental review would be unlawful. For this reason, CFROG requests not only that Implementation Program COS-EE be deleted, but also that the Draft Plan and CAP be revised (1) to remove other references to streamlined analysis of future projects (*see, e.g.*, Draft Plan at 12-4, B-3, B-5, B-24 to B-24, B-57), and (2) to expressly state that the General Plan and GHG Strategy are neither sufficient nor intended to be used to support streamlined environmental analysis under CEQA Guidelines section 15183.5. The DEIR similarly must be revised to remove references to CEQA streamlining based on the General Plan or CAP. *See, e.g.*, DEIR at 4.8-4.

II. The Draft Plan Must Ensure Lawful Application of Air Quality Thresholds.

As discussed in our June 5, 2019 comments, CFROG strongly supports retaining existing air quality thresholds in the Ojai Valley Area Plan. CFROG is pleased to see that these provisions have been carried forward into the Draft Plan as Goal OV-55 and Policy OV-55.1. Draft Plan at OV-30. However, as CFROG's prior comments pointed out, the rest of the County is still subject to a much higher air quality threshold. June 5, 2019 Comments at 12. Those prior comments recommended a policy that would commit the County to adopting more stringent air quality thresholds outside the Ojai Planning Area. *Id.* That policy should be considered as an additional mitigation measure for the Draft Plan's impacts on air quality.

Furthermore, all County air quality thresholds must be interpreted and applied in a manner consistent with CEQA. Our June 5, 2019 comments detailed the ways in which the current Air Quality Assessment Guidelines violate CEQA. June 5, 2019 Comments at 6-10. For this reason, CFROG appreciates the clarifications in Policy HAZ-10.11. In keeping with the revised policy, both the Air Quality Assessment Guidelines and the Initial Study Assessment Guidelines must be revised in a manner that reflects CEQA's requirements as outlined in our June 5, 2019 comments.

III. The DEIR for the 2040 General Plan Fails to Comply with CEQA.

A. The DEIR's Proposed Measures to Weaken General Plan GHG Reduction Policies Lack Support.

The Draft Plan includes policies that would reduce GHG emissions from both trucking and flaring associated with oil and gas production. The DEIR proposes "mitigation measures" that would water down both policies, but fails to establish any legal or evidentiary basis for doing so.

1. Mitigation Measure PR-2 (Weakening Pipeline Requirements)

Currently, oil and produced water from local oil wells are largely transported by truck. Trucking these oil production by-products creates safety hazards on County roads, exposes residents to toxic diesel pollution, and causes substantial amounts of greenhouse gas emissions due to truck vehicle miles travelled. In response to direction from the County Board of Supervisors, the Draft Plan includes Policy COS-7.7: Conveyance for Oil and Produced Water, which addresses this problem by requiring newly permitted oil wells to use pipelines instead of trucks to transport oil and produced water.

The DEIR concludes that, because oil operators located beyond a two-mile radius of a major oil transmission pipeline are likely small producers not extracting a large amount of oil, the added costs to these oil companies of constructing pipeline connections make this policy infeasible to implement and may lead to a loss of petroleum resources. DEIR at 4.12-26. The DEIR therefore proposes Mitigation Measure PR-2, which would revise Policy COS-7.7 to allow trucking if the project proponent demonstrates that conveying water or gas by pipeline would be infeasible. *Id.* at 4.12-31. There are numerous flaws with the DEIR's approach.

First, the DEIR provides no evidence that the cost of constructing pipelines would make continued extraction economically impractical. *See Preservation Action Council v. City of San Jose* (2006) 141 Cal.App.4th 1336, 1352, 1357 (evidence must show alternative is economically impracticable, not merely more expensive, to support finding of infeasibility). The DEIR cites one project that would have required a 6- to 10-mile pipeline as an example (DEIR at 4.12-23 to 4.12-24), but it provides no comprehensive economic analysis or other evidence to support its assumption that all operators more than two miles from an existing pipeline likely would have to transport oil and water by truck. *See id.* at 4.12-25 to 4.12-26. Therefore, the DEIR's proposal lacks the evidentiary support CEQA requires.

The DEIR's assumption that all operators located more than two miles from a pipeline are "smaller oil producing operations that are not extracting a large amount of oil" (DEIR at 4.12-26) particularly lacks factual support. Indeed, a review of oil and gas wells located in Ventura County on the California Geologic Energy Management Division ("CalGEM", formerly DOGGR) website provides evidence to the contrary. For example, two of the largest clusters of active oil wells outside the two-mile radius from major transmission lines in the County are in the Timber Canyon oilfield and in the Sespe oilfield. See, https://maps.conservation.ca.gov/doggr/wellfinder/#/-119.00532/34.42770/12 and DEIR at 4.12-25, Figure 4.12-4. Carbon California owns both the Timber Canyon and Sespe oilfields and operates oil wells in both fields. *See* Carbon Energy Corporation Corporate Overview 2019, at 13 attached as Exhibit 11. Carbon California does not fit the profile of a "smaller oil producing operations that are not extracting a large amount of oil." DEIR at 4.12-26. As indicated in a 2019 Air Pollution Control District filing, Carbon California represented that it produces $300,000 of oil a month or 12% of Carbon's total California production income at Timber Canyon alone. Ventura County Air Pollution Control District, Order Granting Interim Variance, Hearing Board Case No. 878 at 4 (August 26, 2019), attached as Exhibit 12. A revised analysis must evaluate ownership of existing wells outside the two-mile radius from transmission lines, the existing number of wells that already reinject their waste water into wells or already transmit it via pipeline, and the degree to which oil operators can reasonably be expected to consolidate operations to make construction of new transmission lines feasible.

Second, the DEIR provides no criteria for determining whether a project applicant has adequately demonstrated that conveying oil and water by pipeline is infeasible. Instead, Mitigation Measure PR-2 would delegate the feasibility finding to unnamed planning staff. Under CEQA, the lead agency has to determine the feasibility of a project (or by extension, mitigation measures associated with the project) by making written, public findings when the project is approved. Pub. Resources Code § 21081(a); CEQA Guidelines §§ 15091, 15092. CEQA prohibits delegation of the responsibility to adopt findings regarding the feasibility of mitigation. CEQA Guidelines § 15025(b)(2). The revised policy would delegate far more than the simple responsibility to implement mitigation. Rather, Mitigation Measure PR-2 would require County staff to make fundamental policy decisions that affect County residents' public and social health—decisions CEQA requires the County itself to make, in written findings on the record, supported by substantial evidence.

Third, and relatedly, Mitigation Measure PR-2 violate CEQA by improperly deferring formulation of mitigation. Again, the measure permits County staff to allow trucking of oil and produced water if "the proponent demonstrates" that conveyance by pipeline is infeasible. DEIR at 4.12-31. However, as noted above, the measure does not specify any criteria for infeasibility and provides no specific requirements for analysis or documentation related to feasibility. Absent any explicit criteria, County staff could allow trucking of oil and produced water whenever oil producers simply *claim* infeasibility—benefiting oil company profits while exacerbating climate change and saddling County residents with toxic air emissions and safety hazards. Indeed, just this week, the California Court of Appeal invalidated a mitigation measure that required applicants to take certain actions "to the extent feasible," finding the measure both improperly deferred and inconsistent with CEQA's purpose. *See King & Gardiner Farms, LLC v. County of Kern*, No. F077656 (Cal. App. 5 Dist., filed Feb. 25, 2020), slip op. at 40-41.

Generally, mitigation measures should not be deferred nor findings of feasibility delegated to staff. CEQA Guidelines, §§ 15126.4(a)(1)(B), 15025(b)(2).A lead agency may legally defer mitigation under CEQA only if it (1) "adopt[s] specific performance criteria that the mitigation measures were required to satisfy"; (2) shows that "practical considerations prevented the formulation of mitigation measures at the usual time in the planning process;" (3) "commit[s] itself to formulating the mitigation measures in the future." *POET, LLC v. State Air Resources Bd.* (2013) 218 Cal.App.4th 681, 736.) With respect to the proposed revisions to Policy COS-7.7, the County fails to meet any of these requirements.

In sum, as revised by Mitigation Measure PR-2, Policy COS-7.7 would provide no guidance or concrete performance standards on how feasibility determinations must be made. Staff's determinations, made long after the approval of the Draft Plan, would take place out of public view and without a hearing. "[P]ublic participation is an essential part of the CEQA process." *Ballona Wetlands Land Trust v. City of Los Angeles* (2011) 201 Cal.App.4th 455, 467 (internal quotation omitted). Delegating fundamental feasibility findings to unelected staff, without any criteria or performance standards, violates CEQA.

2. Mitigation Measure PR-3 (Weakening Gas Collection Requirements and Flaring Limitations)

Mitigation Measure PR-3 suffers from the same fundamental deficiencies as Mitigation Measure PR-2, discussed above. Mitigation Measure PR-3 would revise Policy COS-7.8: Limited Gas Collection, Use, and Disposal. This policy as proposed in the Draft Plan requires that gases from all new discretionary oil and gas wells be collected for use, sale or proper disposal. Draft Plan, Appendix B at 6-13. The DEIR concludes that Policy COS-7.8 could prove too costly for new discretionary oil and gas wells located outside of a two-mile radius of a major gas transmission pipeline. DEIR at 4.12-30. The DEIR therefore proposes a mitigation measure that revises Policy COS-7.8 to allow flaring and venting outside of emergency situations if the proponent 'demonstrates' that conducting operations without flaring is deemed infeasible. *Id*. But here too, the DEIR fails to provide evidentiary support for its assumptions, improperly delegates fundamental feasibility findings to unelected staff, and improperly defers mitigation by failing to provide criteria or performance standards for evaluating claims of infeasibility. For the same reasons discussed above in connection with Mitigation Measure PR-2, the DEIR's approach does not comport with CEQA.

In sum, Mitigation Measures PR-2 and PR-3 provide no specific performance criteria that prescribe how the mitigation measure's goals will be met, let alone provide adequate direction for County staff. As proposed, the mitigation measures would create a loophole allowing oil companies to escape compliance with Policies COS-7.7 and 7.8 simply by claiming that the cost of a pipeline connection or of gas collection is too high. Because Mitigation Measures PR-2 and PR-3 have no concrete performance standards for determinations of feasibility or how the measures' goals can be achieved, offer no reason as to why the mitigation could not have been developed, and commit only to the most illusory of measures, mitigation is improperly deferred.

Accordingly, the County should maintain both policies as recommended by the Board of Supervisors and as presented in the Draft Plan. All newly permitted discretionary oil wells should be required to convey oil and produced water via pipelines, and all gases produced from new discretionary oil and gas wells should be collected for use, sale or proper disposal.

B. Merely Hortatory General Plan Policies Are Inadequate as Mitigation for CEQA Purposes.

Mitigation measures proposed in an EIR must be "fully enforceable" through permit conditions, agreements, or other legally binding instruments. Pub. Res. Code §

21081.6(b); CEQA Guidelines § 15126.4(a)(2). Many of the General Plan's policies and programs relied on to mitigate impacts related to GHG emissions are vague, optional, directory, or otherwise unenforceable. These policies should be made mandatory. A few examples—out of numerous instances—include the following:

- LU-11.4 Sustainable Technologies: *The County shall encourage discretionary development on commercial and industrial- designated land to incorporate sustainable technologies*.... Draft Plan Appendix B at B-31. (This policy is optional and unenforceable; the word "require" should replace "encourage.")

- LU-18.5 Participation in Climate Change Planning: *The County shall encourage stakeholders in designated disadvantaged communities who are vulnerable to sea level rise or other climate change impacts to have the opportunity to learn about and participate in the decision-making process for adaptation planning within Ventura County*. Draft Plan Appendix B at B-32. (This policy is optional and unenforceable; the word "encourage" should be replaced with "provide opportunities for"; this policy should have an accompanying implementation program that specifies the sort of opportunities the County will provide to facilitate public participation.)

- PFS-2.1 Sustainable Plans and Operations: *The County shall encourage energy efficiency, greenhouse gas reduction features, and resiliency planning into County facility and service plans and operations*. Draft Plan Appendix B at B -43. (This policy is optional and unenforceable; the word "require" should replace "encourage.")

- COS-7.4 Electrically-Powered Equipment for Oil and Gas Exploration and Production. *The County shall require discretionary development for oil and gas exploration and production to use electrically-powered equipment from 100 percent renewable sources and cogeneration, where feasible*.... Draft Plan Appendix B at B -49. (This policy is vague and unenforceable, improperly delegates feasibility findings to staff, and provides no criteria or performance standard for determining feasibility.)

- Program AG-K: *reduce the amount of water that needs to be treated, pumped and conveyed, which requires the use of energy*" Draft Plan at 4.8-41. (This policy is vague and unenforceable as it provides no guidance as to quantities that could be treated, specific treatment methods, or other information on how the County would implement this program.)

Related Implementation Program K: Water-Saving Irrigation Techniques Program is equally unenforceable as it directs the County only to collaborate with and support the UC Cooperative Extension Office educational programs and does not require the agency to take any specific action.

- COS-M Oil and Gas Tax: *The County shall evaluate the feasibility of establishing a local tax on oil and gas operations located in the unincorporated county*. Draft Plan Appendix B at B53. (This policy is vague, unenforceable and voluntary as it does not commit the County to taking any concrete steps toward implementing a tax beyond evaluating its feasibility. The policy should be revised to state "The County shall, by January 1, 2022, evaluate the feasibility of establishing a local tax on oil and gas operations located in the unincorporated county, and if the County determines any such tax is feasible, it shall, by January 1, 2023, develop and propose such a tax measure for voter approval.")

- HAZ-10.1: Air Pollutant Reduction Consistent with the General Plan: The County shall strive to reduce air pollutants from stationary and mobile sources to protect human health and welfare, focusing efforts on shifting patterns and practices that contribute to the areas with the highest pollution exposures and health impacts. Draft Plan Appendix B at B59. (This policy is optional and unenforceable; the words "achieve substantial reductions of" should replace "strive to reduce.")

A general plan's goals and policies are frequently somewhat vague and aspirational. However, the County may rely on such policies to mitigate environmental impacts under CEQA *only if* they represent firm, enforceable commitments. *See Napa Citizens for Honest Gov. v. Napa County Bd. of Supervisors* (2001) 91 Cal.App.4th 342, 358 (citing *Rio Vista Farm Bureau Center v. County of Solano* (1992) 5 Cal.App.4th 351, 377). CEQA requires that mitigation measures actually be implemented—not merely adopted and then disregarded. *Anderson First Coalition v. City of Anderson* (2005) 130 Cal.App.4th 1173, 1186-87; *Federation of Hillside & Canyon Assns. v. City of Los Angeles* (2000) 83 Cal.App.4th 1252, 1261.

Here, the proposed Plan's vague and noncommittal policies and programs (and policies for which no implementation programs are identified) do not enforceably commit the County to specific actions and thus fail to mitigate impacts. Moreover, DEIR proposed Mitigation Measure GHG-4 (New Implementation Program HAZ-X: Greenhouse Gas Reduction Policy Enhancement) fails to remedy the aforementioned failures. Mitigation Measure GHG-4 directs the Climate Emergency Council, to be established under Policy COS-CC, to develop subprograms that "may" include expansions to programs in the General Plan. DEIR at 4.8-47. Aside from the fact that the measure itself indicates that expansion of emission reduction programs is uncertain through use of the word "may," this mitigation measure again defers identification of feasible, effective measures needed to reduce significant impacts. As discussed above, this approach is unlawful. CEQA Guidelines, §§ 15126.4(a)(1)(B).

Because the DEIR cannot ensure that the referenced policies will in fact be implemented to mitigate the proposed Plan's impacts, and because the proposed mitigation further defers identification of mitigation, the policies and measures cannot serve as CEQA mitigation. *See Anderson First*, 130 Cal.App.4th at 1186-87.

C. The DEIR Has An Obligation to Consider Additional General Plan Policies That Would Mitigate the Significant Environmental Effects of Oil and Gas Development.

As indicated in our earlier comments, CFROG is concerned about the effects of oil and gas drilling on communities within the County and more broadly. The drilling and maintenance of oil and gas wells contribute to: local air pollution, climate change, contamination of water supplies, and risks to public health and safety. To this end, the County General Plan should do more to ensure protection of the County's natural resources and to preserve quality of life for all the County's residents.

1. Land Use Element

a. Climate and Public Health Alternative: Prohibit New Oil and Gas Development

Continued and expanded oil and gas production runs counter to the state's 2030 and 2050 GHG reduction goals. *See* Health & Safety Code §§ 38550, 38566; Executive Order S-3-05. Expanded production also runs directly counter to state efforts to reduce both demand and supply of fossil fuels and to achieve carbon neutrality by 2045. Accordingly, in its comments on the Preliminary Draft Plan, CFROG recommended policies that would prohibit new oil and gas development in the County. *See* June 5, 2019 Comments at 3-5.

As those policies were not evaluated in the DEIR, CFROG once again proposes that the following new policies[3] be added to the General Plan Land Use Element as mitigation measures and/or as part of a "Climate and Public Health Alternative" that would reduce the significant impacts of oil and gas development:

Policy LU-xx Prohibition of New Oil and Gas Extraction. The development, construction, installation, or use of any new facility, appurtenance, or above-ground equipment, whether temporary or permanent, mobile or fixed, accessory or principal, for petroleum extraction is prohibited on all lands within the County's unincorporated area as a reasonable means of reducing greenhouse gas emissions and protecting the health and welfare of residents consistent with federal and state law.

Existing oil and gas operations would become nonconforming uses under this policy. Those uses, in turn, should be phased out according to a schedule that acknowledges vested rights and constitutional limitations while simultaneously supporting statewide efforts to reduce both supply and demand of fossil fuels. CFROG thus recommends that the following policies and implementation program be added to the General Plan, again either as mitigation measures or as part of an alternative that would reduce significant environmental impacts:

Policy LU-xx Existing Oil and Gas Facilities. Oil and gas extraction land uses lawfully existing on [*the effective date of the General Plan Update*] may continue as nonconforming uses to the extent allowed under State and local law until they are phased out pursuant to Policy LU-xx. Such uses, while they are continuing, shall not be enlarged, increased, extended, or otherwise expanded or intensified.

Policy LU-xx Phase-Out of Nonconforming Oil and Gas Operations. Nonconforming oil and gas extraction land uses shall be terminated within the shortest period of time necessary to ensure recovery of capital investments and compliance with constitutional limitations.

Implementation Program LU-X: To implement Policies LU-xx, xx, and xx [*Prohibition, Existing Facilities, and Phase-Out*], on or before January 1, 2022, the County shall develop and propose for adoption an ordinance providing for amortization of non-conforming oil and gas land uses, notice and hearing requirements, and any other provisions necessary to phase out such uses in a manner consistent with state and federal

[3] The policies proposed in this letter are substantively equivalent to the policies proposed in CFROG's June 5, 2019 Comments, although the specific wording of some proposals has been revised.

<u>law. The ordinance shall contain provisions sufficient to ensure that all non-conforming oil and gas uses will be discontinued no later than 2045 unless discontinuance is expressly prohibited or precluded by state or federal law.</u>

b. Discretionary Review and Permitting

In the absence of a complete prohibition on new wells, the County should require all new oil wells and proposed expansions at existing facilities to obtain discretionary permits. As discussed in our prior comments, under current Ventura County policies and practices, the vast majority of oil and gas development in the County is not subject to local CEQA review or conformance with current County policies and regulations. This is because the County requires only a zoning clearance for any additional oil wells drilled within the extensive areas covered by antiquated special use permits. Under current County practices, these zoning clearances are considered to be ministerial and thus do not trigger CEQA's environmental review and mitigation requirements. We also understand that the County has not been requiring compliance with updated regulations for these clearances.

CFROG appreciates that the Board of Supervisors recently directed County staff to prepare an ordinance requiring discretionary review of new and expanded oil and gas operations at facilities subject to antiquated special use permits. However, CFROG strongly believes that a policy requiring such review should be included in the General Plan.

The Draft Plan includes policies requiring new or modified *discretionary* oil and gas development to comply with current policies, standards, and conditions (Policy COS-7.3) and for new discretionary oil and gas development to use electrically-powered equipment (Policy COS-7.4) and to restore and revegetate the site after production (Policy COS-7.5). However, these policies apply only if a Project is subject to issuance of a discretionary permit. Because the Draft Plan does not require discretionary review for all new and expanded oil and gas operations, the Draft Plan and its DEIR fail to ensure that such operations will comply with new policies and programs to reduce GHG emissions, as well as address other impacts.

CFROG proposes the following policies to ensure that any new or expanded wells undergo discretionary review.

<u>Policy LU-xx Renewal of Oil and Gas Facility Permits. All applications for renewal of oil and gas facility permits shall undergo discretionary review and shall be subject to updated air emissions requirements and other standards and conditions related</u>

to oil and gas operations. Terms of renewed permits shall be limited in duration to the reasonably expected life of the wells.

Policy LU-xx Expansion of Existing Oil and Gas Operations. Proposed changes to or expansions of existing oil and gas sites, facilities, or activities shall undergo discretionary review to ensure compliance with updated regulations and appropriate environmental review pursuant to the California Environmental Quality Act.

Policy LU-xx Discretionary Review of All New Wells. Discretionary review shall be required for the drilling or construction of any new well, and for the re-drilling or deepening of any existing well, unless any such drilling, construction, re-drilling, or deepening is specifically identified by location and number or specifically authorized in an active discretionary permit. Policy LU-xx Inspection and Monitoring of Oil and Gas Facilities. Approved expansions of existing oil and gas operations shall be conditioned to require monitoring through installation of continuous emission monitoring systems (CEMS) for air quality emissions and continuous effluent quality monitoring system (CEQMS) for water pollution to detect emissions and plumes in real time.

These proposed policies are intended not only to support adoption of the ordinance that the Board of Supervisors directed staff to develop in September 2019, but also to reinforce existing County Code provisions requiring new oil and gas development to be authorized by a discretionary conditional use permit. *See* Non-Coastal Zoning Ordinance ["NCZO"], §§ 8105-4 and 8105-5, "Mineral Resource Development," and "Oil and Gas Exploration and Production"; Coastal Zoning Ordinance ["CZO"], § 8174-5, under heading "Oil and Gas: Exploration and Production"). Similarly, these policies would support County Code provisions requiring discretionary approval in through permit modification for any material change to an existing permit. *See* NCZO, § 8111-6.1; CZO, § 8181-10.4.) These policies would reduce the overall impacts of oil and gas development by ensuring discretionary review, and site-specific mitigation and monitoring following CEQA review.

Likewise, we propose the following General Plan policy to address oil and gas facility operations and expansions under Antiquated Conditional Use Permits.

Policy LU-xx Oil and Gas Facilities Operating with Antiquated Conditional Use Permits. All oil and gas exploration and production operations, including legally existing operations lacking discretionary permits under the County Zoning Ordinance, are automatically subject to all requirements of the County Zoning Ordinance, General Plan, and other local regulations and standards relating to oil and gas exploration, extraction, and production, except to the extent that application of such regulations or standards would impair a vested right under state law.

This policy is feasible as evidenced by County Counsel's position[4] regarding the feasibility of amending the County Code to include a provision requiring antiquated conditional use permits to be and consistent with the Board's direction to staff to update the County Code accordingly. Letter Report from County Counsel, Leroy Smith, to the County Board of Supervisors dated September 10, 2019, at 4, attached as Exhibit 13.

Finally, CFROG previously proposed a policy that would prohibit extreme extraction methods like well stimulation treatments (including fracking) and cyclic steaming for tar sands production. June 5, 2019 Comments at 6. The DEIR did not evaluate this proposed policy. This policy should be evaluated as a mitigation measure for air quality, greenhouse gases, toxic and seismic hazards, and water quality and supply, all of which are adversely affected by extreme extraction.

Policy LU-xx Prohibit Extreme Extraction. The development, construction, installation, or use of any facility, appurtenance, or above-ground equipment, whether temporary or permanent, mobile or fixed, accessory or principal, for well stimulation treatments, cyclic steaming, and steam flooding are prohibited on all lands within the County's unincorporated area.

2. Conservation and Open Space Element

a. Oil and Gas Resources

The Conservation and Open Space Element's proposed policies related to oil and gas resources are also lacking specificity and enforceability. CFROG proposes the revisions to the following proposed General Plan policies:

COS-7.5 Restoration and Revegetation of Sites Used for Oil and Gas Exploration, Extraction, and Production. The County shall require that discretionary development for oil and gas exploration activities and all existing oil and gas development undergoing permit review be conditioned to require the restoration and revegetation of the site if the exploration does not result in oil and gas production facilities or when production activities are terminated.

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[4] "The County has a good legal argument that it can, in general, require newly proposed oil and gas development under antiquated permits to obtain authorization through a discretionary permit modification." See Exhibit 13, at 4.

COS-7.6 Abandoned Oil and Gas Well Identification. The County shall evaluate discretionary development to identify any abandoned oil and gas wells ~~on the project site~~ on all oil and gas operation sites.

In addition, CFROG proposes the following new policies be added to the Conservation and Open Space Element:

Policy COS-xx Nonconforming Oil and Gas Operations. The County shall actively work to discontinue nonconforming oil and gas extraction uses.

Policy COS-xx Review of Existing Permits. The County shall review all oil and gas permits that are 10 years or older to ensure that they are compliant with current standards and regulations to the maximum extent permitted by law.

Policy COS-xx Abandoned Oil and Gas Well Remediation. To prevent contamination of groundwater and leaks to the surface, the County shall require all abandoned oil and gas wells to be cleared of all equipment, plugged, capped and fully remediated in accordance with State and federal requirements within 60 days of ceasing operations.

Policy COS-xx Reuse of Abandoned Oil Fields. The County shall require the reclamation of abandoned oil fields to productive second uses.

Policy COS-xx Off-shore Oil Drilling. The County shall oppose any proposals for new or expanded off-shore oil drilling in the vicinity of Ventura County.

b. Energy Resource Conservation

CFROG recommends the following revisions to the proposed Energy Resource Conservation Policies:

Policy COS-8.1 Reduce Reliance on Fossil Fuels. The County shall promote the development and use of renewable energy resources (e.g., solar, thermal, wind, tidal, bioenergy, hydroelectricity) to reduce dependency on petroleum-based energy sources by developing and implementing incentives for alternative energy development and use.

Policy COS-8.7 Sustainable Building Practices. The County shall ~~promote~~ establish and require sustainable building practices that incorporate a “whole systems” approach for design and construction that consumes less energy, water, and other nonrenewable resources, such as by facilitating passive ventilation and effective use of daylight.

Policy COS-8.8 Renewable Energy Features in Discretionary Development. The County shall ~~encourage~~ require the integration of features that support the generation, transmission, efficient use, and storage of renewable energy sources in discretionary development.

Policy COS-8.9 Urban Tree Canopy Improvements for Energy Conservation. The County shall ~~encourage~~ require all discretionary development to include the planting of shade trees on each property and within parking areas to reduce radiation heat production.

In addition, CFROG proposes that the County add the following new policies related to energy resource conservation to further reduce GHG emissions:

Policy COS-xx Carbon-free Economy. The County will prioritize and facilitate a rapid transition to a carbon-free economy countywide.

Policy COS-xx Non-fossil Fuels for County Facilities and Fleets. The County will actively pursue a rapid transition to a diversity of non-fossil fuel alternatives for all County facilities and vehicle fleets.

Policy COS-xx Non-fossil Fuels Manufacturing and Distribution. The County will actively pursue, through the development of incentives and streamlined permit review, increasing a diversity of renewable energy manufacturing and distribution facilities countywide.

3. Hazards and Safety Element

The Draft Plan's Hazards and Public Safety element recognizes the threats being faced by the County, particularly climate change and seismic activity. Unfortunately, as CFROG pointed out in prior comments, the measures outlined in the Draft Plan are insufficient to protect County residents from these inevitable hazards and other adverse effects of oil and gas activity.

a. Protection from Seismic Hazards.

The Draft Plan fails to provide adequate protection from identified hazards related to oil and gas pipelines. Specifically, Policy HAZ-4.2 requires oil and gas pipelines to avoid intersecting active faults to the extent possible. However, the policy includes no specific measures for pipelines that must cross a fault line to address steps that must be taken to prevent spills from ruptured lines. CFROG suggests additional policies for the County to consider that would address this omission:

Policy HAZ-xx Safety Standards for Cross Fault Line Pipelines. Gas or crude oil transmission and distribution pipelines which cross active or potentially active fault lines shall be subject to additional safety standards, including emergency shutoff capabilities.

Similarly, in proposed Policy HAZ-4.8, the County attempts to prohibit hazardous material storage facilities within areas prone to severe ground shaking. Yet, there is no mention of the detrimental effects of "fracking" or the injection of wastewater into underground geological formations for storage and disposal. Numerous studies have linked fracking to increased seismic activity. In a county crisscrossed by numerous active and potentially active faults, it is only reasonable for the County to consider the effects of fracking on increasing the likelihood of seismic events and the potential dangers associated with this method of resource extraction.

Additionally, the injection of wastewater into underground formations is also linked to increased seismic events, which could trigger a leak within the formation, which in turn may endanger the groundwater quality in the County. *See*, https://www.usgs.gov/faqs/does-production-natural-gas-shales-cause-earthquakes-if-so-how-are-earthquakes-related-these ; "The 2013–2016 induced earthquakes in Harper and Sumner Counties, southern Kansas," Bulletin of the Seismological Society of America. Justin L. Rubinstein, William L. Ellsworth, and Sara L. Dougherty, available at https://pubs.er.usgs.gov/publication/70195671 , abstract attached as Exhibit 14; *see also* "Studies link earthquakes to fracking in the Central and Eastern US," Seismological Society of America, ScienceDaily April 26, 2019, available at https://www.sciencedaily.com/releases/2019/04/190426110601.htm , attached as Exhibit 15. Thus, we recommend the County add a policy requiring any fracking or wastewater disposal project to study the potential impacts of triggering seismic events and the impacts if a seismic event does occur. Such activities should not be allowed without a thorough understanding of the potential consequences and with plans in place to limit those negative consequences. To this extent, CFROG suggests adding a new policy to ensure that all injection into subsurface formations is done with a substantial understanding of the potential effects.

Policy HAZ-xx Seismic and Geotechnical Studies for Well Injection. Require that applicant provide additional seismic and other geotechnical studies which demonstrate that there will be no increased risk of earthquakes, subsidence or related geologic issues resulting from extraction, drilling or injection activities, when within a fault zone.

b. Compliance with Local, State, and Federal Regulations and Standards.

Proposed Policy HAZ-7.1 requires all discretionary permits for proposed oil and gas exploration and production projects to comply with local, state, and federal oil spill prevention regulations. This is insufficient. The County must do more to ensure its residents are safe and the environment protected from oil and gas exploration and production projects. As mentioned above, the County must include specific and quantifiable mitigation measures for existing development as well. While the policy contemplates compliance with local standards, the County does not have any standards in place to supplement federal and state regulations to address the specific problems being faced in Ventura County.

Additionally, state and federal regulations have changed and been updated. If a conditional use permit has been issued more than five years ago, the County should require inspection and enforcement of the existing conditions and evaluation if imposing new conditions would significantly improve the safety of such projects. Permits for operations involving hazardous substances also should be subject to discretionary renewal. To that end, CFROG suggests the County include the following policies in the draft plan:

Policy HAZ-xx Maintain Compliance with Local, State, and Federal Oil Spill Prevention Regulations. Review all oil exploration and production development which has been approved more than five (5) years prior to the effective date of this General Plan for consistency with applicable local, state, and federal oil spill prevention regulations. Establish mitigation activities as needed to maintain the standards and conditions required when the permit was issued.

Policy HAZ-xx Review of Permits Involving Hazardous Materials. Permits for any oil exploration and production projects, and associated production facilities, involving the transport or use of hazardous materials must be effective for no longer than five years, and must be reviewed and either renewed, further conditioned, or denied prior to expiration.

c. Increased Bonding Requirements to Ensure Proper Plugging and Abandonment, and Remediation of Oil Production and Exploration Sites.

Based on the wide array of impacts associated with oil and gas development, CFROG suggests that the County increase the bonding requirement to cover potential negative consequences from spills, failure to properly plug and abandon wells, and failure to properly remediate and restore the well site to other beneficial uses. The increased bonding requirement should be linked to proper plugging and abandonment after extraction has been finished. The oil and gas producers should plug the well and implement an abandonment plan. Such plans should be required prior to approval of the discretionary development and must be followed in the event that the well is deemed inactive. Additionally, the Hazards element fails to address the potential dangers associated with improperly abandoned wells. This omission creates a risk of leaks and spills that could harm County residents that may encounter an abandoned oil and gas well unknowingly. CFROG suggests the draft General Plan include a new policy to increase the bonding requirement as a condition of approval to ensure proper plugging, abandonment, and remediation of oil and gas production and exploration sites.

Policy HAZ-xx Increased Bonding Requirement and Remediation Plans. Enforce decommissioning and abandonment standards for oil extraction and exploration projects as a condition of approval. Require applicants to include a cost estimate for decommissioning and site restoration work following the cessation of extraction activities, and to post a bond for the estimated amount. Conduct an inspection after decommissioning and site restoration to ensure that all remediation activities have been satisfactorily completed. Require operators to dismantle all structures that cannot be effectively reused, and to recycle all materials as much as possible. Require that all hazardous waste, including electronics or toxic materials, is disposed of in accordance with applicable health and environmental safety standards.

d. Inspection and Enforcement of Existing CUP Conditions.

With technological advances and changes to state and federal oil and gas exploration and production regulations, the County should prioritize inspection and enforcement of the conditions of approval for existing oil and gas exploration and production sites. This is particularly true with respect to safety and oil spill prevention measures. To this effect, CFROG suggests including a new policy to inspect oil pipelines and enforce existing CUP conditions.

Policy HAZ-xx Annual Inspection and Enforcement of Existing CUP Conditions. Require annual inspections and enforcement of CUP conditions, including ensuring the most up to date spill prevention and safety technology.

e. Real-Time Detection and Monitoring of Emissions and Plumes.

CFROG suggests the County add a policy to the Draft Plan to require monitoring of oil and gas exploration and production sites, including the pipelines used to convey the oil and gas, through the use of cameras or other technology to detect emissions and plumes in real time:

Policy HAZ-xx Inspection and Monitoring of Oil and Gas Facilities. New discretionary oil and gas development and any proposed expansion of or changes to existing oil and gas operations shall be conditioned to require monitoring through installation of continuous emission monitoring systems (CEMS) for air quality emissions and continuous effluent quality monitoring system (CEQMS) for water pollution, or equivalent monitoring measures (including but not limited to thermal imaging cameras) capable of detecting and recording emissions and plumes in real time.

f. Pipeline Inventory and Maintenance Records.

The Draft Plan indicates that oil and gas transport lines have been mapped on the County's GIS. Draft Plan at 7-21. In addition to mapping these facilities, however, the County should also keep accurate records of maintenance and control technology for these pipelines. It is important to track the age of the pipelines and the technology installed on these pipelines to prevent spills from ruptures. By having this information at hand, the County will have the tools to prioritize specific pipelines for maintenance, and in a seismic event, the ability to identify the pipelines requiring immediate attention. Also, if one pipeline fails, by comparing the age and technology on the pipeline, the County can identify those other pipelines in similar conditions that will need to be replaced prior to another failure. CFROG suggests the addition of a new policy to require oil and gas producers to furnish the County with the relevant records on the maintenance and technology installed on those pipelines.

Policy HAZ-xx (Pipeline Inventory and Maintenance Records). Require all oil and gas producers with active pipelines to furnish the County with accurate and up to date maintenance and safety technology records.

IV. The DEIR's Proposed Buffer Requirements For Oil and Gas Operations Are Insufficient to Protect Public Health.

The Draft Plan proposes setbacks from oil and gas operations to protect sensitive receptors from toxic pollutants. Draft Plan at 6-12. Proposed General Plan policy COS-7.2: Oil Well Distance Criteria would require new discretionary oil wells to be located 1,500 from residences and 2,500 feet from schools. DEIR Mitigation Measure PR-1 proposes revisions to this policy to limit the buffer to 1,500 feet from all sensitive receptors. DEIR at 2-40 and 4.12-18. The GPU DEIR indicates that there are currently 23 active and idle oil wells within 2,500 feet of schools and 715 active wells within 1,500 feet of homes in the County. DEIR at 4.12-14.

A number of recent studies and literature reviews have discussed impacts from oil and gas development, including emissions of criteria and toxic air pollutants, water pollution, noise, light, and biological hazards like Valley Fever.[5] Many of these studies provide a foundation supporting the establishment of setbacks and for imposing setbacks of at least 2,500 feet from oil and gas operations.

For example, a literature review conducted by Nicole J. Wong, MPH, suggests that far greater setback distances are necessary to protect against adverse health outcomes,

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[5] In addition to the studies discussed in detail below, numerous studies and literature reviews have detailed harm from fracking and other forms of oil and gas development. *See, e.g.*, Concerned Health Professionals of NY and Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed. June 2019), attached as Exhibit 16; Kristina Marusic, *After a decade of research, here's what scientists know about the health impacts of fracking*, Environmental Health News (April 15, 2019), *available at* https://www.ehn.org/health-impacts-of-fracking-2634432607.html (visited Feb. 25, 2020). Notably, although these studies focused on the health effects of fracking, a comprehensive review of well stimulation techniques (including fracking) by the California Council on Science and Technology ("CCST") concluded that "[a]ll forms of oil and gas development, not just that enabled by well stimulation, may cause similar public health risks." Seth D. C. Shonkoff, et al., *Chapter Six: Potential Impacts of well Stimulation on Human Health in California*, in Jane C. S. Long, et al., California Council on Science and Technology, An Independent Scientific Assessment of Well Stimulation in California, Volume II: Potential Environmental Impacts of Hydraulic Fracturing and Acid Stimulations at 375 (updated July 2016), available at https://ccst.us/wp-content/uploads/160708-sb4-vol-II-6-1.pdf (visited Feb. 25, 2020).

particularly from exposure to air pollutants.[6] Based on studies showing adverse health effects from air and water pollution at distances well over one-half mile, Ms. Wong concluded that "a 2,500-foot setback recommendation is on the *lower end* of the range of distances where research has determined harmful health and quality of life impacts of toxic emissions and exposures."[7]

In another example, a study[8] considered the minimum distance that might be required in case of a blow-out or explosion event by investigating historical evacuation data. This study determined that the average evacuation zone for such incidences is 0.8 miles, or 4,224 feet.[9] In addition, the Environmental Health Project (EHP), a public health organization consisting of a consortium of experts in environmental studies and public health, agreed that 1.0 to 1.25-mile distance (6,600 feet) from unconventional oil and gas development (i.e., fracking) is an acceptable minimum to protect human health. Additionally, the study recommends greater setback distances for settings where vulnerable subpopulations might gather, such as schools, day care centers, and hospitals.

In sum, these recent reviews, and the numerous scientific studies considered therein, provide scientific and factual support for development of setbacks in excess of 2,500 feet. An setback of at least 2,500 feet is necessary to protect the health and safety of County residents.

Mitigation Measure PR-1 properly expands the list of "sensitive use structures" to which Policy COS-7.2 would apply. DEIR at 4.12-18. However, the measure would reduce the buffer distance from schools from 2,500 feet to 1,500 feet. As discussed above, ample scientific information indicates that a 1,500-foot buffer is likely insufficient to protect public health and safety.

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[6] Nicole J. Wong, MPH, *Existing Scientific Literature on Setback Distances from Oil and Gas Development Sites* (version 2, Nov. 2017), *available at* http://www.stand.la/research--reports.html, attached as Exhibit 17.
[7] *Id.* at 1; see also *id.* at 6 (Table 1) (comparing distances at which several studies documented potential adverse health outcomes with 2,500-foot proposed setback distance) (emphasis added).
[8] Haley, M., McCawley, M., Epstein, A. C., Arrington, B., & Bjerke, E. F. (2016). *Adequacy of current state setbacks for directional high-volume hydraulic fracturing in the Marcellus, Barnett, and Niobrara Shale Plays*. ENVIRONMENTAL HEALTH PERSPECTIVES, 124(9), 1323, available at https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1510547
[9] *Id*. at 3.

In particular, reducing the proposed buffer distance from schools as proposed in Mitigation Measure PR-1 would be both unsupported and unwise. Children are often outdoors at schools, daycare centers, and recreation facilities, where they can be exposed to significant hazards. For example, on March 6, 2006, a small earthquake caused a break in an idle well bore in Upper Ojai, causing oily brine to flow to the surface for months. *See* DOGGR, 2006 Annual Report of the State Oil & Gas Supervisor at 26 (2007), excerpt attached as Exhibit 18; *see also* The Next Big One, VC Reporter (Aug. 22, 2013), at https://vcreporter.com/2013/08/the-next-big-one/ (visited Feb. 25, 2020); Jhon Arbelaez, Shaye Wolf, and Andrew Grinberg, On Shaky Ground: Fracking, Acidizing, and Increased Earthquake Risk in California at 13 (March 2014), attached as Exhibit 19. Drilling near schools and daycares could expose many more children to similar (or far worse) hazards. Therefore, CFROG respectfully requests that the County revise Policy COS-7.2 to require a minimum setback distance of 2,500 feet from *all* sensitive receptors, including schools, daycares, residences, and medical facilities.

Finally, Policy COS-7.2 would apply only to "new discretionary oil and gas wells." DEIR at 4.12-18; Draft Plan at 6-12.[10] The proposed policy thus leaves numerous residents with no protection from existing oil and gas wells. *See* DEIR at 4.12-16 (Figure 4.12-2). Although CFROG recognizes that some of these existing wells may be subject to vested rights, existing operations should nonetheless be amortized and phased out as soon as legally possible.

Accordingly, the County should evaluate an additional mitigation measure consisting of the following policy and implementation program:

<u>Policy COS-xx Phase-Out of Existing Oil and Gas Operations Near Sensitive Uses. Existing oil and gas exploration and production activities located closer than the minimum distance from sensitive use structures established by Policy COS-7.2 shall be terminated within the shortest period of time possible, consistent with protection of any vested rights and applicable constitutional limitations</u>.

<u>Implementation Program COS-X: To implement Policy COS-xx [*Phase-Out*], on or before January 1, 2023, the County shall develop and propose for adoption an ordinance providing for amortization of existing oil and gas exploration and production</u>

[10] As proposed in the Draft Plan, Policy COS-7.2 applies only to "oil wells," while in the DEIR, the policy would apply to "oil and gas wells." The policy clearly should apply to both oil and gas wells.

activities located closer than the minimum distance from sensitive use structures established by Policy COS-7.2, notice and hearing requirements, and any other provisions necessary to phase out such uses as quickly as possible in a manner consistent with state and federal law.

V. The DEIR Improperly Eliminated and Failed to Analyze Alternatives That Would Reduce or Avoid Significant Impacts.

The DEIR does not comply with the requirements of CEQA because it fails to undertake a legally sufficient study of alternatives to the Project. A proper analysis of alternatives is essential to comply with CEQA's mandate that, where feasible, significant environmental damage be avoided. Pub. Resources Code § 21002 (projects should not be approved if there are feasible alternatives that would substantially lessen environmental impacts); CEQA Guidelines §§ 15002(a)(3), 15021(a)(2), 15126(f). The primary purpose of CEQA's alternatives requirement is to explore options that will reduce or avoid adverse impacts on the environment. *Watsonville Pilots Assn. v. City of Watsonville* (2010) 183 Cal.App.4th 1059, 1089. Therefore, the discussion of alternatives must focus on project alternatives that are capable of avoiding or substantially lessening the significant effects of the project, even if such alternatives would impede to some degree the attainment of the project objectives or would be more costly. CEQA Guidelines § 15126.6(b); *see also Watsonville Pilots,* 183 Cal.App.4th at 1089 ("[T]he key to the selection of the range of alternatives is to identify alternatives that meet most of the project's objectives but have a reduced level of environmental impacts").

As a preliminary matter, the DEIR's failure to disclose the extent and severity of the Project's climate impacts necessarily distorts the document's analysis of Project alternatives. As a result, the alternatives are evaluated against an inaccurate representation of the Project's impacts. Proper identification and analysis of alternatives is impossible until Project impacts are fully disclosed. Moreover, as discussed above, the document's analysis is incomplete and/or inaccurate so that it is simply not possible to conduct a comparative evaluation of the Project's and the alternatives' impacts.

In any case, the DEIR improperly circumscribes its analysis of potential Project alternatives and makes no serious attempt to describe an alternative that avoids or substantially minimizes the climate impacts of the Project. Comments on the Notice of Preparation for the EIR, including comments from CFROG, urged the County to analyze alternatives that would reduce oil and gas production. CFROG also requested that the County add policies and programs that would achieve similar purposes in its comments on the Preliminary Draft Plan. See June 5, 2019 Comments at 3-5, 25-30.

The DEIR identifies three alternatives that would address climate impacts related to GHG emissions. These include: the Limit Active and Idle Wells and Reduce Oil Well Emissions Alternative, the Eliminate or Reduce Existing Oil and Gas Wells or Production Alternative, and the Carbon Neutrality Alternative. As discussed in more detail below, the DEIR, however, declined to evaluate any of these proposals as alternatives, and instead rejected them all as infeasible. The DEIR's refusal to evaluate these additional policies, either as alternatives or mitigation measures, was improper.

A. Alternatives That Would Reduce Oil and Gas Production Were Improperly Rejected.

The DEIR rejected alternatives that would limit oil and gas production on two grounds. First, the DEIR found such alternatives "focuse[d] on one specific land use and [did] not comprehensively address most of the basic project objectives." DEIR at 6-9. Yet the DEIR does not identify a single project objective that would not be met by an alternative that provides a comprehensive plan for development in the County while simultaneously reducing reliance on oil and gas exploration and production. Such an alternative would still satisfy most if not all of the objectives listed in the DEIR. It would also avoid or substantially lessen significant impacts of oil and gas development. Nothing in CEQA contemplates or permits elimination of an alternative that meets most project objectives solely on the basis that it would reduce environmental impacts associated with a subset of land uses. And even if CEQA did preclude analysis of alternatives that primarily focus on a subset of land uses, the alternatives' provisions still could serve as mitigation measures for the significant effects of those land uses. Either way, the DEIR fails to justify its elimination of these provisions from detailed consideration.

Second, the DEIR claims eliminating or reducing existing oil and gas operations would "present legal and economic feasibility issues." DEIR at 6-9. This claim, however, is entirely conclusory and lacks any supporting explanation or analysis. It is also wrong.

Reducing both new and existing oil and gas operations in the County is legally feasible. Nearly a century of case law confirms that local governments may determine where oil and gas operations occur, and may even prohibit such operations altogether. *See, e.g.*, *Higgins v. Santa Monica* (1964) 62 Cal.2d 24; *Beverly Oil*, 40 Cal.2d 552; *Pacific Palisades Assn. v. City of Huntington Beach* (1925) 196 Cal. 211; *Hermosa Beach Stop Oil Coalition*, 86 Cal.App.4th 534; *Friel v. Los Angeles County* (1959) 172 Cal.App.2d 142. A 1976 opinion of the Attorney General (59 Ops. Cal. Atty. Gen. 461) suggested that while some local attempts to regulate the precise manner of oil and gas production might be preempted, local governments generally retain their traditional authority to control land use and protect public health; the Attorney General concluded in this context that an ordinance completely prohibiting oil and gas development probably would *not* be preempted. *See id.* at 478, 484.

Moreover, although many existing oil and gas wells in the County may be subject to vested rights, the County may constitutionally require the elimination of vested nonconforming land uses provided owners and operators are given an opportunity to come into compliance during a reasonable amortization period commensurate with the investment involved. *National Advertising Co. v. County of Monterey* (1970) 1 Cal.3d 875, 879. California courts have long recognized amortization periods as valid means to balance the competing interests of a property owner's property rights and a local agency's need to implement zoning changes to benefit public health and welfare. *Gage*, 127 Cal.App.2d at 460; *see also United Bus. Com. v. City of San Diego* (1979) 91 Cal.App.3d 156, 180 (reasonable amortization period satisfies due process requirements); *Livingston Rock and Gravel Co. v. Los Angeles* (1954) 43 Cal.2d 121, 126-28. Other jurisdictions follow this exact approach; for example, the Los Angeles Planning and Zoning Code currently provides a 20-year amortization period for termination of nonconforming oil and gas operations. L.A. Municipal Code § 12.23(C)(4). The DEIR has not demonstrated that reduction or elimination of existing operations is legally infeasible, and thus fails to comply with CEQA as a matter of law. *See City of San Diego v. Board of Trustees of California State University* (2015) 61 Cal.4th 945, 956.

Finally, although the DEIR cites unspecified "economic infeasibility issues," it fails to provide any evidence or analysis to back up its conclusions. An EIR must contain facts and analysis, not just the "bare conclusions of a public agency." *Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d 692, 736 (quoting *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818, 831.)

B. The DEIR Improperly Disclaims the County's Authority to Fight Climate Change.

The DEIR omits detailed consideration of a "carbon neutrality" alternative based primarily on the assumption that the County lacks the authority and the ability to undertake the fundamental changes necessary to avoid the very worst impacts of climate disruption. DEIR at 6-10 to 6-12. Nobody disputes that confronting the climate crisis will require daunting social and economic transformations. Yet this entire section of the DEIR effectively claims that solving the problem is too difficult, too expensive, and ultimately someone else's responsibility. Simply throwing up our hands and allowing the climate crisis to overtake our communities, however, should never be an option.

Nobody would argue that the County must create a carbon-free economy all on its own. The point, rather, is that prompt and decisive action at all levels of government will be necessary to achieve this goal. The DEIR recites a litany of necessary actions, but it makes no effort to distinguish which actions lie wholly or partially within the County's control. The fact that a "coordinated effort of multiple levels of government" may be needed (DEIR at 6-11) does not provide the County with an excuse to claim it has no responsibility to participate. Nor does the DEIR's weak complaint that taking actions within the County's control (such as improving public transit) "may have financial constraints" (*id.*) suffice to demonstrate that all such actions are infeasible. The California Supreme Court has twice rejected public agencies' attempts to disclaim their portion of responsibility for mitigation that required coordination among different agencies and levels of government based on unsupported claims of legal infeasibility. *See City of San Diego*, 61 Cal.4th 945; *City of Marina v. Board of Trustees of California State University* (2006) 39 Cal.4th 341.

A "carbon neutral" alternative would consist of actions the County could take in implementing its General Plan. The DEIR paints a caricature of such an alternative in order to reject it. Whatever the effort required, failure to work toward and achieve a carbon-free economy by mid-century will expose Ventura County to almost incalculable social and economic damage. The County cannot wait until 2040 or beyond for someone else to do the hard work. It has to start now, with a frank and serious look at alternatives that would commit the County to doing its fair share to avoid catastrophe.

VI. Conclusion

We appreciate your consideration of these comments. CFROG looks forward to continuing to work with the Planning Commission, Board of Supervisors, and County staff throughout the General Plan Update process.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Kevin P. Bundy

Attachments:
Exhibit 1 Washington Post, "California climate change: Fires, floods and a fight over free parking," December 5, 2019

Exhibit 2 Stats.2019, ch. 23, Item 0555-001-3228 (Budget Act - Assembly Bill No. 74)

Exhibit 3 Carbon Neutrality Studies Scope of Work, Study 1

Exhibit 4 Carbon Neutrality Studies Scope of Work, Study 2

Exhibit 5 DOGGR 2017 (annual report)

Exhibit 6 Ventura County Air Pollution Control District, Part 70 Permit No. 00012, Section No. 2 at 1 (Table No.2) (May 14, 2019)

Exhibit 7 Bloomberg News, "NASA Flew Gas Detectors Above California, Found 'Super Emitters", November 7, 2019

Exhibit 8 "A Third of California Methane Traced to a Few Super-Emitters," https://climate.nasa.gov/news...

Exhibit 9 Myhre, G., et al., 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

Exhibit 10 Ventura County Methane Plum Data

Exhibit 11 Carbon Energy Corporation Corporate Overview 2019

Exhibit 12 Ventura County Air Pollution Control District, Order Granting Interim Variance, Hearing Board Case No. 878

Exhibit 13 Letter Report from County Counsel, Leroy Smith, to the County Board of Supervisors

Exhibit 14 "The 2013–2016 induced earthquakes in Harper and Sumner Counties, southern Kansas" Bulletin of the Seismological Society of America. Justin L. Rubinstein, William L. Ellsworth, and Sara L. Dougherty [abstract]

Exhibit 15 "Studies Link earthquakes to fracking in the Central and Eastern US, " Seismological Society of America. Science Daily April 26, 2019

Exhibit 16 Concerned Health Professionals of NY and Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed. June 2019)

Exhibit 17 Nicole J. Wong, MPH, *Existing Scientific Literature on Setback Distances from Oil and Gas Development Sites* (version 2, Nov. 2017)

Exhibit 18 DOGGR 2006 Annual Report of the State Oil & Gas Supervisor at 26 (2007) [excerpt]

Exhibit 19 Jhon Arbelaez, Shaye Wolf, and Andrew Grinberg, On Shaky Ground: Fracking, Acidizing, and Increased Earthquake Risk in California (March 2014)

cc: Climate First: Replacing Oil & Gas

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February 27, 2020

Via E-Mail

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Re: County of Ventura 2040 General Plan and Draft Environmental Impact Report – State Clearinghouse No: 2019011026

Dear Ms. Curtis:

This firm represents Climate First: Replacing Oil & Gas ("CFROG") on matters related to the 2040 General Plan ("the Draft Plan") and its draft environmental impact report ("DEIR"). As detailed below, the Draft Plan fails to take meaningful, feasible steps to confront climate change. The DEIR also falls far short of the requirements of the California Environmental Quality Act ("CEQA") (Public Resources Code section 21000 *et seq.*) and CEQA Guidelines (California Code of Regulations, title 14 section 15000 *et seq.*).

As you know, CFROG's primary concerns include the effect of oil and gas development on Ventura County's climate, natural resources, and quality of life. Proximity to oil and gas exploration, extraction, processing, and transportation exposes countless County residents to ongoing harm, exacting a tremendous toll on public health and safety. Moreover, the County is already experiencing severe impacts from climate change, and those impacts are likely to intensify in coming years. As CFROG has pointed out in prior letters, overwhelming scientific evidence shows humanity has only a few years remaining in which to dramatically draw down fossil fuel emissions if we are to preserve a decent chance of avoiding even more severe and lasting disruptions.

Unfortunately, like its predecessor, the Draft Plan does little to promote the policy transitions required to meet this challenge. If anything, the Draft Plan's approach to oil and gas policy largely continues a business-as-usual approach to petroleum extraction. This is so despite the Draft Plan's recognition that the County must reduce greenhouse gas emissions by roughly 60 percent over the next 20 years in order to keep up with reductions demanded by state climate policy.

As explained in CFROG's prior comments,[1] although CFROG recognizes the history and economic importance of the County's oil industry, the time for a transition to cleaner alternative sources of energy and economic sustenance is now. With that principle in mind, CFROG previously submitted recommendations of specific policies and programs to be adopted as part of the General Plan, or if they are not adopted, that they be considered as mitigation measures and/or alternatives in the DEIR for the General Plan. We are disappointed that many of CFROG's recommended policies and programs have neither been included in the Plan nor discussed in the DEIR.

The County's General Plan update process is a critically important planning exercise because so much is at stake. The climate change crisis alone mandates a dramatic refocus away from the business-as-usual approach of facilitating oil and gas extraction in the County. A recent analysis of more than a century of temperature data indicates that temperatures from Santa Barbara southward are warming at double the rate of the continental United States. Washington Post, "California climate change: Fires, floods and a fight over free parking," December 5, 2019, attached as Exhibit 1. Ventura County has suffered an average temperature increase of 4.7 degrees Fahrenheit since preindustrial times and ranks as the fastest-warming county in the lower 48 states. *Id*.

While the Draft Plan contains some laudable policies, it nonetheless fails to demonstrate a serious commitment to tackling this ecological and social crisis. Many of

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[1] This firm previously submitted comments on the Preliminary Draft General Plan Update ("Preliminary Draft") dated June 5, 2019. In that letter we described many substantive flaws in the Preliminary Draft, many of which the County disregarded in preparing the Draft Plan. We also recommended numerous new and amended policies and asked that they be considered as mitigation measures and/or alternatives in the DEIR; most of these recommendations, however, are not addressed at all in the DEIR. Consequently, most of the comments in the June 5 letter remain applicable to the current Draft Plan and DEIR. Our June 5, 2019 letter and accompanying exhibits and references are therefore incorporated herein by reference.

the Draft Plan's policies are merely advisory and lack the enforceable detail necessary to achieve real greenhouse gas reductions. The DEIR, for its part, proposes to water down many of the Draft Plan's provisions even further.

The Draft Plan and DEIR are out of touch with both climate science and state policy. The State of California has begun active planning for a managed transition away from fossil fuels. The 2019 Budget Act allocated significant funding for studies outlining a long-term reduction in both demand for and supply of fossil fuels, in service of the state's goal of achieving carbon neutrality by 2045. *See* Stats.2019, ch. 23, Item 0555-001-3228 (Assembly Bill No. 74), attached as Exhibit 2. The state has adopted a scope of work for each study and the planning effort is underway. *See* Carbon Neutrality Studies Scope of Work, Studies 1 and 2, attached as Exhibits 3, 4. The Draft Plan's commitment to expanded oil and gas operations in Ventura County is contrary to these statewide efforts and profoundly counterproductive.

The 2040 General Plan update offers a critical opportunity to support statewide and global efforts by shifting away from dependence on oil and gas production and expanding renewable energy production and consumption. Such a shift would have tremendous benefits, including reduced air pollution and greenhouse gas ("GHG") emissions, lower energy consumption, fewer impacts to public health and safety, and greater water quality protection. In other words, a shift in direction would provide either an alternative or a series of mitigation measures that could further reduce or avoid many of the Draft Plan's significant environmental impacts.

Unfortunately, the Draft Plan and DEIR fail to provide for any such shift, and instead assume continued expansion of oil and gas extraction, even as statewide production continues to decline and the rest of California begins to plan for a post-carbon future. Indeed, the DEIR admits the Draft Plan will not achieve the County's fair share of reductions needed to meet either short-term or longer-term state climate goals. The Draft Plan's business-as-usual approach will create long term environmental damage, affecting residents and future generations throughout the region.

Finally, as detailed below, the DEIR fails to meet CEQA's requirements. For example, the DEIR fundamentally fails to identify or analyze credible, feasible mitigation measures or alternatives that could reduce or avoid the Draft Plan's significant environmental impacts. CEQA requires enforceable, concrete commitments to mitigation and consideration of a range of potentially feasible alternative approaches that could avoid significant impacts. The DEIR, in contrast, primarily offers vague, voluntary, and unenforceable policies, particularly with respect to anticipated greenhouse gas emissions.

As a result, the DEIR fails to describe measures that could avoid or substantially lessen the proposed Plan's numerous significant impacts.

I. The County's Climate Action Plan Is Ineffective At Reducing GHG Emissions.

As acknowledged in the DEIR for the Draft Plan, the County has a considerable number of oil and gas operations in the unincorporated areas. Draft Plan at 6-12. These facilities contribute to climate disruption. Further expanding local oil and gas development will add even more carbon to the atmosphere, undercut California's efforts to reduce emissions, and further limit our ability to avoid the worst effects of climate change. The General Plan Update—and, in particular, the provisions of the Plan comprising the County's Greenhouse Gas Strategy or Climate Action Plan ("CAP")—offers an important opportunity to reduce emissions from oil and gas development.

Unfortunately, the CAP as described in Appendix B to the Draft Plan largely passes up this opportunity. As explained in more detail below, the CAP presents incomplete and inaccurate data regarding anticipated GHG emissions under the proposed Plan. In addition, the CAP lacks specific, enforceable measures necessary to achieve the established targets and goals for emission reductions. As a result, the CAP is ineffective in reducing anticipated GHG emissions, and the DEIR's conclusions regarding the Draft Plan's climate impacts are without support.

A. The Baseline Inventory of GHG Emissions Is Incomplete and Inaccurate.

As we pointed out in our prior letter on the Preliminary Draft, the baseline inventory of County GHG emissions is the foundation of the CAP. Without a complete and accurate inventory, the County cannot accurately project future business-as-usual ("BAU") emissions or measure the effectiveness of reduction measures in meeting identified targets and goals. Effective policies cannot be built on a flawed inventory. Unfortunately, the CAP inventory remains incomplete, internally inconsistent, and inaccurate.

According to the CAP, 2015 stationary source emissions totaled 275,096 $MTCO_2e$. Draft Plan, Appendix B at B-7 (Table B-2), B-8. This estimate purportedly was derived "by scaling the statewide emissions reported for oil and gas production to the local level using the proportion of oil and gas production in the unincorporated area relative to the statewide total." *Id.* at B-8.

The estimate in the CAP is not clearly supported by data in the DEIR. Appendix D to the DEIR appears to take two different approaches to estimation of stationary source emissions. The first approach (in a spreadsheet entitled "Estimating Ventura County Stationary Source Emissions from Oil and Gas") estimates a total of 284,693 $MTCO_2e$. DEIR, Appendix D at 43. The second approach (apparently using two spreadsheets, one entitled "Statewide Stationary Source Emissions from Oil and Gas" and the second entitled "State Report on Well County and Production of Oil, Gas, and Water by County – 2015") arrives at the "scaled" emissions estimate of 275,096 $MTCO_2e$ discussed in the CAP. DEIR, Appendix D at 44-45. Neither the CAP nor the DEIR appears to explain the discrepancy between the two estimates.

Further inconsistencies in the inventory are similarly unexplained. For example, estimates under the first approach described above show zero emissions from natural gas "fuel combustion" in the County. DEIR, Appendix D at 43. Statewide figures supporting the second approach, however, show that natural gas combustion is by far the single greatest source of CO_2 emissions from the oil and gas sector (13,750,201 MTCO2e, or 69.4% of statewide total CO_2e emissions). *Id.* at 44. Neither the CAP nor the DEIR appears to contain any evidence that unlike the rest of the state, not a single oil and gas operation in Ventura County consumes natural gas. As we pointed out in our letter on the Preliminary Draft Plan, cyclic steaming and steam flooding operations—which often burn natural gas to generate steam—are currently occurring in the County, including in the Oxnard oilfield. DOGGR 2017 (annual report) at 22 (attached as Exhibit 5) to comments on Preliminary Draft Plan). In fact, the Ventura County Air Pollution Control District recently issued a permit to California Resources Production Corporation authorizing operation of steam generators "fired on PUC Natural gas, with PUC natural gas mixed with produced gas as secondary fuel." VCAPCD, Part 70 Permit No. 00012, Section No. 2 at 1 (Table No.2) (May 14, 2019), attached as Exhibit 6; *see also* VCAPCD Rule 74.15.B.1(3)(a) (allowing steam generators to use "alternate fuel" only "due to the curtailment of natural gas service to the individual unit by the natural gas supplier" and only during "the period of natural gas curtailment"). Steam generators in Ventura County clearly use natural gas in the production of oil. The inventory's omission of natural gas combustion emissions is thus inaccurate and unsupported.

The "scaled" estimate of emissions from County oil and gas operations also appears unreasonably low. DEIR Appendix D concludes that Ventura County produces 4.2% of the state's oil and 5.1% of the state's associated gas. DEIR, Appendix D at 45. Yet DEIR Appendix D also concludes that Ventura County contributes only about 1.4% of the statewide GHG emissions from oil and gas (275,096 $MTCO_2e$ out of the statewide total of 19,803,975 $MTCO_2e$). Again, neither the CAP nor the DEIR explains why "scaled" Ventura County emissions are so low compared to the volumes of oil and gas produced.

This stark discrepancy further underscores a point we made in our prior comments: the Preliminary Draft Plan failed to explain or provide evidentiary support for the "scaled" estimate, i.e., for calculating Ventura County emissions as a percentage of statewide emissions from the oil and gas sector rather than based on information specific to exploration and production in Ventura County. Neither the CAP nor the DEIR supplies the missing explanation. Local oil and gas operations may or may not be consistent with statewide averages in terms of the energy (and associated emissions) required for extraction. However, additional justification and explanation of this methodological choice, based on information specific to Ventura County, is necessary—particularly in light of the DEIR's apparent conclusion that County oil and gas emissions are significantly lower than anywhere else in the state, even on a "scaled" basis.

The CAP inventory also continues to omit other sources of GHG emissions from oil and gas production. For example, the inventory does not include emissions from the transport of oil and gas production, particularly freight rail and ocean freight emissions. Draft Plan, Appendix B at B-8. Nor does the inventory include any "downstream" emissions from refining or combustion of County-produced oil and gas. As explained in our prior letter, these emissions should have been included because the County controls activities related to exploration and production of oil and gas. Without these activities, emissions from transportation, refining, and combustion of oil and gas produced in the County would not occur. Where, as here, "downstream" emissions are foreseeable and capable of estimation, they should be disclosed. *Cf. Sierra Club v. Federal Energy Regulatory Com.* (D.C. Cir. 2017) 867 F.3d1357; *Mid States Coalition for Progress v. Surface Transportation Bd.* (8th Cir. 2003) 345 F.3d 520. Nor can the County avoid responsibility for disclosing and analyzing rail and ocean freight emissions simply because it may lack authority to prevent or mitigate the effects of these activities directly. See *Association of Irritated Residents v. Kern County Bd. of Supervisors* (2017) 17 Cal.App.5th 708, 750-52 (federal preemption of railroad regulation did not extend to responsibility for disclosure and analysis of environmental effects of railroad operations under CEQA).

It is also unclear whether the emissions inventory includes aviation emissions. The DEIR includes emission factors for aviation gas and jet fuel. DEIR, Appendix D at 47 and 49. However, the inventory does not appear to include any emissions from aircraft. *Id.* at 27 and 28. Moreover, although the inventory appears to include some emissions from vessels, harborcraft, and cargo handling equipment (*id.* at 27), it is not clear that the inventory includes all emissions related to operations at the Port of Hueneme.

Finally, recent data collected by the National Aeronautics and Space Administration ("NASA"), indicates that emissions from a handful of sites (or "super emitters") account for the vast majority of California's methane emissions. *See,* Bloomberg News article, "NASA Flew Gas Detectors Above California, Found 'Super Emitters", November 7, 2019, attached as Exhibit 7; https://climate.nasa.gov/news/2930/a-third-of-california-methane-traced-to-a-few-super-emitters/ news article, attached as Exhibit 8; and https://methane.jpl.nasa.gov/, . Of the "super emitters" identified around the State, oil and gas operations accounted for 26 percent of all source emissions.

Several of these "super emitters" are located in Ventura County. See Ventura County Methane Plume Data, attached as Exhibit 9. They include, but are not limited to, the Ventura Oil Field, Rincon Oil Field, Bardsdale Oil Field, and South Mountain Oil Field, which were all mapped as emitting methane plumes. Methane is a greenhouse gas that is at least 85 times more potent than carbon dioxide at trapping heat and contributing to global warming over the 20-year period covered by the General Plan.[2] Therefore, addressing these emissions is critical for the County to meet emission reduction targets required under State law.

Despite this available data, the County's Draft Plan and DEIR failed to disclose these emissions, analyze their impacts, or identify feasible measures to ensure emission reductions over the life of the Plan. The result is a CAP that presents flawed baseline data of GHG emissions that undermines the entire planning process. Without an accurate baseline inventory, the DEIR's projected future emissions from the oil and gas sector (see

[2] Current scientific evidence concerning the global warming potential of methane over different time scales is discussed in detail in CFROG's comments on the Preliminary Draft Plan. *See* June 5, 2019 Comments at 16-18 and cited references. Specifically, according to the Intergovernmental Panel on Climate Change's most recent Assessment Report, methane is 85-87 times more potent than carbon dioxide over a 20-year time period, accounting for climate-carbon feedbacks and additional warming from methane oxidation. Myhre, G., et al., 2013: Anthropogenic and Natural Radiative Forcing at 714 (Table 8.7). In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf. An excerpt from the IPCC report is attached as Exhibit 10.

DEIR, Appendix D at 45) have no evidentiary basis. Inasmuch as the County permits oil and gas operations in unincorporated lands in the County, the County has an obligation to consider these emissions and take concrete steps to limit them in the future. The failure to do so renders the CAP fatally flawed. A revised CAP must correct this flaw and include a comprehensive inventory of all emissions, including all emissions from oil and gas operations.

B. Emission Forecasts are Inadequately Supported.

Projections of "business as usual" emissions from the oil and gas sector in the CAP and DEIR lack adequate justification and support. The DEIR assumes oil and gas production will increase by more than one million barrels per year between 2015 and 2040. DEIR Appendix D at 45. Stationary sources are projected not only to remain a significant source of emissions in the County, but also to continue increasing, through 2050. Draft Plan at B-10 (Table B-4).

Appendix B appears to use "County-specific demographic" projections—presumably population growth—as the basis for its future emissions projections, although the precise methodology used is not explained. *See* Draft Plan at B-10. The DEIR similarly bases its projections on "growth rates for population, employment and housing" forecast by the Southern California Association of Governments." DEIR at 4.8-5. Yet neither document explains why stationary source emissions from in-County oil and gas development would be expected to increase due to County population growth. As we noted in our prior comments, the document offers no basis for assuming that local oil and gas development is driven by local population growth in the same manner as transportation or residential or commercial development. Put another way, neither the Draft Plan nor the DEIR offer evidence that local *demand* for oil and gas drives local *production* of oil and gas (or, put another way, that local oil and gas production tracks generic projections of County growth in a linear fashion).

Nor do the Draft Plan or DEIR provide any evidence to support the assumption that County oil and gas production will continue to increase through 2050. *See* DEIR, Appendix D at 45. California production has been declining for many years. *See, e.g.*, U.S. Energy Information Administration, California Field Production of Crude Oil 1980-2018 (attached as Exhibit 3 to June 5, 2019 letter); DOGGR 2017 (attached as Exhibit 2 to June 5, 2019 letter) at 5. The DEIR's assumptions thus appear contrary to the evidence. To the extent some other assumptions lie behind the projected increase in emissions—for example, that production might increase as a result of new or expanded enhanced oil recovery technologies—Appendix B fails to explain what they are.

In fact, Appendix B's projected increase in production is contrary to state policy and trends. Statewide efforts to decarbonize the electrical grid, electrify the transportation sector, and increase building energy efficiency should reduce local demand for oil and gas significantly over the next several decades. As discussed above, the state is actively planning to transition away from fossil fuels—including reductions in both demand and supply—by 2045. *See* Exhibits 2, 3, 4 [Budget Act; Carbon Neutrality Studies Scope of Work 1 and 2]. Unfortunately, the discussion of statewide legislation and policy that could reduce fossil fuel demand and emissions in coming years (Draft Plan at B-11) is incomplete; for example, it does not include Zero Net Energy improvements to the Building Code or incentives for electric vehicles. Nor does Appendix B mention the state's Short-Lived Climate Pollutant strategy. In short, Appendix B's forecast increase in stationary source emissions lacks adequate support and analysis.

Finally, planning for continued expansion of Ventura County oil and gas production flies in the face of both overwhelming climate science and clear state policy. Nowhere do the Draft Plan or the DEIR adequately disclose or analyze the consequences of this approach or its blatant inconsistency with statewide GHG reduction plans and programs. *See* CEQA Guidelines, § 15125(d).

C. The Draft Plan Presents Vague Measures That Cannot Produce the Necessary Emission Reductions and Improperly Defers Development of Implementation Programs.

Appendix B's most fundamental weakness may be its failure to identify a set of GHG reduction measures that comes anywhere close to achieving the County's desired targets and goals. The Draft Plan offers only a vague assurance that the "County shall reduce GHG emissions" through "combination of measures included in the GHG Strategy" (Draft Plan at B-15; Policy COS-10.4), but never addresses how that "combination of measures" will reduce emissions by the amounts necessary.

Indeed, many of the "CAP" measures collected in Appendix B from various other elements of the General Plan represent only soft, unquantifiable commitments to "encourage" or "promote" various actions (see section II.B below for specific examples). Although hortatory, qualitative measures of this sort may be appropriate to supplement more concrete requirements, identification of specific, enforceable measures and quantification of resulting emissions reductions are required to demonstrate consistency with quantitative targets and goals. Enforceable, concrete commitments to mitigation also are required under CEQA. Neither the Draft Plan nor the DEIR contains adequate measures of this kind.

D. The CAP and DEIR Fail to Provide Adequate Mitigation to Reduce the Plan's Emissions.

The DEIR acknowledges that GHG emissions under the proposed Plan would be significant, even with proposed mitigation measures. DEIR at 4.8-49. The DEIR also acknowledges that the Draft Plan would result in future GHG emissions that exceed the State's 2030 and post-2030 targets for emission reduction. DEIR at 4.8-52. However, the DEIR fails to identify feasible mitigation measures that will lessen these significant impacts.

Under CEQA, mitigation measures proposed in an EIR must be "fully enforceable" through permit conditions, agreements, or other legally binding instruments. Pub. Res. Code § 21081.6(b); CEQA Guidelines §15126.4(a)(2). As the DEIR itself admits, a substantial number of the programs and policies proposed in the Plan will not result in quantifiable emissions reductions and thus cannot be counted on to mitigate the Plan's significant GHG impacts. DEIR at 4.8-50. As discussed in more detail in section III.B of this letter below, the programs and policies in the General Plan are unlikely to reduce the Project's impacts because of their voluntary, flexible, and unenforceable nature. Here, the proposed policies are vague and include directory terms like "as appropriate," "where feasible" and "support," rather than mandatory terms like "require," "reduce," and "deny."

Moreover, the Draft Plan and DEIR fail to adequately address methane emissions from the oil and gas sector. The Plan includes programs to address methane emissions from the waste (e.g., PFS-L), water (e.g., Program WR-G) and agriculture (e.g., Programs AG-I, AG-J, and AG-K) sectors. DEIR at 4.8-44. The Plan, however, omits policies, programs, or mitigation measures to reduce methane emissions from oil and gas operations. This omission should be corrected through additional mitigation measures that will effectively limit expansion of oil and gas operations in the County and actively transition the County's economy away from fossil fuels. See, sections III B and C of this letter below for specific policy recommendations related to GHG emissions reductions.

Finally, the DEIR improperly attempts to avoid responsibility for proposing mitigation by claiming the County has no authority "to enforce measures that may potentially infringe upon private property rights, reduce the economic competitiveness of local businesses, or inhibit the ability for residents to travel between residences, jobs, and amenities." DEIR at 4.8-49; *see also id.* at 4.8-39, 4.8-52. While the County obviously must operate within constitutional limits, the DEIR's attempt to disclaim any authority to control activities within its jurisdiction is overbroad to the point of abdication. For more than a century, courts have recognized that local governments may exercise their police powers despite resulting impingements upon property rights and economic competitiveness. *See, e.g.*, *Hadacheck v. Sebastian* (1915) 239 U.S. 394, 409-10. Moreover, to the extent the DEIR is claiming that any additional mitigation (particularly with respect to existing land uses) would be legally infeasible, its conclusory statements regarding lack of authority fall far short of CEQA's requirements. *See, e.g.*, *City of San Diego v. Board of Trustees of California State University* (2015) 61 Cal.4th 945, 956 ("An EIR that incorrectly disclaims the power and duty to mitigate identified environmental effects based on erroneous legal assumptions is not sufficient as an informative document.") (internal quotation omitted). "In mitigating the effects of its projects, a public agency has access to all of its discretionary powers . . . includ[ing] such actions as adopting changes to proposed projects, imposing conditions on their approval, adopting plans or ordinances to control a broad class of projects, and choosing alternative projects." *Id.* at 959. The DEIR's attempt to abdicate the County's regulatory and police power authority has no legal basis and cannot support any finding of infeasibility.

The DEIR also appears to conclude that the County may weigh the Draft Plan's asserted economic and other benefits against its environmental consequences without first proposing and adopting all feasible measures to mitigate or avoid significant effects. *See* DEIR at 4.8-49, 4.8-52. This conclusion rests on a misinterpretation of CEQA. An agency must properly find that mitigation and alternatives are infeasible *before* engaging in any balancing of benefits and harms. *See* Pub. Resources Code § 21081(a)(3), (b); CEQA Guidelines § 15092(b)(2). The County may not disclaim its responsibility to develop feasible mitigation by prematurely claiming that the project's benefits outweigh its environmental drawbacks.

E. The Draft Plan's "GHG Strategy" Does Not Satisfy the Requirements for CEQA Streamlining.

As pointed out in our prior comments, the Draft Plan (and the portions of the Draft Plan comprising the "GHG Strategy" or CAP) fails to provide any basis for streamlining analysis of the cumulative climate impacts of subsequent projects based on consistency with the General Plan or CAP. *See* CEQA Guidelines § 15183.5. The DEIR correctly proposes to eliminate one express reference to streamlining based on the CAP. The Draft Plan and the County's Initial Study Assessment Guidelines, however, should be revised to make explicit that neither the General Plan nor the CAP contains sufficient specific, enforceable GHG reduction measures to support streamlined CEQA review of future projects.

Proposed Implementation Program COS-EE (Draft Plan at B-20) would allow streamlined GHG emissions analysis for projects demonstrating that: the project is consistent with current general plan and zoning designations; that the project incorporates all applicable GHG reduction measures in Appendix B to the General Plan; and the project "clearly demonstrates the method, timing, and process for which the project will comply with applicable GHG reduction measures and/or conditions of approval. Draft Plan, Appendix B at B-20 and B-2. As drafted, however, the CAP falls far short of the requirements of CEQA Guidelines section 15183.5. In order to support a determination that CAP consistency eliminates significant climate effects, a CAP must (among other things) clearly demonstrate that its prescribed measures will actually achieve the reductions necessary to attain the CAP's stated goals. CEQA Guidelines § 15183.5(b)(1)(D). As discussed above, the CAP provides no basis for such a conclusion.

The DEIR proposes a mitigation measure that deletes Implementation Program COS-EE, purportedly on the ground that project-specific review may ensure greater emissions reductions over time than compliance with generic measures in the General Plan and CAP. *See* DEIR at 2-34 and 2-35, MM GHG-3. We agree that Implementation Program COS-EE should be removed from the Draft Plan, and that rigorous review of the climate impacts of future discretionary projects should be required. Until such time as the General Plan identifies policies and programs that lead to quantifiable emission reductions adequate to achieve the Plan's stated goals, streamlining environmental review would be unlawful. For this reason, CFROG requests not only that Implementation Program COS-EE be deleted, but also that the Draft Plan and CAP be revised (1) to remove other references to streamlined analysis of future projects (*see, e.g.*, Draft Plan at 12-4, B-3, B-5, B-24 to B-24, B-57), and (2) to expressly state that the General Plan and GHG Strategy are neither sufficient nor intended to be used to support streamlined environmental analysis under CEQA Guidelines section 15183.5. The DEIR similarly must be revised to remove references to CEQA streamlining based on the General Plan or CAP. *See, e.g.*, DEIR at 4.8-4.

II. The Draft Plan Must Ensure Lawful Application of Air Quality Thresholds.

As discussed in our June 5, 2019 comments, CFROG strongly supports retaining existing air quality thresholds in the Ojai Valley Area Plan. CFROG is pleased to see that these provisions have been carried forward into the Draft Plan as Goal OV-55 and Policy OV-55.1. Draft Plan at OV-30. However, as CFROG's prior comments pointed out, the rest of the County is still subject to a much higher air quality threshold. June 5, 2019 Comments at 12. Those prior comments recommended a policy that would commit the County to adopting more stringent air quality thresholds outside the Ojai Planning Area. *Id.* That policy should be considered as an additional mitigation measure for the Draft Plan's impacts on air quality.

Furthermore, all County air quality thresholds must be interpreted and applied in a manner consistent with CEQA. Our June 5, 2019 comments detailed the ways in which the current Air Quality Assessment Guidelines violate CEQA. June 5, 2019 Comments at 6-10. For this reason, CFROG appreciates the clarifications in Policy HAZ-10.11. In keeping with the revised policy, both the Air Quality Assessment Guidelines and the Initial Study Assessment Guidelines must be revised in a manner that reflects CEQA's requirements as outlined in our June 5, 2019 comments.

III. The DEIR for the 2040 General Plan Fails to Comply with CEQA.

A. The DEIR's Proposed Measures to Weaken General Plan GHG Reduction Policies Lack Support.

The Draft Plan includes policies that would reduce GHG emissions from both trucking and flaring associated with oil and gas production. The DEIR proposes "mitigation measures" that would water down both policies, but fails to establish any legal or evidentiary basis for doing so.

1. Mitigation Measure PR-2 (Weakening Pipeline Requirements)

Currently, oil and produced water from local oil wells are largely transported by truck. Trucking these oil production by-products creates safety hazards on County roads, exposes residents to toxic diesel pollution, and causes substantial amounts of greenhouse gas emissions due to truck vehicle miles travelled. In response to direction from the County Board of Supervisors, the Draft Plan includes Policy COS-7.7: Conveyance for Oil and Produced Water, which addresses this problem by requiring newly permitted oil wells to use pipelines instead of trucks to transport oil and produced water.

The DEIR concludes that, because oil operators located beyond a two-mile radius of a major oil transmission pipeline are likely small producers not extracting a large amount of oil, the added costs to these oil companies of constructing pipeline connections make this policy infeasible to implement and may lead to a loss of petroleum resources. DEIR at 4.12-26. The DEIR therefore proposes Mitigation Measure PR-2, which would revise Policy COS-7.7 to allow trucking if the project proponent demonstrates that conveying water or gas by pipeline would be infeasible. *Id.* at 4.12-31. There are numerous flaws with the DEIR's approach.

First, the DEIR provides no evidence that the cost of constructing pipelines would make continued extraction economically impractical. *See Preservation Action Council v. City of San Jose* (2006) 141 Cal.App.4th 1336, 1352, 1357 (evidence must show alternative is economically impracticable, not merely more expensive, to support finding of infeasibility). The DEIR cites one project that would have required a 6- to 10-mile pipeline as an example (DEIR at 4.12-23 to 4.12-24), but it provides no comprehensive economic analysis or other evidence to support its assumption that all operators more than two miles from an existing pipeline likely would have to transport oil and water by truck. *See id.* at 4.12-25 to 4.12-26. Therefore, the DEIR's proposal lacks the evidentiary support CEQA requires.

The DEIR's assumption that all operators located more than two miles from a pipeline are "smaller oil producing operations that are not extracting a large amount of oil" (DEIR at 4.12-26) particularly lacks factual support. Indeed, a review of oil and gas wells located in Ventura County on the California Geologic Energy Management Division ("CalGEM", formerly DOGGR) website provides evidence to the contrary. For example, two of the largest clusters of active oil wells outside the two-mile radius from major transmission lines in the County are in the Timber Canyon oilfield and in the Sespe oilfield. See, https://maps.conservation.ca.gov/doggr/wellfinder/#/-119.00532/34.42770/12 and DEIR at 4.12-25, Figure 4.12-4. Carbon California owns both the Timber Canyon and Sespe oilfields and operates oil wells in both fields. *See* Carbon Energy Corporation Corporate Overview 2019, at 13 attached as Exhibit 11. Carbon California does not fit the profile of a "smaller oil producing operations that are not extracting a large amount of oil." DEIR at 4.12-26. As indicated in a 2019 Air Pollution Control District filing, Carbon California represented that it produces $300,000 of oil a month or 12% of Carbon's total California production income at Timber Canyon alone. Ventura County Air Pollution Control District, Order Granting Interim Variance, Hearing Board Case No. 878 at 4 (August 26, 2019), attached as Exhibit 12. A revised analysis must evaluate ownership of existing wells outside the two-mile radius from transmission lines, the existing number of wells that already reinject their waste water into wells or already transmit it via pipeline, and the degree to which oil operators can reasonably be expected to consolidate operations to make construction of new transmission lines feasible.

Second, the DEIR provides no criteria for determining whether a project applicant has adequately demonstrated that conveying oil and water by pipeline is infeasible. Instead, Mitigation Measure PR-2 would delegate the feasibility finding to unnamed planning staff. Under CEQA, the lead agency has to determine the feasibility of a project (or by extension, mitigation measures associated with the project) by making written, public findings when the project is approved. Pub. Resources Code § 21081(a); CEQA Guidelines §§ 15091, 15092. CEQA prohibits delegation of the responsibility to adopt findings regarding the feasibility of mitigation. CEQA Guidelines § 15025(b)(2). The revised policy would delegate far more than the simple responsibility to implement mitigation. Rather, Mitigation Measure PR-2 would require County staff to make fundamental policy decisions that affect County residents' public and social health—decisions CEQA requires the County itself to make, in written findings on the record, supported by substantial evidence.

Third, and relatedly, Mitigation Measure PR-2 violate CEQA by improperly deferring formulation of mitigation. Again, the measure permits County staff to allow trucking of oil and produced water if "the proponent demonstrates" that conveyance by pipeline is infeasible. DEIR at 4.12-31. However, as noted above, the measure does not specify any criteria for infeasibility and provides no specific requirements for analysis or documentation related to feasibility. Absent any explicit criteria, County staff could allow trucking of oil and produced water whenever oil producers simply *claim* infeasibility—benefiting oil company profits while exacerbating climate change and saddling County residents with toxic air emissions and safety hazards. Indeed, just this week, the California Court of Appeal invalidated a mitigation measure that required applicants to take certain actions "to the extent feasible," finding the measure both improperly deferred and inconsistent with CEQA's purpose. *See King & Gardiner Farms, LLC v. County of Kern*, No. F077656 (Cal. App. 5 Dist., filed Feb. 25, 2020), slip op. at 40-41.

Generally, mitigation measures should not be deferred nor findings of feasibility delegated to staff. CEQA Guidelines, §§ 15126.4(a)(1)(B), 15025(b)(2).A lead agency may legally defer mitigation under CEQA only if it (1) "adopt[s] specific performance criteria that the mitigation measures were required to satisfy"; (2) shows that "practical considerations prevented the formulation of mitigation measures at the usual time in the planning process;" (3) "commit[s] itself to formulating the mitigation measures in the future." *POET, LLC v. State Air Resources Bd.* (2013) 218 Cal.App.4th 681, 736.) With respect to the proposed revisions to Policy COS-7.7, the County fails to meet any of these requirements.

In sum, as revised by Mitigation Measure PR-2, Policy COS-7.7 would provide no guidance or concrete performance standards on how feasibility determinations must be made. Staff's determinations, made long after the approval of the Draft Plan, would take place out of public view and without a hearing. "[P]ublic participation is an essential part of the CEQA process." *Ballona Wetlands Land Trust v. City of Los Angeles* (2011) 201 Cal.App.4th 455, 467 (internal quotation omitted). Delegating fundamental feasibility findings to unelected staff, without any criteria or performance standards, violates CEQA.

2. Mitigation Measure PR-3 (Weakening Gas Collection Requirements and Flaring Limitations)

Mitigation Measure PR-3 suffers from the same fundamental deficiencies as Mitigation Measure PR-2, discussed above. Mitigation Measure PR-3 would revise Policy COS-7.8: Limited Gas Collection, Use, and Disposal. This policy as proposed in the Draft Plan requires that gases from all new discretionary oil and gas wells be collected for use, sale or proper disposal. Draft Plan, Appendix B at 6-13. The DEIR concludes that Policy COS-7.8 could prove too costly for new discretionary oil and gas wells located outside of a two-mile radius of a major gas transmission pipeline. DEIR at 4.12-30. The DEIR therefore proposes a mitigation measure that revises Policy COS-7.8 to allow flaring and venting outside of emergency situations if the proponent 'demonstrates' that conducting operations without flaring is deemed infeasible. *Id*. But here too, the DEIR fails to provide evidentiary support for its assumptions, improperly delegates fundamental feasibility findings to unelected staff, and improperly defers mitigation by failing to provide criteria or performance standards for evaluating claims of infeasibility. For the same reasons discussed above in connection with Mitigation Measure PR-2, the DEIR's approach does not comport with CEQA.

In sum, Mitigation Measures PR-2 and PR-3 provide no specific performance criteria that prescribe how the mitigation measure's goals will be met, let alone provide adequate direction for County staff. As proposed, the mitigation measures would create a loophole allowing oil companies to escape compliance with Policies COS-7.7 and 7.8 simply by claiming that the cost of a pipeline connection or of gas collection is too high. Because Mitigation Measures PR-2 and PR-3 have no concrete performance standards for determinations of feasibility or how the measures' goals can be achieved, offer no reason as to why the mitigation could not have been developed, and commit only to the most illusory of measures, mitigation is improperly deferred.

Accordingly, the County should maintain both policies as recommended by the Board of Supervisors and as presented in the Draft Plan. All newly permitted discretionary oil wells should be required to convey oil and produced water via pipelines, and all gases produced from new discretionary oil and gas wells should be collected for use, sale or proper disposal.

B. Merely Hortatory General Plan Policies Are Inadequate as Mitigation for CEQA Purposes.

Mitigation measures proposed in an EIR must be "fully enforceable" through permit conditions, agreements, or other legally binding instruments. Pub. Res. Code §

21081.6(b); CEQA Guidelines § 15126.4(a)(2). Many of the General Plan's policies and programs relied on to mitigate impacts related to GHG emissions are vague, optional, directory, or otherwise unenforceable. These policies should be made mandatory. A few examples—out of numerous instances—include the following:

- LU-11.4 Sustainable Technologies: *The County shall encourage discretionary development on commercial and industrial- designated land to incorporate sustainable technologies....* Draft Plan Appendix B at B-31. (This policy is optional and unenforceable; the word "require" should replace "encourage.")

- LU-18.5 Participation in Climate Change Planning: *The County shall encourage stakeholders in designated disadvantaged communities who are vulnerable to sea level rise or other climate change impacts to have the opportunity to learn about and participate in the decision-making process for adaptation planning within Ventura County*. Draft Plan Appendix B at B-32. (This policy is optional and unenforceable; the word "encourage" should be replaced with "provide opportunities for"; this policy should have an accompanying implementation program that specifies the sort of opportunities the County will provide to facilitate public participation.)

- PFS-2.1 Sustainable Plans and Operations: *The County shall encourage energy efficiency, greenhouse gas reduction features, and resiliency planning into County facility and service plans and operations*. Draft Plan Appendix B at B -43. (This policy is optional and unenforceable; the word "require" should replace "encourage.")

- COS-7.4 Electrically-Powered Equipment for Oil and Gas Exploration and Production. *The County shall require discretionary development for oil and gas exploration and production to use electrically-powered equipment from 100 percent renewable sources and cogeneration, where feasible....* Draft Plan Appendix B at B -49. (This policy is vague and unenforceable, improperly delegates feasibility findings to staff, and provides no criteria or performance standard for determining feasibility.)

- Program AG-K: *reduce the amount of water that needs to be treated, pumped and conveyed, which requires the use of energy*" Draft Plan at 4.8-41. (This policy is vague and unenforceable as it provides no guidance as to quantities that could be treated, specific treatment methods, or other information on how the County would implement this program.)

Related Implementation Program K: Water-Saving Irrigation Techniques Program is equally unenforceable as it directs the County only to collaborate with and support the UC Cooperative Extension Office educational programs and does not require the agency to take any specific action.

- COS-M Oil and Gas Tax: *The County shall evaluate the feasibility of establishing a local tax on oil and gas operations located in the unincorporated county*. Draft Plan Appendix B at B53. (This policy is vague, unenforceable and voluntary as it does not commit the County to taking any concrete steps toward implementing a tax beyond evaluating its feasibility. The policy should be revised to state "The County shall, by January 1, 2022, evaluate the feasibility of establishing a local tax on oil and gas operations located in the unincorporated county, and if the County determines any such tax is feasible, it shall, by January 1, 2023, develop and propose such a tax measure for voter approval.")

- HAZ-10.1: Air Pollutant Reduction Consistent with the General Plan: The County shall strive to reduce air pollutants from stationary and mobile sources to protect human health and welfare, focusing efforts on shifting patterns and practices that contribute to the areas with the highest pollution exposures and health impacts. Draft Plan Appendix B at B59. (This policy is optional and unenforceable; the words "achieve substantial reductions of" should replace "strive to reduce.")

A general plan's goals and policies are frequently somewhat vague and aspirational. However, the County may rely on such policies to mitigate environmental impacts under CEQA *only if* they represent firm, enforceable commitments. *See Napa Citizens for Honest Gov. v. Napa County Bd. of Supervisors* (2001) 91 Cal.App.4th 342, 358 (citing *Rio Vista Farm Bureau Center v. County of Solano* (1992) 5 Cal.App.4th 351, 377). CEQA requires that mitigation measures actually be implemented—not merely adopted and then disregarded. *Anderson First Coalition v. City of Anderson* (2005) 130 Cal.App.4th 1173, 1186-87; *Federation of Hillside & Canyon Assns. v. City of Los Angeles* (2000) 83 Cal.App.4th 1252, 1261.

Here, the proposed Plan's vague and noncommittal policies and programs (and policies for which no implementation programs are identified) do not enforceably commit the County to specific actions and thus fail to mitigate impacts. Moreover, DEIR proposed Mitigation Measure GHG-4 (New Implementation Program HAZ-X: Greenhouse Gas Reduction Policy Enhancement) fails to remedy the aforementioned failures. Mitigation Measure GHG-4 directs the Climate Emergency Council, to be established under Policy COS-CC, to develop subprograms that "may" include expansions to programs in the General Plan. DEIR at 4.8-47. Aside from the fact that the measure itself indicates that expansion of emission reduction programs is uncertain through use of the word "may," this mitigation measure again defers identification of feasible, effective measures needed to reduce significant impacts. As discussed above, this approach is unlawful. CEQA Guidelines, §§ 15126.4(a)(1)(B).

Because the DEIR cannot ensure that the referenced policies will in fact be implemented to mitigate the proposed Plan's impacts, and because the proposed mitigation further defers identification of mitigation, the policies and measures cannot serve as CEQA mitigation. *See Anderson First*, 130 Cal.App.4th at 1186-87.

C. The DEIR Has An Obligation to Consider Additional General Plan Policies That Would Mitigate the Significant Environmental Effects of Oil and Gas Development.

As indicated in our earlier comments, CFROG is concerned about the effects of oil and gas drilling on communities within the County and more broadly. The drilling and maintenance of oil and gas wells contribute to: local air pollution, climate change, contamination of water supplies, and risks to public health and safety. To this end, the County General Plan should do more to ensure protection of the County's natural resources and to preserve quality of life for all the County's residents.

1. Land Use Element

a. Climate and Public Health Alternative: Prohibit New Oil and Gas Development

Continued and expanded oil and gas production runs counter to the state's 2030 and 2050 GHG reduction goals. *See* Health & Safety Code §§ 38550, 38566; Executive Order S-3-05. Expanded production also runs directly counter to state efforts to reduce both demand and supply of fossil fuels and to achieve carbon neutrality by 2045. Accordingly, in its comments on the Preliminary Draft Plan, CFROG recommended policies that would prohibit new oil and gas development in the County. *See* June 5, 2019 Comments at 3-5.

As those policies were not evaluated in the DEIR, CFROG once again proposes that the following new policies[3] be added to the General Plan Land Use Element as mitigation measures and/or as part of a "Climate and Public Health Alternative" that would reduce the significant impacts of oil and gas development:

Policy LU-xx Prohibition of New Oil and Gas Extraction. The development, construction, installation, or use of any new facility, appurtenance, or above-ground equipment, whether temporary or permanent, mobile or fixed, accessory or principal, for petroleum extraction is prohibited on all lands within the County's unincorporated area as a reasonable means of reducing greenhouse gas emissions and protecting the health and welfare of residents consistent with federal and state law.

Existing oil and gas operations would become nonconforming uses under this policy. Those uses, in turn, should be phased out according to a schedule that acknowledges vested rights and constitutional limitations while simultaneously supporting statewide efforts to reduce both supply and demand of fossil fuels. CFROG thus recommends that the following policies and implementation program be added to the General Plan, again either as mitigation measures or as part of an alternative that would reduce significant environmental impacts:

Policy LU-xx Existing Oil and Gas Facilities. Oil and gas extraction land uses lawfully existing on [*the effective date of the General Plan Update*] may continue as nonconforming uses to the extent allowed under State and local law until they are phased out pursuant to Policy LU-xx. Such uses, while they are continuing, shall not be enlarged, increased, extended, or otherwise expanded or intensified.

Policy LU-xx Phase-Out of Nonconforming Oil and Gas Operations. Nonconforming oil and gas extraction land uses shall be terminated within the shortest period of time necessary to ensure recovery of capital investments and compliance with constitutional limitations.

Implementation Program LU-X: To implement Policies LU-xx, xx, and xx [*Prohibition, Existing Facilities, and Phase-Out*], on or before January 1, 2022, the County shall develop and propose for adoption an ordinance providing for amortization of non-conforming oil and gas land uses, notice and hearing requirements, and any other provisions necessary to phase out such uses in a manner consistent with state and federal

[3] The policies proposed in this letter are substantively equivalent to the policies proposed in CFROG's June 5, 2019 Comments, although the specific wording of some proposals has been revised.

law. The ordinance shall contain provisions sufficient to ensure that all non-conforming oil and gas uses will be discontinued no later than 2045 unless discontinuance is expressly prohibited or precluded by state or federal law.

b. Discretionary Review and Permitting

In the absence of a complete prohibition on new wells, the County should require all new oil wells and proposed expansions at existing facilities to obtain discretionary permits. As discussed in our prior comments, under current Ventura County policies and practices, the vast majority of oil and gas development in the County is not subject to local CEQA review or conformance with current County policies and regulations. This is because the County requires only a zoning clearance for any additional oil wells drilled within the extensive areas covered by antiquated special use permits. Under current County practices, these zoning clearances are considered to be ministerial and thus do not trigger CEQA's environmental review and mitigation requirements. We also understand that the County has not been requiring compliance with updated regulations for these clearances.

CFROG appreciates that the Board of Supervisors recently directed County staff to prepare an ordinance requiring discretionary review of new and expanded oil and gas operations at facilities subject to antiquated special use permits. However, CFROG strongly believes that a policy requiring such review should be included in the General Plan.

The Draft Plan includes policies requiring new or modified *discretionary* oil and gas development to comply with current policies, standards, and conditions (Policy COS-7.3) and for new discretionary oil and gas development to use electrically-powered equipment (Policy COS-7.4) and to restore and revegetate the site after production (Policy COS-7.5). However, these policies apply only if a Project is subject to issuance of a discretionary permit. Because the Draft Plan does not require discretionary review for all new and expanded oil and gas operations, the Draft Plan and its DEIR fail to ensure that such operations will comply with new policies and programs to reduce GHG emissions, as well as address other impacts.

CFROG proposes the following policies to ensure that any new or expanded wells undergo discretionary review.

Policy LU-xx Renewal of Oil and Gas Facility Permits. All applications for renewal of oil and gas facility permits shall undergo discretionary review and shall be subject to updated air emissions requirements and other standards and conditions related to oil and gas operations. Terms of renewed permits shall be limited in duration to the reasonably expected life of the wells.

Policy LU-xx Expansion of Existing Oil and Gas Operations. Proposed changes to or expansions of existing oil and gas sites, facilities, or activities shall undergo discretionary review to ensure compliance with updated regulations and appropriate environmental review pursuant to the California Environmental Quality Act.

Policy LU-xx Discretionary Review of All New Wells. Discretionary review shall be required for the drilling or construction of any new well, and for the re-drilling or deepening of any existing well, unless any such drilling, construction, re-drilling, or deepening is specifically identified by location and number or specifically authorized in an active discretionary permit. Policy LU-xx Inspection and Monitoring of Oil and Gas Facilities. Approved expansions of existing oil and gas operations shall be conditioned to require monitoring through installation of continuous emission monitoring systems (CEMS) for air quality emissions and continuous effluent quality monitoring system (CEQMS) for water pollution to detect emissions and plumes in real time.

These proposed policies are intended not only to support adoption of the ordinance that the Board of Supervisors directed staff to develop in September 2019, but also to reinforce existing County Code provisions requiring new oil and gas development to be authorized by a discretionary conditional use permit. *See* Non-Coastal Zoning Ordinance ["NCZO"], §§ 8105-4 and 8105-5, "Mineral Resource Development," and "Oil and Gas Exploration and Production"; Coastal Zoning Ordinance ["CZO"], § 8174-5, under heading "Oil and Gas: Exploration and Production"). Similarly, these policies would support County Code provisions requiring discretionary approval in through permit modification for any material change to an existing permit. *See* NCZO, § 8111-6.1; CZO, § 8181-10.4.) These policies would reduce the overall impacts of oil and gas development by ensuring discretionary review, and site-specific mitigation and monitoring following CEQA review.

Likewise, we propose the following General Plan policy to address oil and gas facility operations and expansions under Antiquated Conditional Use Permits.

Policy LU-xx Oil and Gas Facilities Operating with Antiquated Conditional Use Permits. All oil and gas exploration and production operations, including legally existing operations lacking discretionary permits under the County Zoning Ordinance, are automatically subject to all requirements of the County Zoning Ordinance, General Plan, and other local regulations and standards relating to oil and gas exploration, extraction, and production, except to the extent that application of such regulations or standards would impair a vested right under state law.

This policy is feasible as evidenced by County Counsel's position[4] regarding the feasibility of amending the County Code to include a provision requiring antiquated conditional use permits to be and consistent with the Board's direction to staff to update the County Code accordingly. Letter Report from County Counsel, Leroy Smith, to the County Board of Supervisors dated September 10, 2019, at 4, attached as Exhibit 13.

Finally, CFROG previously proposed a policy that would prohibit extreme extraction methods like well stimulation treatments (including fracking) and cyclic steaming for tar sands production. June 5, 2019 Comments at 6. The DEIR did not evaluate this proposed policy. This policy should be evaluated as a mitigation measure for air quality, greenhouse gases, toxic and seismic hazards, and water quality and supply, all of which are adversely affected by extreme extraction.

Policy LU-xx Prohibit Extreme Extraction. The development, construction, installation, or use of any facility, appurtenance, or above-ground equipment, whether temporary or permanent, mobile or fixed, accessory or principal, for well stimulation treatments, cyclic steaming, and steam flooding are prohibited on all lands within the County's unincorporated area.

2. Conservation and Open Space Element

a. Oil and Gas Resources

The Conservation and Open Space Element's proposed policies related to oil and gas resources are also lacking specificity and enforceability. CFROG proposes the revisions to the following proposed General Plan policies:

COS-7.5 Restoration and Revegetation of Sites Used for Oil and Gas Exploration, Extraction, and Production. The County shall require that discretionary development for oil and gas exploration activities and all existing oil and gas development undergoing permit review be conditioned to require the restoration and revegetation of the site if the exploration does not result in oil and gas production facilities or when production activities are terminated.

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[4] "The County has a good legal argument that it can, in general, require newly proposed oil and gas development under antiquated permits to obtain authorization through a discretionary permit modification." See Exhibit 13, at 4.

COS-7.6 Abandoned Oil and Gas Well Identification. The County shall evaluate discretionary development to identify any abandoned oil and gas wells ~~on the project site~~ on all oil and gas operation sites.

In addition, CFROG proposes the following new policies be added to the Conservation and Open Space Element:

Policy COS-xx Nonconforming Oil and Gas Operations. The County shall actively work to discontinue nonconforming oil and gas extraction uses.

Policy COS-xx Review of Existing Permits. The County shall review all oil and gas permits that are 10 years or older to ensure that they are compliant with current standards and regulations to the maximum extent permitted by law.

Policy COS-xx Abandoned Oil and Gas Well Remediation. To prevent contamination of groundwater and leaks to the surface, the County shall require all abandoned oil and gas wells to be cleared of all equipment, plugged, capped and fully remediated in accordance with State and federal requirements within 60 days of ceasing operations.

Policy COS-xx Reuse of Abandoned Oil Fields. The County shall require the reclamation of abandoned oil fields to productive second uses.

Policy COS-xx Off-shore Oil Drilling. The County shall oppose any proposals for new or expanded off-shore oil drilling in the vicinity of Ventura County.

b. Energy Resource Conservation

CFROG recommends the following revisions to the proposed Energy Resource Conservation Policies:

Policy COS-8.1 Reduce Reliance on Fossil Fuels. The County shall promote the development and use of renewable energy resources (e.g., solar, thermal, wind, tidal, bioenergy, hydroelectricity) to reduce dependency on petroleum-based energy sources by developing and implementing incentives for alternative energy development and use.

Policy COS-8.7 Sustainable Building Practices. The County shall ~~promote~~ establish and require sustainable building practices that incorporate a "whole systems" approach for design and construction that consumes less energy, water, and other nonrenewable resources, such as by facilitating passive ventilation and effective use of daylight.

Policy COS-8.8 Renewable Energy Features in Discretionary Development. The County shall ~~encourage~~ require the integration of features that support the generation, transmission, efficient use, and storage of renewable energy sources in discretionary development.

Policy COS-8.9 Urban Tree Canopy Improvements for Energy Conservation. The County shall ~~encourage~~ require all discretionary development to include the planting of shade trees on each property and within parking areas to reduce radiation heat production.

In addition, CFROG proposes that the County add the following new policies related to energy resource conservation to further reduce GHG emissions:

Policy COS-xx Carbon-free Economy. The County will prioritize and facilitate a rapid transition to a carbon-free economy countywide.

Policy COS-xx Non-fossil Fuels for County Facilities and Fleets. The County will actively pursue a rapid transition to a diversity of non-fossil fuel alternatives for all County facilities and vehicle fleets.

Policy COS-xx Non-fossil Fuels Manufacturing and Distribution. The County will actively pursue, through the development of incentives and streamlined permit review, increasing a diversity of renewable energy manufacturing and distribution facilities countywide.

3. Hazards and Safety Element

The Draft Plan's Hazards and Public Safety element recognizes the threats being faced by the County, particularly climate change and seismic activity. Unfortunately, as CFROG pointed out in prior comments, the measures outlined in the Draft Plan are insufficient to protect County residents from these inevitable hazards and other adverse effects of oil and gas activity.

a. Protection from Seismic Hazards.

The Draft Plan fails to provide adequate protection from identified hazards related to oil and gas pipelines. Specifically, Policy HAZ-4.2 requires oil and gas pipelines to avoid intersecting active faults to the extent possible. However, the policy includes no specific measures for pipelines that must cross a fault line to address steps that must be taken to prevent spills from ruptured lines. CFROG suggests additional policies for the County to consider that would address this omission:

Policy HAZ-xx Safety Standards for Cross Fault Line Pipelines. Gas or crude oil transmission and distribution pipelines which cross active or potentially active fault lines shall be subject to additional safety standards, including emergency shutoff capabilities.

Similarly, in proposed Policy HAZ-4.8, the County attempts to prohibit hazardous material storage facilities within areas prone to severe ground shaking. Yet, there is no mention of the detrimental effects of "fracking" or the injection of wastewater into underground geological formations for storage and disposal. Numerous studies have linked fracking to increased seismic activity. In a county crisscrossed by numerous active and potentially active faults, it is only reasonable for the County to consider the effects of fracking on increasing the likelihood of seismic events and the potential dangers associated with this method of resource extraction.

Additionally, the injection of wastewater into underground formations is also linked to increased seismic events, which could trigger a leak within the formation, which in turn may endanger the groundwater quality in the County. *See*, https://www.usgs.gov/faqs/does-production-natural-gas-shales-cause-earthquakes-if-so-how-are-earthquakes-related-these ; "The 2013–2016 induced earthquakes in Harper and Sumner Counties, southern Kansas," Bulletin of the Seismological Society of America. Justin L. Rubinstein, William L. Ellsworth, and Sara L. Dougherty, available at https://pubs.er.usgs.gov/publication/70195671 , abstract attached as Exhibit 14; *see also* "Studies link earthquakes to fracking in the Central and Eastern US," Seismological Society of America, ScienceDaily April 26, 2019, available at https://www.sciencedaily.com/releases/2019/04/190426110601.htm , attached as Exhibit 15. Thus, we recommend the County add a policy requiring any fracking or wastewater disposal project to study the potential impacts of triggering seismic events and the impacts if a seismic event does occur. Such activities should not be allowed without a thorough understanding of the potential consequences and with plans in place to limit those negative consequences. To this extent, CFROG suggests adding a new policy to ensure that all injection into subsurface formations is done with a substantial understanding of the potential effects.

Policy HAZ-xx Seismic and Geotechnical Studies for Well Injection. Require that applicant provide additional seismic and other geotechnical studies which demonstrate that there will be no increased risk of earthquakes, subsidence or related geologic issues resulting from extraction, drilling or injection activities, when within a fault zone.

b. Compliance with Local, State, and Federal Regulations and Standards.

Proposed Policy HAZ-7.1 requires all discretionary permits for proposed oil and gas exploration and production projects to comply with local, state, and federal oil spill prevention regulations. This is insufficient. The County must do more to ensure its residents are safe and the environment protected from oil and gas exploration and production projects. As mentioned above, the County must include specific and quantifiable mitigation measures for existing development as well. While the policy contemplates compliance with local standards, the County does not have any standards in place to supplement federal and state regulations to address the specific problems being faced in Ventura County.

Additionally, state and federal regulations have changed and been updated. If a conditional use permit has been issued more than five years ago, the County should require inspection and enforcement of the existing conditions and evaluation if imposing new conditions would significantly improve the safety of such projects. Permits for operations involving hazardous substances also should be subject to discretionary renewal. To that end, CFROG suggests the County include the following policies in the draft plan:

Policy HAZ-xx Maintain Compliance with Local, State, and Federal Oil Spill Prevention Regulations. Review all oil exploration and production development which has been approved more than five (5) years prior to the effective date of this General Plan for consistency with applicable local, state, and federal oil spill prevention regulations. Establish mitigation activities as needed to maintain the standards and conditions required when the permit was issued.

Policy HAZ-xx Review of Permits Involving Hazardous Materials. Permits for any oil exploration and production projects, and associated production facilities, involving the transport or use of hazardous materials must be effective for no longer than five years, and must be reviewed and either renewed, further conditioned, or denied prior to expiration.

c. Increased Bonding Requirements to Ensure Proper Plugging and Abandonment, and Remediation of Oil Production and Exploration Sites.

Based on the wide array of impacts associated with oil and gas development, CFROG suggests that the County increase the bonding requirement to cover potential negative consequences from spills, failure to properly plug and abandon wells, and failure to properly remediate and restore the well site to other beneficial uses. The increased bonding requirement should be linked to proper plugging and abandonment after extraction has been finished. The oil and gas producers should plug the well and implement an abandonment plan. Such plans should be required prior to approval of the discretionary development and must be followed in the event that the well is deemed inactive. Additionally, the Hazards element fails to address the potential dangers associated with improperly abandoned wells. This omission creates a risk of leaks and spills that could harm County residents that may encounter an abandoned oil and gas well unknowingly. CFROG suggests the draft General Plan include a new policy to increase the bonding requirement as a condition of approval to ensure proper plugging, abandonment, and remediation of oil and gas production and exploration sites.

Policy HAZ-xx Increased Bonding Requirement and Remediation Plans. Enforce decommissioning and abandonment standards for oil extraction and exploration projects as a condition of approval. Require applicants to include a cost estimate for decommissioning and site restoration work following the cessation of extraction activities, and to post a bond for the estimated amount. Conduct an inspection after decommissioning and site restoration to ensure that all remediation activities have been satisfactorily completed. Require operators to dismantle all structures that cannot be effectively reused, and to recycle all materials as much as possible. Require that all hazardous waste, including electronics or toxic materials, is disposed of in accordance with applicable health and environmental safety standards.

d. Inspection and Enforcement of Existing CUP Conditions.

With technological advances and changes to state and federal oil and gas exploration and production regulations, the County should prioritize inspection and enforcement of the conditions of approval for existing oil and gas exploration and production sites. This is particularly true with respect to safety and oil spill prevention measures. To this effect, CFROG suggests including a new policy to inspect oil pipelines and enforce existing CUP conditions.

Policy HAZ-xx Annual Inspection and Enforcement of Existing CUP Conditions. Require annual inspections and enforcement of CUP conditions, including ensuring the most up to date spill prevention and safety technology.

e. Real-Time Detection and Monitoring of Emissions and Plumes.

CFROG suggests the County add a policy to the Draft Plan to require monitoring of oil and gas exploration and production sites, including the pipelines used to convey the oil and gas, through the use of cameras or other technology to detect emissions and plumes in real time:

Policy HAZ-xx Inspection and Monitoring of Oil and Gas Facilities. New discretionary oil and gas development and any proposed expansion of or changes to existing oil and gas operations shall be conditioned to require monitoring through installation of continuous emission monitoring systems (CEMS) for air quality emissions and continuous effluent quality monitoring system (CEQMS) for water pollution, or equivalent monitoring measures (including but not limited to thermal imaging cameras) capable of detecting and recording emissions and plumes in real time.

f. Pipeline Inventory and Maintenance Records.

The Draft Plan indicates that oil and gas transport lines have been mapped on the County's GIS. Draft Plan at 7-21. In addition to mapping these facilities, however, the County should also keep accurate records of maintenance and control technology for these pipelines. It is important to track the age of the pipelines and the technology installed on these pipelines to prevent spills from ruptures. By having this information at hand, the County will have the tools to prioritize specific pipelines for maintenance, and in a seismic event, the ability to identify the pipelines requiring immediate attention. Also, if one pipeline fails, by comparing the age and technology on the pipeline, the County can identify those other pipelines in similar conditions that will need to be replaced prior to another failure. CFROG suggests the addition of a new policy to require oil and gas producers to furnish the County with the relevant records on the maintenance and technology installed on those pipelines.

Policy HAZ-xx (Pipeline Inventory and Maintenance Records). Require all oil and gas producers with active pipelines to furnish the County with accurate and up to date maintenance and safety technology records.

IV. The DEIR's Proposed Buffer Requirements For Oil and Gas Operations Are Insufficient to Protect Public Health.

The Draft Plan proposes setbacks from oil and gas operations to protect sensitive receptors from toxic pollutants. Draft Plan at 6-12. Proposed General Plan policy COS-7.2: Oil Well Distance Criteria would require new discretionary oil wells to be located 1,500 from residences and 2,500 feet from schools. DEIR Mitigation Measure PR-1 proposes revisions to this policy to limit the buffer to 1,500 feet from all sensitive receptors. DEIR at 2-40 and 4.12-18. The GPU DEIR indicates that there are currently 23 active and idle oil wells within 2,500 feet of schools and 715 active wells within 1,500 feet of homes in the County. DEIR at 4.12-14.

A number of recent studies and literature reviews have discussed impacts from oil and gas development, including emissions of criteria and toxic air pollutants, water pollution, noise, light, and biological hazards like Valley Fever.[5] Many of these studies provide a foundation supporting the establishment of setbacks and for imposing setbacks of at least 2,500 feet from oil and gas operations.

For example, a literature review conducted by Nicole J. Wong, MPH, suggests that far greater setback distances are necessary to protect against adverse health outcomes,

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[5] In addition to the studies discussed in detail below, numerous studies and literature reviews have detailed harm from fracking and other forms of oil and gas development. *See, e.g.*, Concerned Health Professionals of NY and Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed. June 2019), attached as Exhibit 16; Kristina Marusic, *After a decade of research, here's what scientists know about the health impacts of fracking*, Environmental Health News (April 15, 2019), *available at* https://www.ehn.org/health-impacts-of-fracking-2634432607.html (visited Feb. 25, 2020). Notably, although these studies focused on the health effects of fracking, a comprehensive review of well stimulation techniques (including fracking) by the California Council on Science and Technology ("CCST") concluded that "[a]ll forms of oil and gas development, not just that enabled by well stimulation, may cause similar public health risks." Seth D. C. Shonkoff, et al., *Chapter Six: Potential Impacts of well Stimulation on Human Health in California*, in Jane C. S. Long, et al., California Council on Science and Technology, An Independent Scientific Assessment of Well Stimulation in California, Volume II: Potential Environmental Impacts of Hydraulic Fracturing and Acid Stimulations at 375 (updated July 2016), available at https://ccst.us/wp-content/uploads/160708-sb4-vol-II-6-1.pdf (visited Feb. 25, 2020).

particularly from exposure to air pollutants.[6] Based on studies showing adverse health effects from air and water pollution at distances well over one-half mile, Ms. Wong concluded that "a 2,500-foot setback recommendation is on the *lower end* of the range of distances where research has determined harmful health and quality of life impacts of toxic emissions and exposures."[7]

In another example, a study[8] considered the minimum distance that might be required in case of a blow-out or explosion event by investigating historical evacuation data. This study determined that the average evacuation zone for such incidences is 0.8 miles, or 4,224 feet.[9] In addition, the Environmental Health Project (EHP), a public health organization consisting of a consortium of experts in environmental studies and public health, agreed that 1.0 to 1.25-mile distance (6,600 feet) from unconventional oil and gas development (i.e., fracking) is an acceptable minimum to protect human health. Additionally, the study recommends greater setback distances for settings where vulnerable subpopulations might gather, such as schools, day care centers, and hospitals.

In sum, these recent reviews, and the numerous scientific studies considered therein, provide scientific and factual support for development of setbacks in excess of 2,500 feet. An setback of at least 2,500 feet is necessary to protect the health and safety of County residents.

Mitigation Measure PR-1 properly expands the list of "sensitive use structures" to which Policy COS-7.2 would apply. DEIR at 4.12-18. However, the measure would reduce the buffer distance from schools from 2,500 feet to 1,500 feet. As discussed above, ample scientific information indicates that a 1,500-foot buffer is likely insufficient to protect public health and safety.

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[6] Nicole J. Wong, MPH, *Existing Scientific Literature on Setback Distances from Oil and Gas Development Sites* (version 2, Nov. 2017), *available at* http://www.stand.la/research--reports.html, attached as Exhibit 17.
[7] *Id.* at 1; see also *id.* at 6 (Table 1) (comparing distances at which several studies documented potential adverse health outcomes with 2,500-foot proposed setback distance) (emphasis added).
[8] Haley, M., McCawley, M., Epstein, A. C., Arrington, B., & Bjerke, E. F. (2016). *Adequacy of current state setbacks for directional high-volume hydraulic fracturing in the Marcellus, Barnett, and Niobrara Shale Plays*. ENVIRONMENTAL HEALTH PERSPECTIVES, 124(9), 1323, available at https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1510547
[9] *Id*. at 3.

In particular, reducing the proposed buffer distance from schools as proposed in Mitigation Measure PR-1 would be both unsupported and unwise. Children are often outdoors at schools, daycare centers, and recreation facilities, where they can be exposed to significant hazards. For example, on March 6, 2006, a small earthquake caused a break in an idle well bore in Upper Ojai, causing oily brine to flow to the surface for months. *See* DOGGR, 2006 Annual Report of the State Oil & Gas Supervisor at 26 (2007), excerpt attached as Exhibit 18; *see also* The Next Big One, VC Reporter (Aug. 22, 2013), at https://vcreporter.com/2013/08/the-next-big-one/ (visited Feb. 25, 2020); Jhon Arbelaez, Shaye Wolf, and Andrew Grinberg, On Shaky Ground: Fracking, Acidizing, and Increased Earthquake Risk in California at 13 (March 2014), attached as Exhibit 19. Drilling near schools and daycares could expose many more children to similar (or far worse) hazards. Therefore, CFROG respectfully requests that the County revise Policy COS-7.2 to require a minimum setback distance of 2,500 feet from *all* sensitive receptors, including schools, daycares, residences, and medical facilities.

Finally, Policy COS-7.2 would apply only to "new discretionary oil and gas wells." DEIR at 4.12-18; Draft Plan at 6-12.[10] The proposed policy thus leaves numerous residents with no protection from existing oil and gas wells. *See* DEIR at 4.12-16 (Figure 4.12-2). Although CFROG recognizes that some of these existing wells may be subject to vested rights, existing operations should nonetheless be amortized and phased out as soon as legally possible.

Accordingly, the County should evaluate an additional mitigation measure consisting of the following policy and implementation program:

<u>Policy COS-xx Phase-Out of Existing Oil and Gas Operations Near Sensitive Uses. Existing oil and gas exploration and production activities located closer than the minimum distance from sensitive use structures established by Policy COS-7.2 shall be terminated within the shortest period of time possible, consistent with protection of any vested rights and applicable constitutional limitations</u>.

<u>Implementation Program COS-X: To implement Policy COS-xx [*Phase-Out*], on or before January 1, 2023, the County shall develop and propose for adoption an ordinance providing for amortization of existing oil and gas exploration and production</u>

[10] As proposed in the Draft Plan, Policy COS-7.2 applies only to "oil wells," while in the DEIR, the policy would apply to "oil and gas wells." The policy clearly should apply to both oil and gas wells.

activities located closer than the minimum distance from sensitive use structures established by Policy COS-7.2, notice and hearing requirements, and any other provisions necessary to phase out such uses as quickly as possible in a manner consistent with state and federal law.

V. The DEIR Improperly Eliminated and Failed to Analyze Alternatives That Would Reduce or Avoid Significant Impacts.

The DEIR does not comply with the requirements of CEQA because it fails to undertake a legally sufficient study of alternatives to the Project. A proper analysis of alternatives is essential to comply with CEQA's mandate that, where feasible, significant environmental damage be avoided. Pub. Resources Code § 21002 (projects should not be approved if there are feasible alternatives that would substantially lessen environmental impacts); CEQA Guidelines §§ 15002(a)(3), 15021(a)(2), 15126(f). The primary purpose of CEQA's alternatives requirement is to explore options that will reduce or avoid adverse impacts on the environment. *Watsonville Pilots Assn. v. City of Watsonville* (2010) 183 Cal.App.4th 1059, 1089. Therefore, the discussion of alternatives must focus on project alternatives that are capable of avoiding or substantially lessening the significant effects of the project, even if such alternatives would impede to some degree the attainment of the project objectives or would be more costly. CEQA Guidelines § 15126.6(b); *see also Watsonville Pilots,* 183 Cal.App.4th at 1089 ("[T]he key to the selection of the range of alternatives is to identify alternatives that meet most of the project's objectives but have a reduced level of environmental impacts").

As a preliminary matter, the DEIR's failure to disclose the extent and severity of the Project's climate impacts necessarily distorts the document's analysis of Project alternatives. As a result, the alternatives are evaluated against an inaccurate representation of the Project's impacts. Proper identification and analysis of alternatives is impossible until Project impacts are fully disclosed. Moreover, as discussed above, the document's analysis is incomplete and/or inaccurate so that it is simply not possible to conduct a comparative evaluation of the Project's and the alternatives' impacts.

In any case, the DEIR improperly circumscribes its analysis of potential Project alternatives and makes no serious attempt to describe an alternative that avoids or substantially minimizes the climate impacts of the Project. Comments on the Notice of Preparation for the EIR, including comments from CFROG, urged the County to analyze alternatives that would reduce oil and gas production. CFROG also requested that the County add policies and programs that would achieve similar purposes in its comments on the Preliminary Draft Plan. See June 5, 2019 Comments at 3-5, 25-30.

The DEIR identifies three alternatives that would address climate impacts related to GHG emissions. These include: the Limit Active and Idle Wells and Reduce Oil Well Emissions Alternative, the Eliminate or Reduce Existing Oil and Gas Wells or Production Alternative, and the Carbon Neutrality Alternative. As discussed in more detail below, the DEIR, however, declined to evaluate any of these proposals as alternatives, and instead rejected them all as infeasible. The DEIR's refusal to evaluate these additional policies, either as alternatives or mitigation measures, was improper.

A. Alternatives That Would Reduce Oil and Gas Production Were Improperly Rejected.

The DEIR rejected alternatives that would limit oil and gas production on two grounds. First, the DEIR found such alternatives "focuse[d] on one specific land use and [did] not comprehensively address most of the basic project objectives." DEIR at 6-9. Yet the DEIR does not identify a single project objective that would not be met by an alternative that provides a comprehensive plan for development in the County while simultaneously reducing reliance on oil and gas exploration and production. Such an alternative would still satisfy most if not all of the objectives listed in the DEIR. It would also avoid or substantially lessen significant impacts of oil and gas development. Nothing in CEQA contemplates or permits elimination of an alternative that meets most project objectives solely on the basis that it would reduce environmental impacts associated with a subset of land uses. And even if CEQA did preclude analysis of alternatives that primarily focus on a subset of land uses, the alternatives' provisions still could serve as mitigation measures for the significant effects of those land uses. Either way, the DEIR fails to justify its elimination of these provisions from detailed consideration.

Second, the DEIR claims eliminating or reducing existing oil and gas operations would "present legal and economic feasibility issues." DEIR at 6-9. This claim, however, is entirely conclusory and lacks any supporting explanation or analysis. It is also wrong.

Reducing both new and existing oil and gas operations in the County is legally feasible. Nearly a century of case law confirms that local governments may determine where oil and gas operations occur, and may even prohibit such operations altogether. *See, e.g.*, *Higgins v. Santa Monica* (1964) 62 Cal.2d 24; *Beverly Oil*, 40 Cal.2d 552; *Pacific Palisades Assn. v. City of Huntington Beach* (1925) 196 Cal. 211; *Hermosa Beach Stop Oil Coalition*, 86 Cal.App.4th 534; *Friel v. Los Angeles County* (1959) 172 Cal.App.2d 142. A 1976 opinion of the Attorney General (59 Ops. Cal. Atty. Gen. 461) suggested that while some local attempts to regulate the precise manner of oil and gas production might be preempted, local governments generally retain their traditional authority to control land use and protect public health; the Attorney General concluded in this context that an ordinance completely prohibiting oil and gas development probably would *not* be preempted. *See id.* at 478, 484.

Moreover, although many existing oil and gas wells in the County may be subject to vested rights, the County may constitutionally require the elimination of vested nonconforming land uses provided owners and operators are given an opportunity to come into compliance during a reasonable amortization period commensurate with the investment involved. *National Advertising Co. v. County of Monterey* (1970) 1 Cal.3d 875, 879. California courts have long recognized amortization periods as valid means to balance the competing interests of a property owner's property rights and a local agency's need to implement zoning changes to benefit public health and welfare. *Gage*, 127 Cal.App.2d at 460; *see also United Bus. Com. v. City of San Diego* (1979) 91 Cal.App.3d 156, 180 (reasonable amortization period satisfies due process requirements); *Livingston Rock and Gravel Co. v. Los Angeles* (1954) 43 Cal.2d 121, 126-28. Other jurisdictions follow this exact approach; for example, the Los Angeles Planning and Zoning Code currently provides a 20-year amortization period for termination of nonconforming oil and gas operations. L.A. Municipal Code § 12.23(C)(4). The DEIR has not demonstrated that reduction or elimination of existing operations is legally infeasible, and thus fails to comply with CEQA as a matter of law. *See City of San Diego v. Board of Trustees of California State University* (2015) 61 Cal.4th 945, 956.

Finally, although the DEIR cites unspecified "economic infeasibility issues," it fails to provide any evidence or analysis to back up its conclusions. An EIR must contain facts and analysis, not just the "bare conclusions of a public agency." *Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d 692, 736 (quoting *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818, 831.)

B. The DEIR Improperly Disclaims the County's Authority to Fight Climate Change.

The DEIR omits detailed consideration of a "carbon neutrality" alternative based primarily on the assumption that the County lacks the authority and the ability to undertake the fundamental changes necessary to avoid the very worst impacts of climate disruption. DEIR at 6-10 to 6-12. Nobody disputes that confronting the climate crisis will require daunting social and economic transformations. Yet this entire section of the DEIR effectively claims that solving the problem is too difficult, too expensive, and ultimately someone else's responsibility. Simply throwing up our hands and allowing the climate crisis to overtake our communities, however, should never be an option.

Nobody would argue that the County must create a carbon-free economy all on its own. The point, rather, is that prompt and decisive action at all levels of government will be necessary to achieve this goal. The DEIR recites a litany of necessary actions, but it makes no effort to distinguish which actions lie wholly or partially within the County's control. The fact that a "coordinated effort of multiple levels of government" may be needed (DEIR at 6-11) does not provide the County with an excuse to claim it has no responsibility to participate. Nor does the DEIR's weak complaint that taking actions within the County's control (such as improving public transit) "may have financial constraints" (*id.*) suffice to demonstrate that all such actions are infeasible. The California Supreme Court has twice rejected public agencies' attempts to disclaim their portion of responsibility for mitigation that required coordination among different agencies and levels of government based on unsupported claims of legal infeasibility. *See City of San Diego*, 61 Cal.4th 945; *City of Marina v. Board of Trustees of California State University* (2006) 39 Cal.4th 341.

A "carbon neutral" alternative would consist of actions the County could take in implementing its General Plan. The DEIR paints a caricature of such an alternative in order to reject it. Whatever the effort required, failure to work toward and achieve a carbon-free economy by mid-century will expose Ventura County to almost incalculable social and economic damage. The County cannot wait until 2040 or beyond for someone else to do the hard work. It has to start now, with a frank and serious look at alternatives that would commit the County to doing its fair share to avoid catastrophe.

VI. Conclusion

We appreciate your consideration of these comments. CFROG looks forward to continuing to work with the Planning Commission, Board of Supervisors, and County staff throughout the General Plan Update process.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Kevin P. Bundy

Attachments:
Exhibit 1 Washington Post, "California climate change: Fires, floods and a fight over free parking," December 5, 2019

Exhibit 2 Stats.2019, ch. 23, Item 0555-001-3228 (Budget Act - Assembly Bill No. 74)

Exhibit 3 Carbon Neutrality Studies Scope of Work, Study 1

Exhibit 4 Carbon Neutrality Studies Scope of Work, Study 2

Exhibit 5 DOGGR 2017 (annual report)

Exhibit 6 Ventura County Air Pollution Control District, Part 70 Permit No. 00012, Section No. 2 at 1 (Table No.2) (May 14, 2019)

Exhibit 7 Bloomberg News, "NASA Flew Gas Detectors Above California, Found 'Super Emitters", November 7, 2019

Exhibit 8 "A Third of California Methane Traced to a Few Super-Emitters," https://climate.nasa.gov/news...

Exhibit 9 Myhre, G., et al., 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

Exhibit 10 Ventura County Methane Plum Data

Exhibit 11 Carbon Energy Corporation Corporate Overview 2019

Exhibit 12 Ventura County Air Pollution Control District, Order Granting Interim Variance, Hearing Board Case No. 878

Exhibit 13 Letter Report from County Counsel, Leroy Smith, to the County Board of Supervisors

Exhibit 14 "The 2013–2016 induced earthquakes in Harper and Sumner Counties, southern Kansas" Bulletin of the Seismological Society of America. Justin L. Rubinstein, William L. Ellsworth, and Sara L. Dougherty [abstract]

Exhibit 15 “Studies Link earthquakes to fracking in the Central and Eastern US, ” Seismological Society of America. Science Daily April 26, 2019

Exhibit 16 Concerned Health Professionals of NY and Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (6th ed. June 2019)

Exhibit 17 Nicole J. Wong, MPH, *Existing Scientific Literature on Setback Distances from Oil and Gas Development Sites* (version 2, Nov. 2017)

Exhibit 18 DOGGR 2006 Annual Report of the State Oil & Gas Supervisor at 26 (2007) [excerpt]

Exhibit 19 Jhon Arbelaez, Shaye Wolf, and Andrew Grinberg, On Shaky Ground: Fracking, Acidizing, and Increased Earthquake Risk in California (March 2014)

cc: Climate First: Replacing Oil & Gas

EXHIBIT 1

The Washington Post
2°C: BEYOND THE LIMIT

°C ⟷ °F

2°C: Beyond the limit

2°C: BEYOND THE LIMIT

By **Scott Wilson**
Photos by **Michael Robinson Chavez**
Graphics by **John Muyskens**

DEC. 5, 2019

°C ⟷ °F

SANTA BARBARA, Calif. — When the fire came this time, blowing in fast and ashy from the dry hills around her camping resort, manager Terri Bowman was ready.

The past few years had prepared her for what had once been unthinkable. First, the Sherpa Fire scorched the hills around the camp in June 2016. Then, unusually heavy rains sent a wall of mud through El Capitan Canyon in January 2017, washing two camp buildings and a car into the Pacific Ocean. The resort closed for four months.

Bowman spent $250,000 shoring up the steep, loose hillsides of the canyon, which gives the resort its name. She also bought generators that she put to use in September, when Southern California Edison cut off power for a day to reduce the risk of fire.

Then, in late October, plumes of smoke from the Real Fire appeared above the canyon walls. Bowman and her staff hurried from cabin to yurt to cabin, telling guests to leave. They dialed cellphone numbers collected as part of an emergency evacuation plan at check-in. They guided cars and buses along a one-lane road toward the highway, including a class of first-graders forced to cancel a weekend retreat.

The only casualty was her bottom line.

“We just kind of shifted into action, we were so used to it,” said Bowman, resigned to the new realities in the canyon where she has done business for nearly two decades. “Relatively nothing happened here until 2016. Since then, it has been an annual event.”

Life in Southern California, once as mild and predictable as the weather, is being transformed as the climate grows hotter, drier and in some regions windier, fueling more intense wildfires, deadly mudslides and prolonged extreme drought.

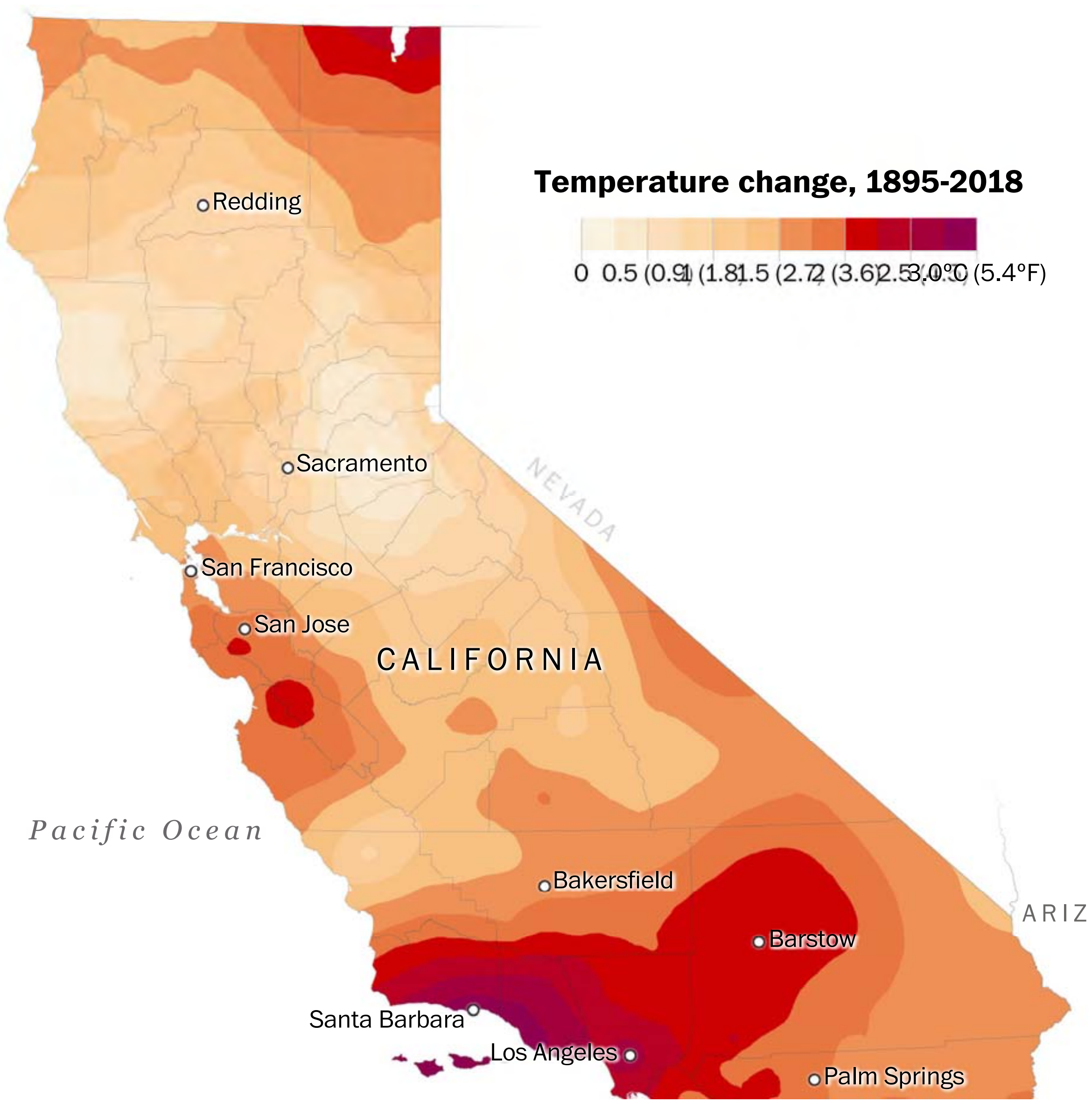
The changing natural world is in turn forcing a fundamental social reckoning, altering the choice of crops on some of the nation’s most bountiful farms, erasing the certainty of electrical power in some of its wealthiest homes and exposing the limits of environmental activism among some of its most liberal voters.

The cradle of the Earth Day movement is confronting the consequences of a warming Earth.

The coastal curve that bends south from Santa Barbara through the Los Angeles metroplex to the arroyos along the Mexican border is warming at double the rate of the continental United States, according to a Washington Post analysis of more than a century of temperature data. And during the past five years, the pace has accelerated.

2°C: BEYOND THE LIMIT *Click any temperature underlined in the story to convert between Celsius and Fahrenheit* °C ⟷ °F

Since 1895, the average temperature in Santa Barbara County has warmed by 2.3 degrees Celsius (4.1 degrees Fahrenheit), according to The Post's analysis. Neighboring Ventura County has heated up even more rapidly. With an average temperature increase of 2.6 degrees Celsius (4.7 degrees Fahrenheit) since preindustrial times, Ventura ranks as the fastest-warming county in the Lower 48 states.



Source: National Oceanic and Atmospheric Administration

Warming here already has exceeded the threshold set in the 2015 Paris climate accords, which President Barack Obama joined and the Trump administration has promised to leave. The agreement concluded that average warming worldwide should be held “well below” 2 degrees Celsius (3.6 degrees Fahrenheit) to avoid potentially catastrophic consequences — but it already has warmed by more than 1 degree Celsius (1.8 degrees Fahrenheit).

Across California, the growing heat and loss of moisture threatens the iconic coastal redwood forests and the Joshua trees of the southern desert. Bird populations have been ravaged by drought, with several once-prominent desert habitats losing 43 percent of their species in the past century, according to a study published last year in the Proceedings of the National Academy of Sciences.

Offshore, the warming ocean has depleted once-expansive kelp forests around the Channel Islands and has thrown oyster, crab and urchin harvests into disarray.

Thirteen whales washed ashore dead this year in the San Francisco Bay area, and when marine biologists went searching for answers, they found that many of them had empty stomachs.

CHOOSE A COUNTY

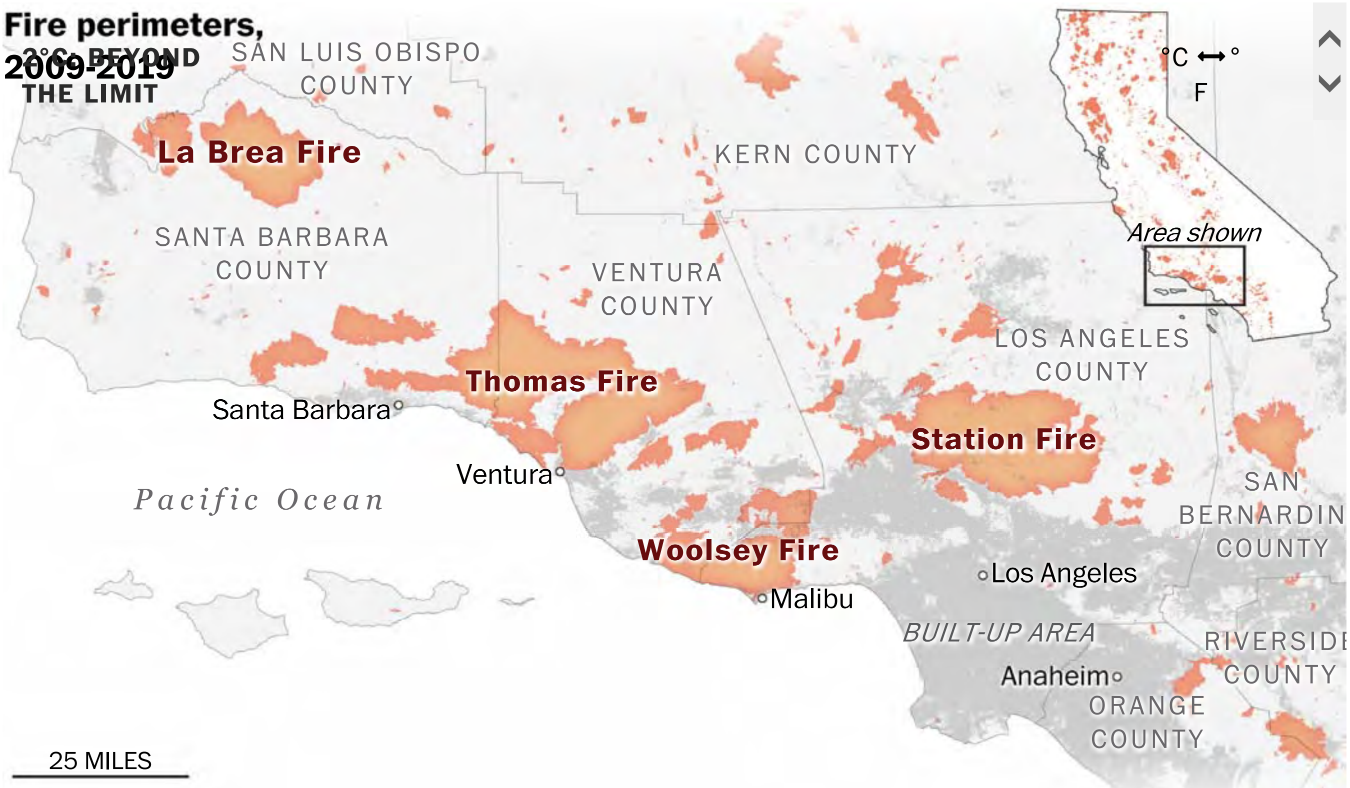
Annual temperature change, 1895-2018

In Santa Barbara County, the dangers of this grave new world came into focus with the Thomas Fire in 2017. The blaze started in early December, late by traditional standards and a sign that the fire season is now effectively year-round. It was the largest in state history at the time, burning more than 281,000 acres.

Residents were forced to evacuate at the height of the holiday season in the wealthy, woodsy suburb of Montecito. Many were just getting back home when a severe storm forecast prompted a second evacuation order. Tired of living in hotels or crashing with friends, many people ignored it.

Stripped by fire, soaked by rain, the steep hillsides above town collapsed in the predawn hours of Jan. 9, 2018. The torrent of earth killed 23 people, carrying some out of their houses and all the way to the sea.

The twin disasters caused more than $2 billion in damage and focused attention on the shifting climate.



Sources: CalFire; USGS GeoMAC Wildland Fire Support. Fire perimeters as of Nov. 15, 2019

"Before the fire and flood, people here thought of climate change in similar ways as they thought of the refugee crisis in other parts of the world — something important but remote," said Santa Barbara County Supervisor Das Williams, whose district was hit hard by the fire and its aftermath. "Now, I'm confronted with the fact we had a mass casualty event that was climate enhanced."

The possible remedies are improvisational — and, so far, largely ineffective.

Despite Santa Barbara's heritage as the birthplace of the modern environmental movement, the county is falling far short of its own anti-pollution goals, which are meant to serve as a model for others to follow. The failure has activists here wondering: If a place with Santa Barbara's predominantly green electorate and political class is unwilling or unable to change, who will?

This is a tourist town, a weekend resort for the Los Angeles wealthy, a place that has become shorthand for getaway glamour thanks to a once-popular daytime soap opera named for it. Several years ago, the county adopted goals consistent with California's overall target to cut the greenhouse gas emissions that cause global warming to zero over the next 25 years.

But the government here has bumped up against local business interests, from downtown retailers and restaurants to the oil industry, that oppose more environmental regulation and even such seemingly minor changes to civic life as a reduction in downtown parking. Those interests are often decisive in determining local elections.

The results, so far, have been dismal. In 2015, the county pledged to reduce greenhouse gas emissions by 15 percent compared with 2007 levels. Two years later, a progress report found that, rather than reducing those emissions, Santa Barbara was actually exceeding its 2007 levels by 14 percent.

"The city's legacy tells a story about how progressive it is on environmental matters," said Leah Stokes, a political science professor at the University of California at Santa Barbara, who specializes in energy and environmental politics. "But in our own backyard, we are not nearly as progressive as we think."

2°C: BEYOND THE LIMIT

°C ⟷ °F

The Thomas Fire in December 2017 was the first sign that Santa Barbara's climate had changed and that wildfires had become more severe. It burned 281,000 acres, and heavy rains a month later killed 23 people. (Stuart Palley for The Washington Post)

A state of change

Along Santa Barbara's Del Playa Drive, the cliffs above the Pacific Ocean are disappearing with the rising sea.

One apartment building, popular with UCSB students, was condemned three years ago after the cliffs beneath it crumbled into the water. Last fall, the city's planning department said in a report that, unless conditions change, erosion could claim up to 78 percent of the city's bluffside beaches by 2060.

Reilly Ehrlich, a senior psychology major, waited several years for a spot in her apartment at the edge of a precipice, now so eroded it is being braced by netting. By the hammock and barbecue out back is a sign attached to the fence. It shows a stick figure falling backward off a cartoon cliff, warning people to keep their distance.

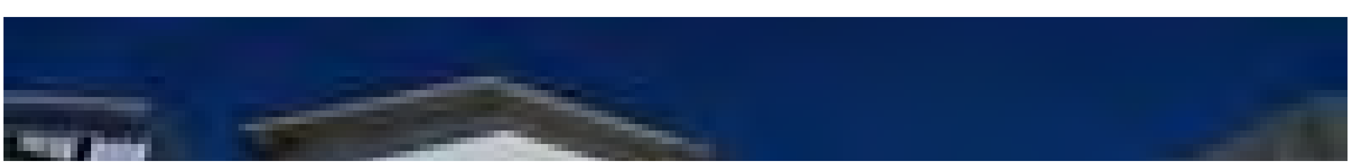
"It's crazy waking up to this view," Ehrlich said, the blue Santa Barbara Channel sparkling behind her. "But we always talk about how this house will not be here in 20 years."

Scientists have no clear answer for why this region is heating up so fast. But they say a century of urbanization in Los Angeles and Orange counties probably plays a role, bringing more traffic up and down the region's single north-south coastal highway.

Temperature inversions — the appearance of a layer of warm air in the upper atmosphere — are commonplace regionwide but today hold in the larger amounts of smog and heat. Scientists here say the warming waters offshore are beginning to resemble tropical oceans that, according to local fishermen and farmers, are intensifying the dry winds that cascade down the steep coastal range and deepen the effects of drought.

A shift in weather patterns has affected the morning cloud cover known as the marine layer, pushing the foggy early-summer "June gloom" into a late-summer "Fog-gust." The marine layer also has thinned out, declining by as much as 50 percent since 1970, according to A. Park Williams, a research professor at Columbia University's Lamont-Doherty Earth Observatory.

That results in less coastal moisture, and more risk of fire.

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2°C: BEYOND THE LIMIT

Amber Stevens, right, a student at UCSB, plays with friends in Isla Vista. The cliffs below the apartments used as student housing are disappearing as a rising ocean slowly erodes them.

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2°C: BEYOND THE LIMIT

Some of the cliffs overlooking the Santa Barbara Channel have been reinforced with netting and concrete columns.

°C ⟷ °F

2°C: BEYOND THE LIMIT

In neighboring Ventura County, the fastest warming in the Lower 48 states, high tides and rough seas are eating away at this seaside parking lot.

°C ⟷ °F

A quarter of California's 40 million residents now live in high-risk fire zones.

For the past three autumns, tens of thousands of people have packed up family photos, home deeds and marriage licenses to evacuate in fearful, fire-driven migrations, from the Sierra Nevada to San Diego. More than 6,000 residents were forced from their homes here Nov. 25, when the Cave Fire flared up in the Santa Ynez Mountains, burning thousands of acres of chaparral-covered hillside.

Wildfires have long been a fact of life here, but today's fires are simply more intense. The three most severe in state history — measured by acreage burned, homes destroyed and lives lost — have happened in the past two years. In the coastal counties running from Santa Barbara to San Diego, four of the five worst fire seasons of the past half century have burned in the last two decades.

State Sen. Henry Stern (D-Canoga Park), whose home burned in the 2018 Woolsey Fire in Malibu, doesn't know anymore what to tell his constituents north of Los Angeles, who have experienced several fires and electricity outages this fall.

"I feel like I am failing them," he said.

Seeking to reduce fire risk and financial liability, utilities have begun intentionally cutting off power. This year alone, nearly 3 million Californians were left in the dark for days. State officials say generator sales have soared 1,400 percent.

"What we have seen is a complete lack of preparedness," said Trent Robbins, chief executive of Santa Barbara-based Global Power Supply, where customer calls for generator sales and rentals quadrupled in October. "This is like climate change writ small — you know it's coming, but you are not preparing."

What has surprised those who live, work and study the climate in Santa Barbara is how precipitously the warming is happening. A recent study of the Santa Barbara-area climate projected that "the number of extremely hot days will likely double by 2050."

"It's been hard to connect the dots," said Santa Barbara County Supervisor Joan Hartmann, whose district includes parts of the Santa Ynez Valley, where she has had a home for two decades. Hartmann said she had never been forced to evacuate by fire until last year. She has since had to leave home twice.

Now she and her neighbors meet regularly, often in living rooms over a glass of the valley's famous pinot noir, to discuss the confounding climate.

"We're asking each other, 'Who has the horses if something happens? Who is frail and needs extra help?' " she said. "This is also about social resilience now, about neighborhoods looking for ways to protect themselves."

Rapid warming and extreme weather have affected the coastal sweep from Santa Barbara to San Diego counties. The 2018 Woolsey Fire in Malibu killed three people and torched over 1,600 buildings. (Kyle Grillot for The Washington Post)

‘Global weirding’

On July 6, 2018, a huge high-pressure system over Colorado helped spin a mass of hot air into Southern California.

By 11 a.m., temperatures reached 90 degrees Fahrenheit (32.2 degrees Celsius), so Guner Tautrim, whose family has farmed Orella Ranch for seven generations, worked with his father to spray down their pigs, chickens and horses with water before taking refuge inside.

“The crazy thing happened around 3 p.m., when the temperature just started going up and up,” Tautrim said.

It spiked to 115 degrees Fahrenheit (46.1 degrees Celsius), then, nearly as abruptly, cooled down after sunset. Such an hours-long super spike had happened only once before in Santa Barbara — 149 years ago.

“I call what’s happening here ‘global weirding,’ ” said Tautrim, whose farm was deeded through a Spanish land grant more than two centuries ago.

The damage was severe: Dozens of Tautrim’s animals died in the heat, and his neighbors saw entire avocado harvests fail. Some scorched orchards have yet to recover, and the hills behind his redwood house are parched to the color of desert sand.

Those losses add up.

Last year, Santa Barbara farmers and ranchers took in $1.5 billion in revenue, a nearly 5 percent decline from the previous year, according to an annual report that began with an introduction titled: “2018 — A year of extreme weather and events.”

The unpredictability has prompted experimentation along the windblown Gaviota Coast, a 76-mile comma of beach and orchards that make up the largest stretch of undeveloped land in Southern California.

Set between the mountains and the sea, Eric Hvolboll’s La Paloma Ranch once filled with water during the rainy season, forming fishing ponds used by the Chumash tribes hundreds of years ago.

Now it is dry.

The ranch's 746 acres of slope and ravine, cropland and pasture have shifted thanks to a combination of drought and technology. The primary crop since 1969 has been avocado, profitable but water intensive in a place with very little water left. It was the first crop on the farm to need irrigation.

Now crawling up the hillside are neat rows of agave, the spiky plant that in Mexico produces tequila. It is among the least thirsty of crops and, in some ways, takes La Paloma Ranch back to the pre-irrigation days of Hvolboll's grandparents, who relied on the rain alone to grow garbanzo beans, walnuts and lima beans.

La Paloma Ranch manager John Kleinwachter plants tropical crops that are more resilient to the county's drier, warmer climate.

Agave is new to coastal Southern California, and the owners of La Paloma Ranch are not sure yet whether it's commercially viable.

A small Ventura distillery has started selling liquor made from La Paloma’s agave, the latest craft offering added to Southern California’s homegrown wine and beer.

“The question I had to ask was, ‘Is there a way we can make money and not use water?’ ” said Hvolboll, a lawyer by training. “We still don’t know if we can make money doing this.”

A small Ventura distillery turns the agave into craft tequila — though it can’t be labeled tequila because it isn’t from that region of Mexico. It is selling in small batches, and Hvolboll said he hopes to switch out some of his avocados for the durable plants.

“Our working assumption is that we are going to have less and less water,” said Hvolboll, 64. “Maybe not tomorrow, maybe not in my life. But we have to look at all options around that assumption.”

Four years ago, in the midst of the state’s historic drought, Jay Ruskey winnowed his avocado orchard. At the time, the reservoir in the valley where much of Santa Barbara's water originates was at just 6 percent of capacity.

"I don't think people had any idea how close we came to simply running out of water," Ruskey said.

He too, is turning to more tropical crops: finger limes native to Australia, dragon fruit, passion fruit, and now, coffee, which he sells under the brand Frinj. The coffee trees run downhill between his avocado trees, benefiting from the shade.

"These last 10 years have been very different from the first 20 years," said Ruskey, 47, who has owned his farm since 1990. "I could step aside, and someone would replace me. Or I can change."

Jay Ruskey has winnowed his avocado orchard and turned to planting more exotic fruits on his farm, including the dragon fruit shown here.

Ruskey is a local pioneer in growing coffee in Southern California. He markets his coffee under the Frinj brand and has clients with whom he consults as far south as San Diego.

Avocado is a water-intensive crop. A drought four years ago persuaded Ruskey to diversify his plants.

‘No teeth in these plans’

If there is a God-given civic right in which Santa Barbarans believe, it is bountiful and convenient free public parking.

Studies have found that there is no greater predictor of the number of cars on the road than the availability of free parking. And in Santa Barbara County, the biggest contributor to air pollution and greenhouse gas emissions is the car.

Environmentalists are lobbying to put an end to it and to even replace parking lots on prime downtown real estate with housing. But that campaign has so far failed to budge the city council on an issue the business community says is key to profitability.

“Parking is the third rail of Santa Barbara politics,” said Michael Chiacos, a native of the city who works with the nonprofit Community Environmental Council.

Sacrifices in service of environmental goals have been tough to come by in Santa Barbara, local environmentalists say — evidence, perhaps, of the county’s conflicted history.

Huge oil deposits make the region one of California’s primary producers and shape its politics, despite a seminal environmental disaster in January 1969. Then, a Unocal rig blowout cracked the sea floor, spilling 3 million barrels of oil, the third-largest spill in U.S. history. To this day, beachgoers find tar on their feet from the still-seeping oil.

State forestry conservation crews, made up of inmates pictured here, clean up Santa Barbara's beaches on Feb. 6, 1969, after a gigantic oil spill. The accident inspired the Earth Day movement. (Wally Fong/AP)

The disaster gave rise to Earth Day, and much of the environmental expertise and activism that grew up around the movement is still based here. But Santa Barbara is often accused of caring more about how it looks than how it lives.

Several government-sanctioned architectural review boards make sure the city's breezy, Mediterranean aesthetic remains intact, supported by many staff members. But until recently, only one person was directly responsible for moving the city toward renewable energy sources.

The county conducts a full inventory of its greenhouse gas emissions only once every three years. And its Climate Action Plan imposes no mandatory regulations on businesses or individuals.

“There are no teeth in these plans. The rules are just words on paper,” said Tomás Morales Rebecchi, the senior Central Coast organizer for the nonprofit Food & Water Watch. “No one is there to enforce it.”

Williams, the county supervisor, once used the term “environmental poseurs” to describe the gap between Santa Barbara’s talk on the environment and its actions.

“We’re always willing to make changes that cost nothing, but never willing to take steps that really change things and that will cost something,” said Edward France, the former executive director of the Santa Barbara Bicycle Coalition.

There has been some progress. The city council recently voted to create a program that allows utility customers to select the source of their electricity. Residents will automatically receive 100 percent renewable power from desert solar panels, which can be more expensive, unless they choose not to participate.

But the oil industry still has clout. In 2014, it spent big to defeat a county referendum that would have banned “high-intensive” drilling operations such as fracking and steam injection. And county officials are actively considering a proposal to allow a major drilling expansion in the north, a move environmentalists say would directly contradict their climate goals.

“We’ve got this wave of new oil projects being proposed, but we also have a climate action plan,” said Linda Krop, chief counsel of the Environmental Defense Center, a local organization that emerged after the 1969 oil spill.

“You can’t responsibly approve one, and claim to be serious about the other.”

Drill horses line Route 33 in Ventura County. The region’s push for a greener economy has at times been complicated by the big-money legacy of oil, which is bountiful along the coast and offshore.

Fire in the valley

On a warm late-September evening, several dozen farmers and ranchers gathered inside the stuffy gymnasium of Los Olivos Elementary School to learn about one of the more peculiar aspects of living in a place that is warming faster than most anywhere in the country.

Eric Daniels, regional policy and external affairs director for Pacific Gas and Electric, the state’s largest utility, had been invited to explain a decision to begin cutting power to their homes in the hope of preventing wildfires caused by downed lines.

“My office has been inundated with questions about this,” Hartmann, the county supervisor, told the audience. “What is frustrating right now is that we need to protect our residents, but we do not have a say over these shutdowns.”

Daniels said PG&E would act only in times of extreme risk and would try to give people two-days’ notice before turning off electricity to their water pumps, refrigerated warehouses and homes.

“This will give you and your loved ones time to get your emergency kits ready,” he said.

Larry Saarloos, owner of Saarloos and Sons winery, spent hundreds of thousands of dollars on fire prevention measures around his vineyard, only to find after a power outage that they didn't work.

In the audience sat Larry Saarloos, a vintner who has spent more than $100,000 building his own Maginot Line against wildfire. Over the past three years, Saarloos installed two fire hydrants, new alarms and an advanced system of sprinklers and cisterns on his 100-acre ranch, a mix of horses, cattle and grapes that his family turns into well-regarded syrah and cabernet sauvignon.

The price seemed a small one to pay as fall approached. One dry, breezy day in early September, two fires sparked nearby, their pillars of smoke bracketing his home. He turned to his wife, Linda, and assured her that all would be fine when he turned on the sprinklers to wet the place down.

But when he flipped the switch, nothing happened. The power had been cut by an equipment failure.

Mark Mesesan, a PG&E spokesman, said smoke and airborne debris had caused an electrical fault. "This is an area where we're working to improve," he said via email.

To Saarloos, the experience was an unpleasant introduction to a confusing new world.

“Everything I just told you I did, the steps I took, meant absolutely nothing to the protection of my home when the fire came,” he said. “I might as well not have spent any money at all.”

Those who followed had questions, unanswerable now. Would PG&E, now bankrupt with billions of dollars in fire-related liability costs, reimburse them for lost produce? Would the state offer tax breaks for generator purchases? Or would they simply be left in the dark when the fires came?

“We’ve got a lot of folks working on those things right now,” said Matthew Pontes, the assistant county executive officer of Santa Barbara. “I hope we have some better answers for you soon.”

The Getty Fire in Los Angeles burned a dozen homes in late October, ahead of Halloween, this one on a ridgeline near Brentwood.

Chris Mooney contributed to this report.

METHODOLOGY

To analyze warming temperatures in the United States, The Washington Post used the National Oceanic and Atmospheric Administration's Climate Divisional Database (nClimDiv), which provides monthly temperature data at the national, state and county level between 1895 and 2018 for the Lower 48 states. NOAA does not provide this data for Hawaii, and its data for Alaska begins in 1925.

We calculated annual mean temperature trends in each state and county in the Lower 48 states using linear regression — analyzing both annual average temperatures and temperatures for the three-month winter season (December, January and February). While not the only approach for analyzing temperature changes over time, this is a widely used method.

Annual temperature averages in the interactive county feature are displayed as departures from the 1895-2018 average temperature for each county. These departures from the average are referred to as "temperature anomalies" by climate scientists.

To make the maps, we applied the same linear regression method for annual average temperatures to NOAA's Gridded 5km GHCN-Daily Temperature and Precipitation Dataset (nClimGrid), which is the basis for nClimDiv. For mapping purposes, the resolution of the data was increased using bilinear interpolation.

The nClimDiv and nClimGrid datasets were accessed June 10 and July 22 respectively.

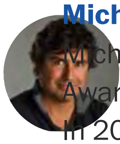
Fire perimeters for 2019 from USGS GeoMAC Wildland Fire Support were accessed Nov. 15. Fire perimeters for past years are from the California Department of Forestry and Fire Protection.

Credits

Project by Trish Wilson. Editing by Lori Montgomery. Design and development by Madison Walls and Irfan Uraizee. Graphics editing by Monica Ulmanu. Photo editing by Olivier Laurent. Copy editing by Whitney Juckno.

Scott Wilson

Scott Wilson is a senior national correspondent for The Washington Post, covering California and the West. He has previously served as The Post's national editor, chief White House correspondent, deputy assistant managing editor for foreign news, and as a correspondent in Latin America and in the Middle East.



Michael Robinson Chavez

Michael Robinson Chavez, a staff photographer, recently won a Robert F. Kennedy Award for his coverage of social problems created by the drug trade plaguing Mexico. In 2018 he covered the rise of autocracy in Eastern Europe.

John Muyskens

John Muyskens is a graphics editor at the Washington Post specializing in data reporting.

321 Comments

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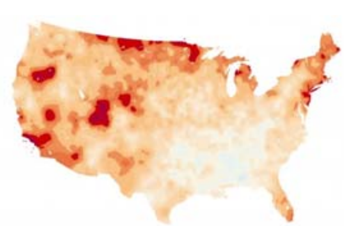
Extreme climate change in the United States: Here are America's fastest-warming places



More than a century of temperature data shows much of the U.S. Northeast is in the grip of extreme warming, with winter heating up more quickly than other seasons.

2°C: BEYOND THE LIMIT

°C ⟷ °F

In California, a hotter and drier environment has spurred bigger and faster-moving infernos

Amid the ashes of one of the state's worst fire seasons on record, father and son firefighters describe how significantly their work has changed.

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EXHIBIT 2

Assembly Bill No. 74

CHAPTER 23

An act making appropriations for the support of the government of the State of California and for several public purposes in accordance with the provisions of Section 12 of Article IV of the Constitution of the State of California, relating to the state budget, to take effect immediately, budget bill.

[Approved by Governor June 27, 2019. Filed with Secretary of State June 27, 2019.]

I object to the following appropriations contained in Assembly Bill 74.

Item 0250-301-0001—For capital outlay, Judicial Branch. I delete this item.

I am eliminating the $2,800,000 appropriation for the El Dorado County Courthouse. While I understand that there is a need to build this new courthouse, this expenditure authority is premature until the Judicial Council completes the statutorily-required statewide facilities needs assessment.

Item 0521-101-0001—For local assistance, Secretary of Transportation. I sustain this item.

Chapter 934, Statutes of 2018, requires the Transportation Agency, in consultation with the Natural Resources Agency, to conduct an assessment of the North Coast Railroad Authority to determine what is needed to dissolve the authority and dispense with its assets and liabilities, and to report on the assessment to the Legislature before July 1, 2020. I am sustaining the $8,800,000 for expenses related to dissolving the North Coast Railroad Authority; however, these funds will not be released until the required assessment of assets and liabilities is completed. The Administration is committed to the dissolution of the North Coast Railroad Authority.

Item 0650-491—Reappropriation, Office of Planning and Research. I revise this item by deleting Provision 1.

This veto is technical in nature and deletes Provision 1 to conform to the Legislature's intent.

Item 7320-001-0001—For support of Public Employment Relations Board. I revise this item from $17,251,000 to $14,751,000 by reducing:

(1) 6070-Public Employment Relations Board from $17,371,000 to $14,871,000; and by deleting Provision 1.

I am deleting the $2,500,000 legislative augmentation, which would provide additional resources to the Public Employment Relations Board. The expenditure authority is premature. A recent mission-based review of the Board resulted in adding 18 positions and $4,300,000. My Administration will continue to monitor and review workload and backlogs and propose any needed changes.

I am also deleting Provision 1 to conform to this action.

With the above deletions, revisions, and reductions, I hereby approve Assembly Bill 74.

GAVIN NEWSOM, Governor

Item		Amount
Schedule:		
(1) 0340-Support	1,354,000	
0555-001-0193—For support of Secretary for Environmental Protection, payable from the Waste Discharge Permit Fund		627,000
Schedule:		
(1) 0340-Support	627,000	
0555-001-0226—For support of Secretary for Environmental Protection, payable from the California Tire Recycling Management Fund		133,000
Schedule:		
(1) 0340-Support	133,000	
0555-001-0235—For support of Secretary for Environmental Protection, payable from the Public Resources Account, Cigarette and Tobacco Products Surtax Fund		96,000
Schedule:		
(1) 0340-Support	96,000	
0555-001-0387—For support of Secretary for Environmental Protection, payable from the Integrated Waste Management Account, Integrated Waste Management Fund		279,000
Schedule:		
(1) 0340-Support	279,000	
0555-001-0439—For support of Secretary for Environmental Protection, payable from the Underground Storage Tank Cleanup Fund		1,377,000
Schedule:		
(1) 0340-Support	1,377,000	
0555-001-0679—For support of Secretary for Environmental Protection, payable from the State Water Quality Control Fund		201,000
Schedule:		
(1) 0340-Support	201,000	
0555-001-0890—For support of Secretary for Environmental Protection, payable from the Federal Trust Fund		300,000
Schedule:		
(1) 0340-Support	300,000	
0555-001-3058—For support of Secretary for Environmental Protection, payable from the Water Rights Fund		37,000
Schedule:		
(1) 0340-Support	37,000	
0555-001-3228—For support of Secretary for Environmental Protection, payable from the Greenhouse Gas Reduction Fund		3,000,000

Item Amount

Schedule:

(1) 0340-Support................................ 3,000,000

Provisions:

1. Of the funds appropriated in this item, $1,500,000 shall be available for a study to identify strategies to significantly reduce emissions from vehicles and to achieve carbon neutrality in the sector, including the transition to zero-emission light-duty vehicles, in particular, passenger vehicles, the transition to zero-emission heavy vehicles, and the adoption of other technology to significantly reduce emissions from heavy vehicles; the role of alternative fuels; and the impact of land use policy. The study shall include, but not be limited to, strategies for reducing vehicle miles traveled, including increasing transit ridership. The Secretary for Environmental Protection shall consult with the State Air Resources Board, Energy Resources Conservation and Development Commission, the Transportation Agency, the Office of Planning and Research, and the Governor's Office of Business and Economic Development on the study.
2. Of the funds appropriated in this item, $1,500,000 shall be available for a study to identify strategies to decrease demand and supply of fossil fuels, while managing the decline of fossil fuel use in a way that is economically responsible and sustainable. The Secretary for Environmental Protection shall contract with the University of California system to produce this study. An interagency state team led by the California Environmental Protection Agency shall further develop the scope of the study in order to evaluate pathways to achieve a carbon neutral economy by 2045, manage the decline of in-state production as the state's fossil fuel demand decreases, and assess potential impacts to disadvantaged and low-income communities and strategies to address those impacts. The Secretary for Environmental Protection shall consult with the Natural Resources Agency, the Transportation Agency, the Labor and Workforce Development Agency, and the Office of Planning and Research on the study.

EXHIBIT 3

Study 1 Draft Scope of Work

CalEPA Contract with Regents of the University of California; Institute of Transportation Studies

Draft 12/18/19

Purpose: Governor Newsom affirmed the state's goal of achieving carbon neutrality by 2045 in the 2019 Budget Act. To achieve our carbon neutrality goal, the state will need to reduce dramatically our greenhouse gas emissions while permanently removing carbon from the atmosphere. These efforts will include: managing strategic statewide reductions in fossil fuel demand and supply; electrifying key sectors and end uses; and making significant investments in transitioning the transportation sector and the electrical grid to zero carbon emissions. These shifts will need to take place alongside targeted investments in communities and in the state's workforce to ensure that this transition maximizes equity, resiliency, health, and environmental quality across the state.

The transportation sector is an especially important priority for the state. When including fossil fuel extraction and refining, the transportation sector accounts for half of California's greenhouse gas emissions. Additionally, California's transportation sector relies primarily on petroleum fuels, significant amounts of which are produced and sourced from within the state.

Through the 2019 Budget Act, the Newsom Administration funded two studies to identify strategies to reduce the demand for and supply of fossil fuels, with the goal of dramatically reducing emissions across the transportation sector. The purpose of this agreement is to produce one of two comprehensive, integrated studies that identify paths to significantly reduce transportation-related fossil fuel demand and emissions, and, in parallel, manage a strategic, responsible decline in transportation-related fossil fuel supply. This agreement's study will focus on managing the decline in demand.

The two integrated studies will share common guiding principles and will incorporate common workforce and affordability considerations. The studies will also share aligned scenarios and strategies that the state, local governments and others may consider and implement to support achieving the state's carbon neutrality goal. To the extent possible and relevant to the unique characteristics of the state's local and regional economies, the studies shall also draw upon lessons learned from other models of economic and social transitions.

The guiding principles underlying each of the two studies are:

a. <u>Equity.</u> Equitably distribute all benefits associated with achieving carbon neutrality. Achieve environmental justice and shared prosperity in the context of a changing climate.

b. Health. Improve and protect public health. Prioritize health, safety, and opportunity for the state's most vulnerable and disadvantaged residents, and for communities disproportionately burdened by pollution.
c. Environment. Improve and protect environmental quality across the state.
d. Resilience and Adaptation. Develop resilience and adaptive capacity locally, across the state.
e. High Road Jobs. Foster sustainable and diversified local and regional economies, and prioritize the creation of accessible high quality jobs for all communities, particularly the state's most vulnerable and disadvantaged residents and resource-dependent communities.
f. Affordability and Access. Deliver affordable, accessible, and reliable non-fossil fuel options and technologies.
g. Minimize Impacts Beyond Our Borders. Minimize emissions leakage and external costs beyond the state's borders, to the maximum extent possible.

CalEPA and its interagency partners will facilitate shared and equal access to decision making and related processes during the development of the studies.

Study 1 Reducing Transportation-Related Fossil Fuel Demand and Emissions

For purposes of the two studies, carbon neutrality means achieving a balance between sources and sinks of greenhouse gas (GHG) emissions. The focus of the studies will be to evaluate how to both reduce emissions from fossil energy and industrial sources and how to increase sinks.

This study shall be coordinated and integrated with the other study referred to above, here called "Study 2," and shall not duplicate the work of Study 2. Study 2 will focus on strategies to manage the decline in transportation-related fossil fuel supply and will be led by researchers at the University of California, Santa Barbara ("UCSB Team").

The two studies will coordinate the development of potential transportation-related GHG emissions trajectories in California and will develop a common set of scenarios that reduce transportation-related fossil fuel demand, and, in parallel, manage the decline in transportation-related fossil fuel supply.

Focus Areas: The contractor shall expend a majority of its time and effort in investigating these Focus Areas as elements of a roadmap to achieve carbon neutrality by 2045:

1. **Evaluate market characteristics of the transportation sector and policies already underway and/or under consideration** for California, including:
    a. Current market characteristics and trends: global, regional and local trends in prices for and access to zero-emission vehicles between now and 2045; global trends in battery capacity/electric vehicle range; current number and percentage of zero-emission vehicles in light, medium and heavy duty fleets; length of time of ownership of internal combustion

engine vehicles; sales data from primary and secondary markets, to the extent possible; number of and geographic need for electric vehicle charging stations, hydrogen fueling stations, and gasoline stations; gasoline and electric prices; observed current and potential future barriers to access to and the selection of zero emission vehicles; factors driving changes in travel behavior; and factors affecting vehicle and ride sharing and public transit ridership options and cost

   b. <u>Current employment characteristics and trends:</u> existing jobs in terms of (1) number (by occupation and industry); (2) quality (e.g., wages, benefits, autonomy, voice); and (3) access (e.g., demography, geography, educational status, and educational or career pathways) across the transportation sector.
   c. <u>Current relevant policies</u>: fuel standards; vehicle mandates and incentive programs, vehicle trade-in and rebate policies; incentives for developing refueling infrastructure for alternative fuels (electricity and hydrogen); purchasing and finance criteria; transportation network company regulations; land use policies; active and public transportation policies
2. **Scenarios for reducing transportation-related fossil fuel demand and emissions** that include all the strategies listed in sections 3 through 6. Analysis should include:
   a. Indicative milestones or targets, e.g., for fleet composition, transit ridership, and other influential indicators; where possible, these should be benchmarked against existing policies and goals
   b. Reductions in transportation fuel demand corresponding with milestones and targets outlined above
   c. Changes in travel demand and behavior due to changes in housing costs, supply and location; land use; transportation infrastructure; emergence of new mobility options; and other changes in society, technology and policy
   d. Assessments of the health, social, environmental and economic benefits associated with a dramatic reduction in vehicle emissions across state, regional and local geographies, and with an overall reduction in vehicle miles traveled
   e. Assessment of transportation access and needs, particularly for vulnerable communities and mobility disadvantaged travelers
   f. Where possible, scenarios will include the net effect of combinations of levels of ambition in each strategy (i.e., different pathways to achieve zero or very low emissions)
3. Strategies to **accelerate the adoption of light-duty zero-emission vehicles (ZEVs)**, including:
   a. The role of purchase incentives and mandates for new and used ZEVs (e.g., applicability or eligibility; amount; timing, duration, and quantity)
   b. Greenhouse gas emission performance standards and feebate policies
   c. Incentives for dealers and automakers to expand availability of ZEVs
   d. Market development, model availability and range

    e. Expanded charging (and hydrogen fueling) infrastructure and impacts on existing infrastructure, including electric and fossil fuel supply infrastructure
    f. Strategies to transition existing light-duty fleets with a focus on those owned and used by low-income residents and the workforce
4. Strategies to **reduce vehicle miles traveled**, including:
    a. Strategies available to state and local governments to improve housing availability and affordability, and to focus economic activity near existing housing
    b. Strategies to develop land-use policies and provide transportation alternatives
    c. Strategies to increase public transit ridership
    d. Strategies to increase active transportation, e.g., walking and bicycling
    e. Strategies that consider the role of technologies including connected and automated vehicles, shared mobility, and micromobility services
    f. Strategies that consider roadway and vehicle pricing mechanisms
    g. Strategies that encourage ride sharing and vehicle sharing (greater load factors)
5. Strategies to **accelerate use of alternative fuel sources and similar technologies** for light-, medium-, and heavy-duty vehicles and other modes of transportation (e.g., aviation, rail and marine)
6. Strategies to **accelerate the transition to zero-emission medium- and heavy-duty vehicles (including off-road vehicles regulated by the state) and related freight infrastructure** (e.g., railyards, shipyards, ports and distribution and logistics centers)
7. Strategies to **increase economic opportunity, high quality job creation, and integrated skill delivery**, including:
    a. How the above scenarios (e.g., VMT reduction, ZEV adoption, alternative fuels scenarios, and new mobility and automation in transportation) will affect employment in industries including logistics, port operations, manufacturing, construction, operations and maintenance.
    b. The role quality transportation will play in providing access to jobs and supporting other careers.
    c. What projected labor market indicators (e.g., job numbers, quality, and access) for each milestone in the transitions identified above will tell us about the research and/or policies necessary to advance economic opportunity for all Californians, especially those in disadvantaged, low income and vulnerable communities.

EXHIBIT 4

Study 2 Draft Scope of Work

CalEPA Contract with the University of California, Santa Barbara

Draft 12/18/19

Purpose: Governor Newsom affirmed the state's goal of achieving carbon neutrality by 2045 in the 2019 Budget Act. To achieve our goal, the state will need to reduce dramatically our greenhouse gas emissions while permanently removing carbon from the atmosphere. These efforts will include managing strategic statewide reductions in fossil fuel demand and supply; electrifying key sectors and end uses; and making significant investments in transitioning the transportation sector and the electrical grid to zero carbon emissions. These shifts will need to take place alongside targeted investments in communities and in the state's workforce to ensure that this transition maximizes equity, resiliency, health, and environmental quality across the state.

The transportation sector is an especially important priority for the state. When including fossil fuel extraction and refining, the transportation sector accounts for half of California's greenhouse gas emissions. Additionally, California's transportation sector relies primarily on petroleum fuels, significant amounts of which are produced and sourced from within the state.

Through the 2019 Budget Act, the Newsom Administration funded two studies to identify strategies to reduce the demand for and supply of fossil fuels, with the goal of dramatically reducing emissions across the transportation sector. The purpose of this agreement is to produce one of two comprehensive, integrated studies that identify paths to significantly reduce transportation-related fossil fuel demand and emissions, and, in parallel, manage a strategic, responsible decline in transportation-related fossil fuel supply. This agreement's study will focus on managing the decline in supply.

The two integrated studies will share common guiding principles and will incorporate common workforce and affordability considerations. The studies will also share aligned scenarios and strategies that the state, local governments and others may consider and implement to support achieving the state's carbon neutrality goal. To the extent possible and relevant to the unique characteristics of the state's local and regional economies, the studies shall also draw upon lessons learned from other models of economic and social transitions.

The guiding principles underlying each of the two studies are:

a. Equity. Equitably distribute all benefits associated with achieving carbon neutrality. Achieve environmental justice and shared prosperity in the context of a changing climate.

b. Health. Improve and protect public health. Prioritize health, safety, and opportunity for the state's most vulnerable and disadvantaged residents, and for communities disproportionately burdened by pollution.
c. Environment. Improve and protect environmental quality across the state.
d. Resilience and Adaptation. Develop resilience and adaptive capacity locally, across the state.
e. High Road Jobs. Foster sustainable and diversified local and regional economies, and prioritize the creation of accessible high quality jobs for all communities, particularly the state's most vulnerable and disadvantaged residents and resource-dependent communities.
f. Affordability and Access. Deliver affordable, accessible, and reliable non-fossil fuel options and technologies.
g. Minimize Impacts Beyond our Borders. Minimize emissions leakage and external costs beyond the state's borders, to the maximum extent possible.

CalEPA and its interagency partners will facilitate shared and equal access to decision making and related processes during the development of the studies.

Study 2

Supply of Transportation Fuels

For purposes of the two studies, carbon neutrality means achieving a balance between sources and sinks of greenhouse gas (GHG) emissions. The focus of the studies will be to evaluate how to both reduce emissions from fossil energy and industrial sources and how to increase sinks.

This study shall be coordinated and integrated with the other study referred to above, here called "Study 1," and shall not duplicate the work of Study 1. Study 1 will focus on strategies to reduce transportation-related fossil fuel demand and emissions and will be led by researchers at the University of California Institute of Transportation Studies ("ITS Team").

The two studies will coordinate the development of potential transportation-related GHG emissions trajectories in California and will develop a common set of scenarios that reduce transportation-related fossil fuel demand, and, in parallel, manage the decline in transportation-related fossil fuel supply.

Focus Areas: The contractor shall expend a majority of its time and effort in investigating these Focus Areas as elements of a roadmap to achieve carbon neutrality by 2045:

1. **Evaluate key characteristics, trends and policies already underway and/or under consideration for California**, including:

   a. Current emissions characteristics: overall emissions (e.g., GHG, criteria air pollutants and other toxic contaminants) associated with transportation-related fossil fuel (“transportation fuels”) production (which includes extraction, refining and distribution) and GHG sinks associated with transportation fuels, e.g., carbon, capture and storage (CCS).

b. Current market characteristics and trends: global prices and carbon footprint of transportation fuels; projected prices and supply of transportation fuels; fleet-specific transportation fuel use in California; percentage of imported transportation fuels refined in California; percentage of transportation fuel supply produced in state; and comparative carbon content from different transportation fuel sources used in California.

c. Current employment characteristics and trends: existing jobs in terms of (1) number (by occupation and industry); (2) quality (e.g., wages, benefits, autonomy, voice); and (3) access (e.g., demography, geography, educational status, and educational or career pathways) across transportation fuel production (i.e., extraction, refining and distribution).

d. Current distributional characteristics and trends: (1) distribution and geographic concentration of exposures to and health burdens and vulnerabilities associated with local pollution (e.g., from GHG emissions, criteria air pollutants and other toxic contaminants) and other health and safety risks; and (2) distribution of transportation fuel costs across the state.

e. Current relevant policies: (1) policies and strategies that impact the supply of transportation fuels, including those that manage the decline in supply and those that incentivize production (e.g., tax subsidies); (2) workforce policies; (3) local pollution reduction policies; (4) land use policies; (5) permitting criteria and issuance thresholds for transportation fuel production and use permits; and (6) policies that support low-income workers and residents.

2. **Identify scenarios to manage the decline of the state’s transportation fuel supply in conjunction with the fuel demand reduction** outlined in Study 1. Across these scenarios the study will identify and evaluate:

   a. Reductions in transportation fuel supply (1) for all transportation-related uses and (2) from all sources.

   b. Health and safety benefits across state, regional and local geographies including changes in location, magnitude and concentration of supply-related activities and local pollutants, among others.

   c. Economic impacts and opportunities across state, regional and local economies, including changes in fuel costs across locations, and changes to and impacts on state and local tax revenues, among others.

d. Environmental benefits across state, regional and local geographies associated with reductions in supply, including improved air and water quality, among others.

e. Changes in GHG sinks related to transportation fuel production.

f. Workforce impacts, challenges and opportunities, including those associated with market transitions and economic development, and those represented by changes in job numbers, quality and access, and changes in career pathways, across local and regional economies. Include a focus on:
    i. Support for an inclusive, high-road transition (i.e., one attentive to job quality and access that addresses the interests of workers and community).
    ii. Development or expansion of state, industry and/or regional partnerships;
    iii. Identification of potential sector-specific and cross-sector approaches;
    iv. Creation and provision of social and economic safety nets; and,
    v. Facilitation of industry transition planning.

g. Policies and strategies that maximize benefits and opportunities, and manage impacts, to communities that bear the greatest emissions burdens associated with transportation fuel production and communities that are resource-dependent, including: (1) local pollution reduction policies; (2) land use policies; (3) permitting criteria and issuance thresholds for all oil and gas production and use permits; (4) policies that support and advance economic opportunities for low-income workers and residents, and (5) policies to limit social dislocation; among others.

EXHIBIT 5

PR03

2017 Report of California Oil and Gas Production Statistics

* Figures in this report are estimates based on available production data.

Department of Conservation

Division of Oil, Gas, & Geothermal Resources

STATE OF CALIFORNIA
EDMUND G. BROWN JR., *Governor*

NATURAL RESOURCES AGENCY
JOHN LAIRD, *Secretary*

DEPARTMENT OF CONSERVATION
DAVID BUNN, *Director*

2017 ANNUAL REPORT OF CALIFORNIA OIL AND GAS PRODUCTION STATISTICS

DIVISION OF OIL, GAS, AND GEOTHERMAL RESOURCES
Kenneth A. Harris, Jr., *State Oil and Gas Supervisor*

SACRAMENTO
SEPTEMBER 2018

CALIFORNIA 2017 OIL AND GAS PRODUCTION

OIL PRODUCTION

Production

California's oil production for 2017 was 174.0 MMbl, a decrease of approximately 6.8 percent from 2016. California onshore production decreased approximately 6.7 percent from 2016 and offshore decreased approximately 7.8 percent from 2016.

As of January 1, 2011, this report will not show any Federal OCS production.
Federal OCS production data may be found at **https://www.data.boem.gov/homepg/data_center/production/PacificFreeProd.asp**

State Oil Production (MMbbl per year)
Without Federal OCS Production

Year	2017	2016	2015	2014	2013
State Onshore	163.4	175.2	188.7	191.2	185.5
State Offshore	10.6	11.5	13.0	14.2	14.2
Total	174.0	186.7	201.7	205.4	199.7

Oil Production from the Largest Fields (MMbbl per year)
Without Federal OCS Production

Field Name	2017	2016	2015	2014	2013
Midway-Sunset	22.1	24.7	28.2	29.3	28.8
Kern River	21.9	24.3	25.7	25.3	25.7
Belridge, South	21.2	22.6	22.9	23.6	23.5
Cymric	16.2	16.9	16.5	15.7	14.5
Wilmington	11.6	12.6	9.7	10.0	9.8
Lost Hills	9.5	10.3	11.2	11.2	10.8
Elk Hills	9.1	10.1	11.3	12.0	12.8
San Ardo	7.2	7.9	7.8	7.7	7.2
Coalinga	6.6	6.4	6.8	6.1	5.5
Poso Creek	4.4	4.2	4.0	3.6	2.8

Figure 1 graphically depicts the relative oil production among the top 10 largest producing fields in the table above.

Price

The posted price for Midway-Sunset 13 degree API gravity crude oil averaged \$48.19. The year started at \$47.17 per barrel and ended at \$59.24. The high for 2017 was the year-end price of \$59.24. The low for the year was \$41.01 in June.

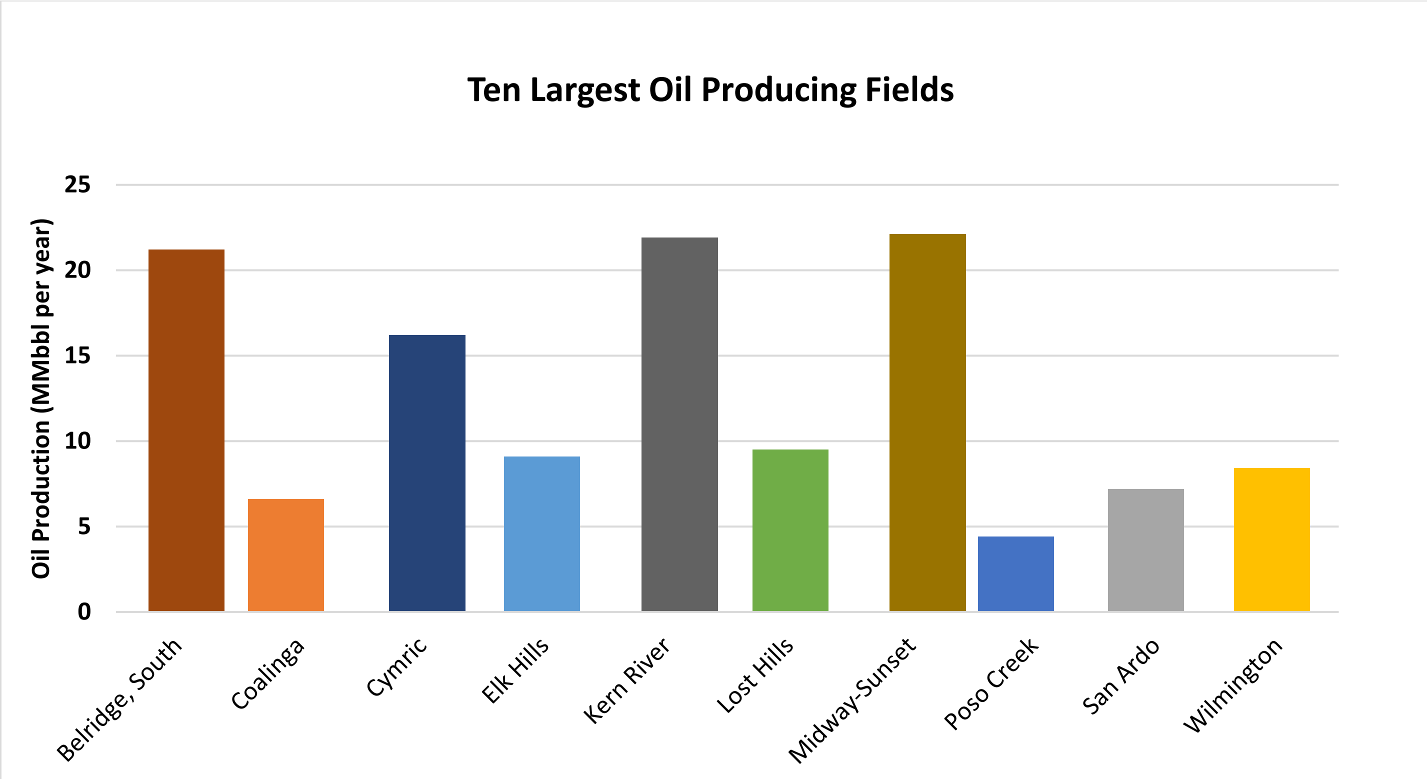


Figure 1. Ten largest producing oil fields in California in 2017.

GAS PRODUCTION

Production

California's net gas production (associated and non-associated) for 2017 was 162.7 Bcf, an increase of 3.6 percent from the 2016 figure of 157.3 Bcf. The associated gas production increased about 7.7 Bcf, and the non-associated gas production decreased about 2.3 Bcf.

State Net Gas Production (Bcf per year)
Without Federal OCS Production

Year	2017	2016	2015	2014	2013
Total Associated	142.4	134.7	154.8	151.9	175.4
Total Non-Associated	20.3	22.6	28.0	35.0	41.4
Total	162.7	157.3	182.8	186.9	216.7*

State Net Gas Production (Bcf per year)
Without Federal OCS Production

Year	2017	2016	2015	2014	2013
Total Onshore	158.7	152.9	178.0	181.2	211.4
Total Offshore	4.0	4.4	5.0	5.7	5.3
Total	162.7	157.3	182.8*	186.9	216.7

Net Associated Gas Production from the Largest Fields (Bcf per year)

Without Federal OCS Production

Field Name	Net Gas Production
Elk Hills	56.2
Buena Vista	13.3
Kern River	10.3
Belridge, South	8.1
Vallecitos	6.7
Midway-Sunset	4.5
Lost Hills	4.5
Asphalto	4.0
Wilmington	3.7
Cymric	2.8

Figure 2 graphically depicts the relative associated gas production among the top 10 largest producing fields in the table above.

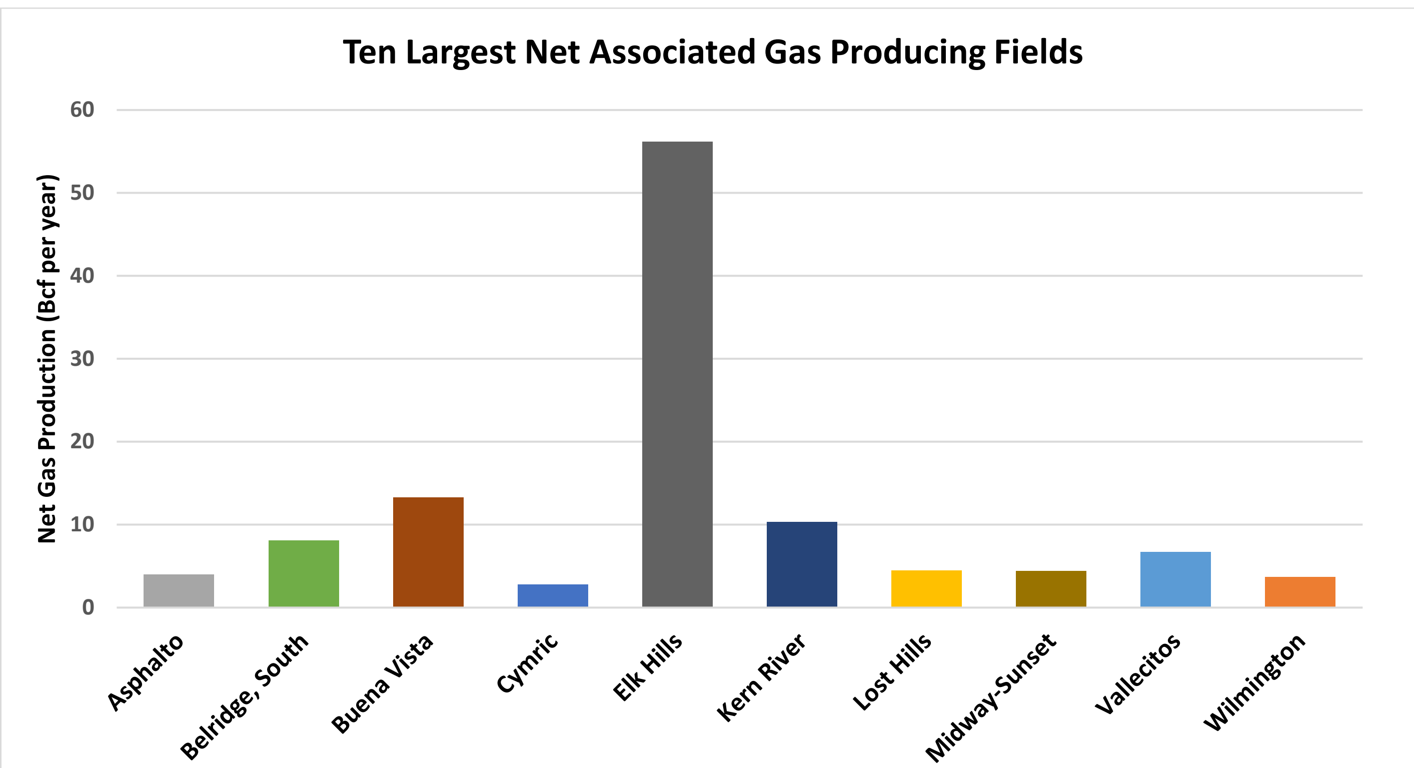


Figure 2. Ten largest fields net associated gas production in 2017.

Net Non-Associated Gas Production from the Largest Fields (Bcf per year)

Without Federal OCS Production

Field Name	Net Gas Production
Rio Vista Gas	4.8
Willows-Beehive Bend Gas	2.9
Grimes Gas	2.8
Sutter Buttes Gas	1.6
Sycamore Gas	0.6
French Camp Gas	0.5
Malton-Black Butte Gas	0.5
Grimes, West, Gas	0.4
Tompkins Hill Gas	0.4
Union Island Gas	0.4

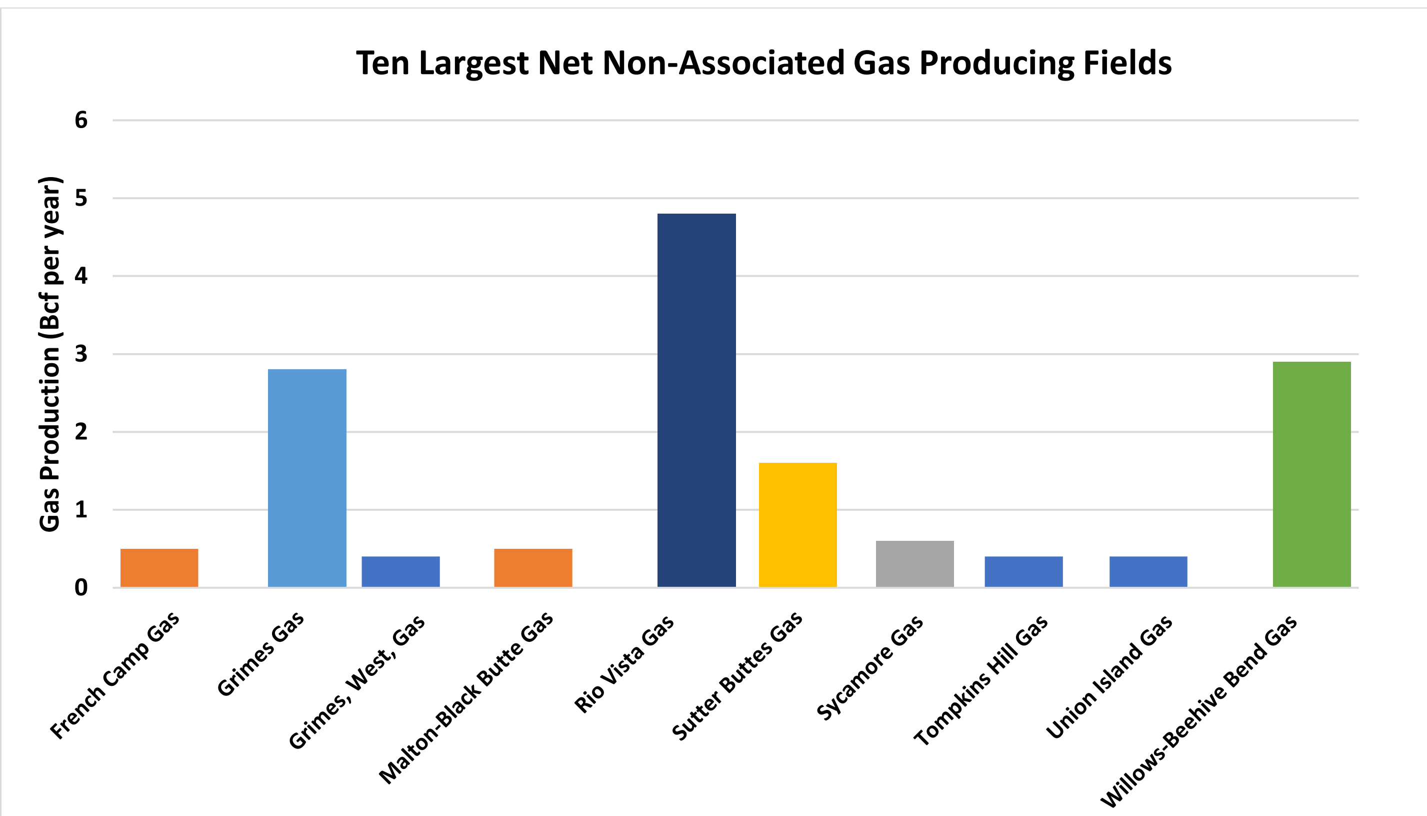


Figure 3. Ten largest fields net non-associated gas production in 2017.

Gas Storage

Gas withdrawn from underground gas storage facilities during 2017 totaled 156.0 Bcf, while gas injected was 152.9 Bcf, yielding a net decrease in storage of 3.1 Bcf.

Price

According to the U.S. Energy Information Administration, the average Natural Gas Citygate Price in California for 2017 was $3.37 per Mcf. The January 2017 price of $3.87 represented the high for the year with $2.95 in October being the lowest.

NOTE ON CONFIDENTIAL PRODUCTION:
Individual confidential well production is not available on Well Search (https://secure.conservation.ca.gov/WellSearch). However, confidential production data is included in Pool, Area, and Field totals of this report. It is also included in District, County, Statewide, and Operator totals.

California Oil Production

Figure 4 depicts California oil production over time (including Federal OCS production).

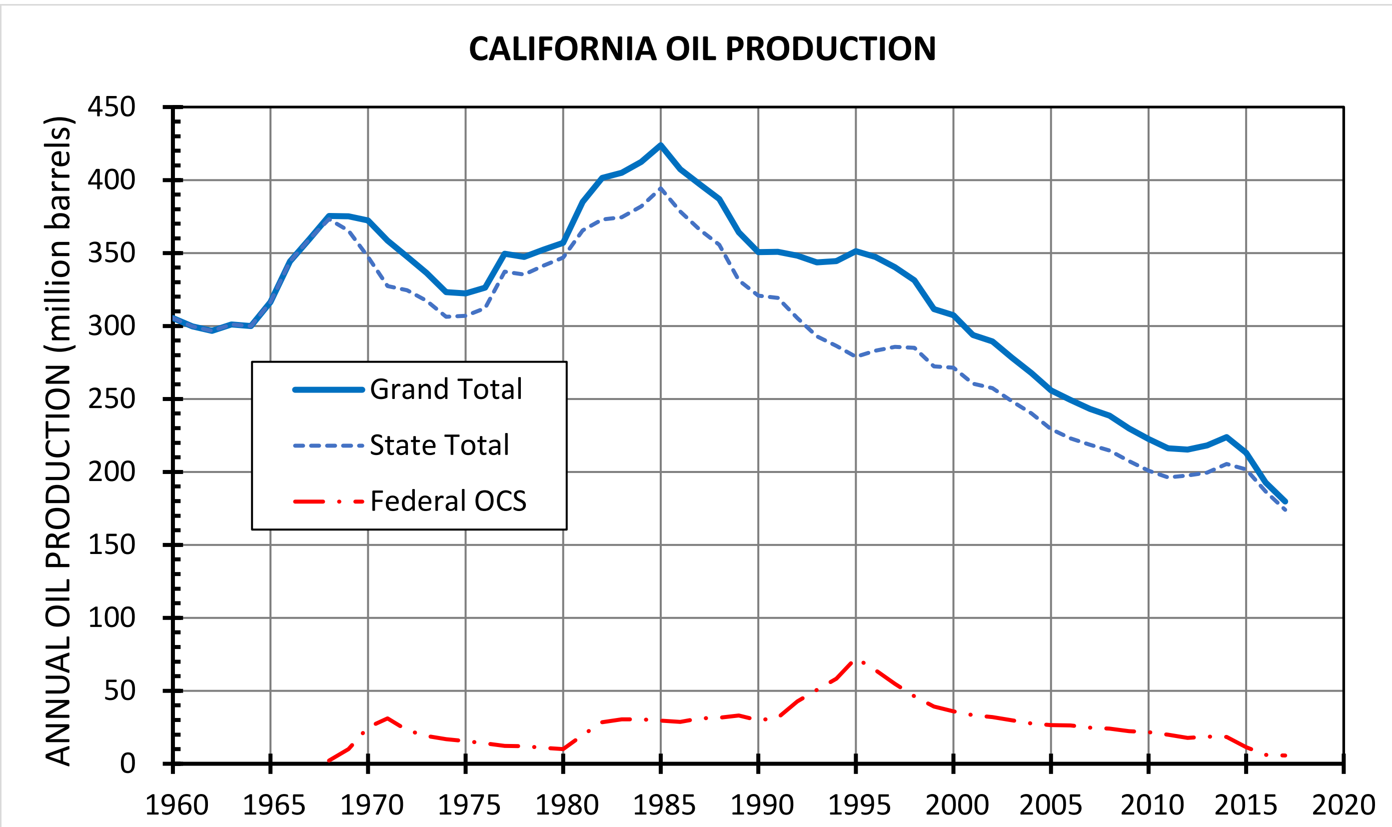


Figure 4. California oil production.

California Gas Production

Figure 5 depicts California total gas production (associated and non-associated) over time (including Federal OCS production).

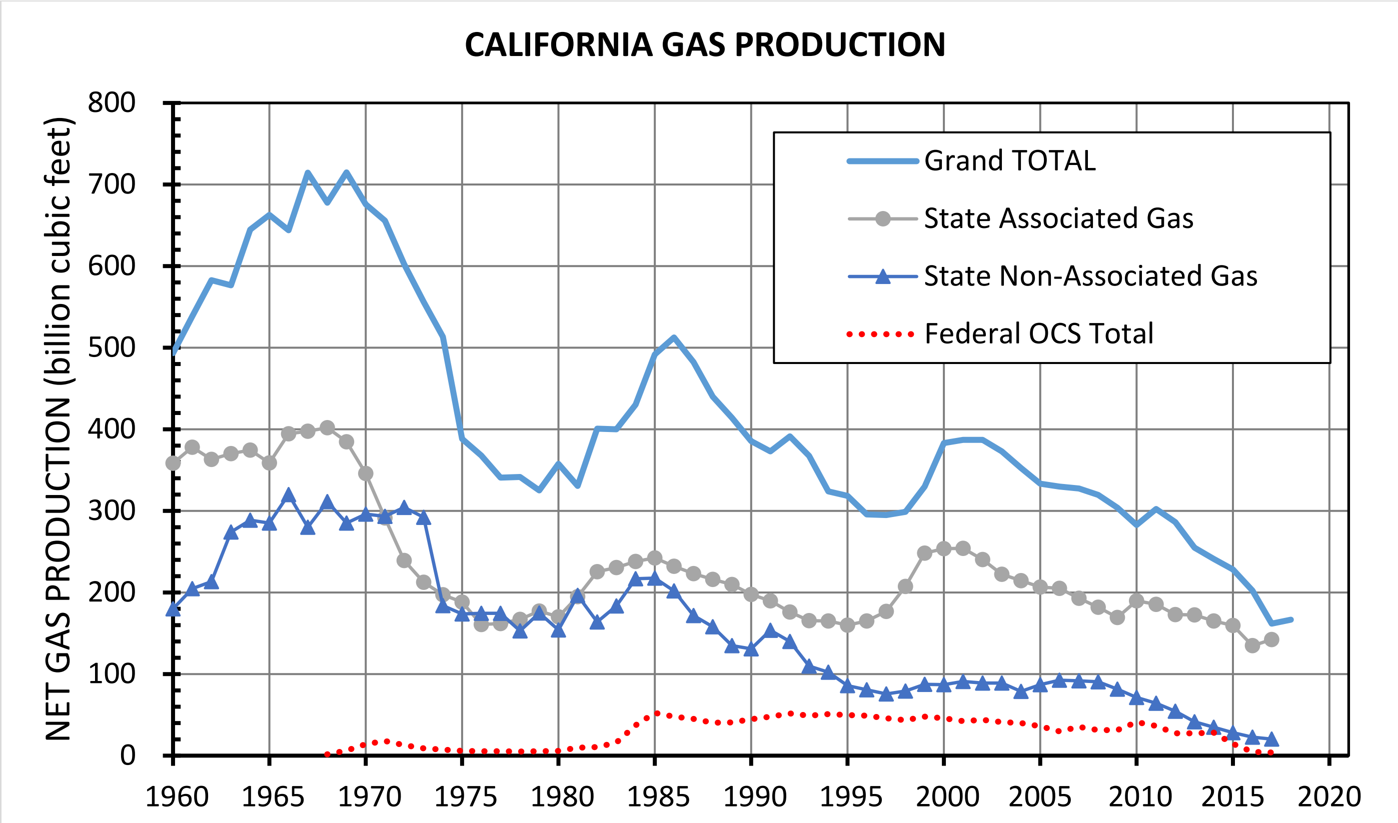
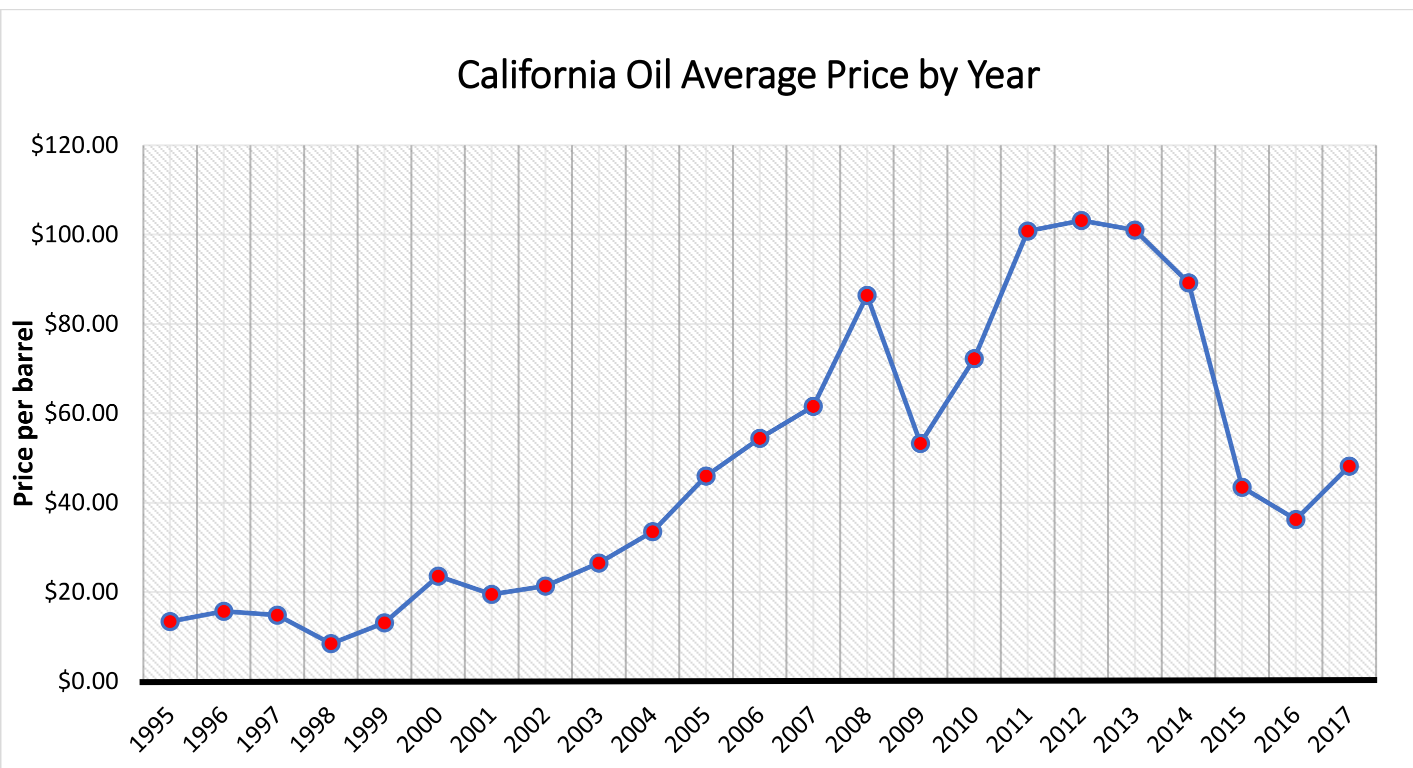
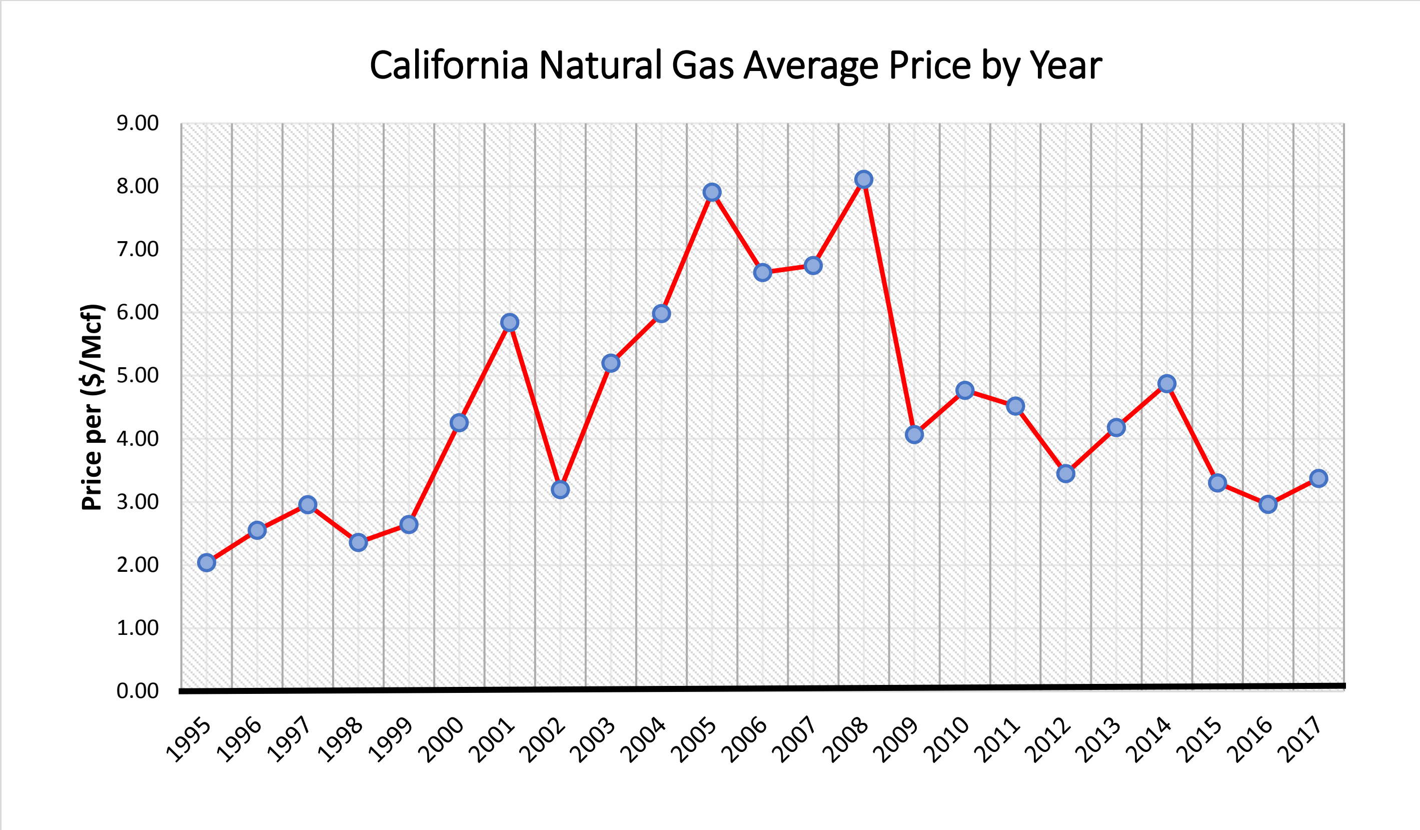


Figure 5. California total gas production.





CALIFORNIA 2017 INJECTION

Injection

The table below lists the injection volumes for 2017. Water flood, water disposal, steam flood, and cyclic steam operations all decreased from 2016 to 2017, while gas injection increased from 2016 to 2017. There has been no recorded air injection over the past five years.

Injection Rate (MMbbl or Bcf* per year)

Without Federal OCS Injection

Year	2017	2016	2015	2014	2013
Water Flood	1,619.6	1,636.2	1,571.2	1,458.7	1,418.6
Water Disposal	694.3	734.7	919.8	909.2	837.1
Steam Flood	395.9	414.1	448.8	430.1	376.2
Cyclic-Steam	133.2	149.4	193.2	184.8	168.1
Gas Injection*	152.9	112.4	197.3	273.4	178.5
Air Injection*	0	0	0	0	0

OIL, ASSOCIATED GAS AND WATER PRODUCTION BY DISTRICT AND FIELD

Oil produced as condensate from dry gas wells is not included in the totals in the table below.

District 1 Field Name	Oil Produced (bbl)	Net Gas Production (Mcf)	Water Produced (bbl)
Any Field	0	0	0
Bandini	6,040	0	19,984
Belmont Offshore	494,100	257,462	9,798,167
Beverly Hills	462,641	568,267	6,501,623
Brea-Olinda	986,856	805,663	6,376,074
Cheviot Hills	40,830	41,186	125,232
Chino-Soquel	540	0	0
Coyote, East	210,781	67,421	4,765,957
Dominguez	28,000	40,529	52,778
El Segundo	24,009	4,877	354,683
Esperanza	4,847	771	1,665
Howard Townsite	6,829	17,101	1,368
Huntington Beach	1,589,545	484,151	64,832,982
Huntington Beach	425,227	78,427	9,465,821
Hyperion	10,331	0	1,517
Inglewood	2,032,002	915,970	123,204,570
Las Cienegas	200,650	179,524	2,320,254
Long Beach	1,369,414	574,481	33,787,791
Long Beach Airport	7,993	756	39,396
Los Angeles City	7,903	9,750	19,299
Los Angeles Downtown	30,110	24,516	599,172
Los Angeles, East	0	41	0
Mahala	7,325	5,130	3,496
Montebello	416,541	226,292	32,857,423
Newport	0	29,489	0
Newport, West	49,263	74,398	1,365,976
Newport, West	21,673	11,906	302,165
Olive	54,619	7,175	91,795
Playa Del Rey	48,765	115,047	978,888
Potrero (ABD)	0	0	0
Prado-Corona	0	0	0
Richfield	236,271	52,189	4,547,421

District 1 Field Name	Oil Produced (bbl)	Net Gas Production (Mcf)	Water Produced (bbl)
Rosecrans, South	8,623	7,725	18,003
Salt Lake	48,466	37,054	208,361
Salt Lake, South	11,496	49,780	980,393
San Vicente	218,810	218,476	701,306
Sansinena	173,049	174,119	311,400
Santa Fe Springs	806,219	249,782	46,961,378
Sawtelle	158,776	51,751	507,855
Seal Beach	376,686	291,507	7,041,085
Torrance	324,043	68,870	5,824,775
Walnut	5,404	0	5,353
Whittier	67,139	158,069	66,637
Wilmington	8,366,854	3,064,295	434,167,928
Wilmington	3,265,618	646,654	142,361,122
District 1 Onshore Production Total	**12,255,161**	**5,863,115**	**434,090,845**
District 1 Offshore Production Total	**10,472,172**	**3,817,814**	**509,101,242**
District 1 Production Total	**22,727,333**	**9,680,929**	**943,192,087**

District 2 Field Name	Oil Produced (bbl)	Net Gas Production (Mcf)	Water Produced (bbl)
Aliso Canyon	82,101	201,869	734,876
Any Field	0	0	0
Bardsdale	145,029	243,826	968,625
Big Mountain	15,267	62,245	32,034
Cabrillo	19,054	49,305	36,501
Canada Larga	707	0	965
Cascade	116,474	174,795	147,428
Castaic Hills	6,411	1,492	8,318
Chaffee Canyon	1,663	20,187	863
Del Valle	26,041	28,175	190,497
Eureka Canyon	735	963	3,918
Fillmore	0	0	0
Hasley Canyon	28,362	5,157	52,965
Holser	14,945	15,063	12,753
Honor Rancho	6,105	1,173,769	9,763
District 2 Field Name	**Oil Produced (bbl)**	**Net Gas Production (Mcf)**	**Water Produced (bbl)**

Hopper Canyon	0	2,984	0
Montalvo, West	191,107	175,038	357,157
Montalvo, West	128,407	41,236	755,193
Moorpark West	2,904	1,158	6,172
Newhall	0	0	0
Newhall-Potrero	60,130	83,166	112,531
Oak Canyon	21,536	44,352	97,939
Oak Park	9,654	3,299	23,914
Oakridge	104,659	78,669	781,094
Oat Mountain	64,970	89,104	67,739
Ojai	190,154	764,391	410,765
Oxnard	385,262	21,824	431,285
Piru Creek (ABD)	0	0	0
Placerita	574,985	0	24,510,647
Ramona	34,675	70,302	39,058
Ramona, North	0	0	0
Rincon	198,019	196,469	2,382,653
Rincon	3,967	109	56,945
San Miguelito	324,120	301,995	3,887,658
Santa Clara Avenue	33,689	19,286	76,606
Santa Susana	11,298	46,797	37,573
Saticoy	28,227	28,125	95,978
Sespe	332,726	839,831	326,483
Shiells Canyon	55,303	256,829	102,099
Simi	0	0	0
South Mountain	485,043	749,165	500,002
Tapia	15,278	1,767	655,553
Tapo Canyon, South	10,250	2,937	4,964
Tapo Ridge	0	0	0
Tapo, North	0	0	0
Temescal	65,454	64,440	223,574
Timber Canyon	23,236	65,614	4,242
Torrey Canyon	89,253	146,370	96,736
Ventura	4,077,487	2,242,630	41,396,372
Wayside Canyon	11,090	2,086	26,976
District 2 Field Name	**Oil Produced (bbl)**	**Net Gas Production (Mcf)**	**Water Produced (bbl)**
West Mountain	12,933	10,003	6,647

District 2 Onshore Production Total	**7,813,636**	**8,151,675**	**79,259,959**
District 2 Offshore Production Total	**195,074**	**175,147**	**414,102**
District 2 Production Total	**8,008,710**	**8,326,822**	**79,674,061**

District 3 Field Name	Oil Produced (bbl)	Net Gas (Mcf)	Water Produced (bbl)
Any Field	27,600	132,889	1,029,533
Arroyo Grande	546,411	472,859	10,524,747
Barham Ranch	83,642	231,884	164,492
Careaga Canyon	5,109	28,261	301,263
Casmalia	112,011	18,329	5,981,092
Cat Canyon	1,547,485	648,423	11,273,091
Cuyama, South	176,822	111,550	13,182,936
Elwood	0	0	0
Elwood, South, Offshore	0	1,836	0
Four Deer (ABD)	2,256	4,149	17,809
Jesus Maria	0	0	0
La Goleta Gas	0	0	0
Lompoc	256,470	230,862	18,302,847
Los Alamos	7,816	6,764	0
Lynch Canyon	230,371	0	4,810,912
McCool Ranch	8,728	0	1,163,452
Monroe Swell	0	0	0
Morales Canyon	0	0	0
Orcutt	908,855	798,565	33,454,972
Paris Valley	0	0	0
Russell Ranch	47,517	84,466	1,070,617
San Ardo	7,237,786	1,015,500	127,768,930
Santa Maria Valley	126,779	106,562	2,816,149
Sargent	23,656	1,014	29,832
Zaca	187,267	1,322	7,775,173
District 3 Onshore Production Total	**11,536,581**	**3,893,399**	**239,667,847**
District 3 Offshore Production Total	**0**	**1,836**	**0**
District 3 Production Total	**11,536,581**	**3,895,235**	**239,667,847**

District 4 Field Name	Oil Produced (bbl)	Net Gas (Mcf)	Water Produced (bbl)
Ant Hill	14,770	2,772	1,436,211
Antelope Hills	102,598	5,090	584,269
Antelope Hills, North	258,651	0	2,615,568
Any Field	445,378	450,438	395,805
Asphalto	171,474	3,957,372	9,614,145
Beer Nose	6,165	6,347	440
Belgian Anticline	25,116	79,059	317,555
Bellevue	22,931	13,752	667,475
Bellevue, West	23,428	16,014	179,867
Belridge, North	1,893,487	2,204,037	30,630,602
Belridge, South	21,165,892	8,112,253	313,822,415
Blackwells Corner	10,916	0	44,198
Bowerbank	0	0	0
Buena Vista	1,208,354	13,311,774	49,976,053
Calders Corner	0	0	0
Canal	15,894	16,647	148,663
Canfield Ranch	73,804	95,159	452,741
Carneros Creek	17,097	26,543	51,113
Chico-Martinez	26,745	0	240,034
Cienaga Canyon	14,062	58,445	222,159
Coles Levee, North	169,027	158,918	736,727
Coles Levee, South	63,352	825,445	72,206
Comanche Point	15,644	0	568,397
Cymric	16,159,585	2,768,987	122,464,701
Deer Creek	27,827	0	2,835,459
Deer Creek, North	688	0	4,179
Devils Den	9,005	346	62,304
Dyer Creek	6,237	0	427,496
Edison	558,525	119,533	9,177,392
Edison, Northeast	537	0	1,199
Elk Hills	9,110,083	56,159,681	139,548,826
Fruitvale	386,181	122,262	6,769,011
Greeley	127,190	184,640	2,579,599
Jasmin	163,350	0	19,010,461
District 4 Field Name	Oil Produced (bbl)	Net Gas (Mcf)	Water Produced (bbl)
Jerry Slough (ABD)	2,508	0	0

Kern Bluff	11,273	0	1,018,153
Kern Front	3,684,493	54,587	153,483,121
Kern River	21,935,328	10,266,743	217,926,966
Landslide	24,669	25,274	1,053,595
Los Lobos	289	0	0
Lost Hills	9,504,333	4,454,003	94,900,949
Lost Hills, Northwest	17,625	248	469,801
McDonald Anticline	51,260	8,625	1,083,898
McKittrick	3,004,060	147,185	29,915,646
Midway-Sunset	22,090,325	4,500,559	190,586,460
Monument Junction	83,653	245,352	766,809
Mount Poso	1,464,138	32,923	25,316,261
Mountain View	80,622	40,538	493,889
Paloma	14,478	54,778	18,387
Pioneer	1,981	3,500	419
Pleito	714,593	364,016	1,051,840
Poso Creek	4,419,307	759,127	174,100,353
Railroad Gap	98,624	1,911,510	1,567,850
Rio Bravo	225,845	336,019	5,716,359
Rio Viejo	53,033	16,880	99,360
Rose	264,067	122,677	1,215,603
Rosedale	9,690	0	5,981
Rosedale Ranch	120,298	94,749	6,081,529
Round Mountain	2,488,607	51,677	170,013,969
San Emidio Nose	4,263	4,657	7,077
Semitropic	26,254	14,981	20,370
Shafter, North	501,419	444,785	1,633,992
Stockdale	108,310	41,717	48,933
Strand	6,366	4,804	20,584
Tejon	232,106	72,378	18,519,412
Tejon Hills	7,913	513	242,014
Tejon, North	32,599	267,290	75,135
Temblor Ranch	214	0	85,600
Ten Section	65,128	30,277	1,775,117
District 4 Field Name	**Oil Produced (bbl)**	**Net Gas (Mcf)**	**Water Produced (bbl)**
Union Avenue	5,897	9,100	22,794
Valpredo	0	0	0

Wasco	0	0	0
Welcome Valley	0	0	0
Wheeler Ridge	59,773	43,678	459,703
White Wolf	11,797	6,235	4,548
Yowlumne	72,457	49,604	2,283,501
District 4 Onshore Production Total	**123,793,588**	**113,176,503**	**1,817,743,248**
District 4 Offshore Production Total	**0**	**0**	**0**
District 4 Production Total	**123,793,588**	**113,176,503**	**1,817,743,248**

District 5 Field Name	Oil Produced (bbl)	Net Gas (Mcf)	Water Produced (bbl)
Any Field	28,326	15,464	114,359
Bitterwater	1,394	0	300
Burrel	11,859	14,635	1,583,883
Burrel, Southeast	0	0	0
Camden	0	0	0
Coalinga	6,574,515	257,251	75,809,209
Coalinga, East, Extension	4,137	3,318	263,326
Guijarral Hills	2,377	1,504	22,856
Helm	58,157	35,394	434,514
Jacalitos	93,188	25,070	405,869
Kettleman City (ABD)	0	0	0
Kettleman Middle Dome	39,989	66,938	94,061
Kettleman North Dome	99,884	67,833	1,321,329
Kreyenhagen (ABD)	0	0	0
Pleasant Valley	0	0	0
Pyramid Hills	44,603	2,146	157,249
Raisin City	148,052	76,143	4,472,903
Riverdale	75,225	40,456	295,223
San Joaquin	3,252	1,605	106,727
Tulare Lake	0	0	0
Vallecitos	748,306	6,743,776	1,408,983
District 5 Field Name	**Oil Produced (bbl)**	**Net Gas (Mcf)**	**Water Produced (bbl)**
Van Ness Slough	0	0	0
District 5 Onshore Production Total	**7,933,264**	**7,351,533**	**86,490,791**
District 5 Offshore Production Total	**0**	**0**	**0**
District 5 Production Total	**7,933,264**	**7,351,533**	**86,490,791**

District 6 Field Name	Oil Produced (bbl)	Net Gas (Mcf)	Water Produced (bbl)
Half Moon Bay	52	0	0
La Honda	0	0	0
Livermore	8,715	644	24,641
Oil Creek	0	0	0
Petrolia	0	0	0
District 6 Onshore Production Total	**8,715**	**644**	**24,641**
District 6 Offshore Production Total	**0**	**0**	**0**
District 6 Production Total	**8,715**	**644**	**24,641**

Summary

District	Oil Produced (bbl)	Net Gas (Mcf)	Water Produced (bbl)
District 1	22,727,333	9,680,929	943,192,087
District 2	8,008,710	8,326,822	79,674,061
District 3	11,536,581	3,895,235	239,667,847
District 4	123,793,588	113,176,503	1,817,743,248
District 5	7,933,264	7,351,533	86,490,791
District 6	8,767	644	24,641
State Total	**174,008,243**	**142,431,666**	**3,166,792,675**

CONDENSATE, NON-ASSOCIATED GAS, AND WATER PRODUCTION BY DISTRICT AND FIELD

District 1 Field Name	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
Los Angeles Downtown	0	863	0
Prado-Corona	0	0	0
Seal Beach	0	1,384	0
Wilmington	0	0	0
District 1 Production Total	**0**	**2,247**	**0**

District 2 Field Name	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
Aliso Canyon	0	0	0
Del Valle	432	4,724	24,799
Montalvo, West	0	0	0
Tapia	0	0	0
District 2 Production Total	**432**	**4,724**	**24,799**

District 3 Field Name	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
Cuyama, South	460	448	67,311
La Goleta Gas	0	0	0
District 3 Production Total	**460**	**448**	**67,311**

District 4 Field Name	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
Any Field	0	0	0
Antelope Hills	0	0	0
Belgian Anticline	0	10,155	0
Bowerbank	0	0	0
Buena Vista	0	79,600	0
Cal Canal Gas	19,006	60,209	117,891
Canal	0	0	0
Coles Levee, North	0	0	0
Elk Hills	0	1,283,078	0
Monument Junction	0	0	0
Mountain View	0	0	0
District 4 Field Name	**Condensate (bbl)**	**Net Gas (Mcf)**	**Water (bbl)**

Paloma	0	0	0
Railroad Gap	0	0	0
Rio Bravo	5,660	34,881	81,635
Semitropic	0	0	0
Strand	0	0	0
Ten Section	0	0	0
Trico Gas	0	0	0
District 4 Production Total	**24,666**	**1,467,923**	**199,526**

District 5 Field Name	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
Any Field	0	0	0
Chowchilla Gas	0	0	0
Gill Ranch Gas	0	45,774	0
Hollister	0	0	0
Kettleman North Dome	0	0	0
Merrill Avenue Gas	0	0	0
Merrill Avenue, Southeast, Gas	0	83,204	547
Moffat Ranch Gas	0	278,438	535
Oakdale Gas	0	29	0
District 5 Production Total	**0**	**407,445**	**1,082**

District 6 Field Name	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
Any Field	0	118,547	2,941
Afton Gas	0	2,845	0
Arbuckle Gas	0	21,294	342
Bounde Creek Gas	0	115,918	1,000
Brentwood, East, Gas	0	0	0
Buckeye Gas	0	212,600	1,156
Bunker Gas	0	0	0
Butte Sink Gas	0	0	0
Butte Slough Gas	0	226,882	524
Cache Creek Gas	0	0	0
Clarksburg Gas	0	0	0
District 6 Field Name	**Condensate (bbl)**	**Net Gas (Mcf)**	**Water (bbl)**
Collegeville, East, Gas	0	0	0

Compton Landing Gas	0	14,598	2,597
Conway Ranch Gas	0	0	0
Denverton Creek Gas	190	121,081	4,630
Dunnigan Hills Gas	0	0	0
Durham Gas	0	0	0
Dutch Slough Gas	0	0	0
East Islands Gas	0	0	0
Everglade Gas	0	0	0
French Camp Gas	0	500,599	15,157
Grimes Gas	0	2,819,082	44,257
Grimes, West, Gas	0	356,518	2,251
Grizzly Bluff Gas	0	46,879	12
Hood-Franklin Gas	0	12,393	109
Howells Point Gas	0	0	0
King Island Gas	0	71,348	0
Kirby Hill Gas	0	0	0
Kirk Gas	0	124,998	1,928
Kirkwood Gas	0	2,149	99
Knights Landing Gas	0	0	0
Larkin, West, Gas	0	0	0
Lathrop Gas	0	240,721	6,785
Lindsey Slough Gas	183	355,023	3,993
Little Butte Creek Gas	0	0	0
Lone Tree Creek Gas	0	0	0
Lone Star Gas	0	77,740	461
Los Medanos Gas	0	35,886	87
Maine Prairie Gas	0	0	0
Malton-Black Butte Gas	0	493,635	11,191
Medora Lake Gas	79	2,265	232
McMullin Ranch Gas	0	0	0
Millar Gas	0	5,255	16
Moon Bend Gas	0	135,618	3,417
Nicolaus Gas	0	0	0
Ord Bend Gas	0	0	0
Orland Gas	0	0	0
District 6 Field Name	**Condensate (bbl)**	**Net Gas (Mcf)**	**Water (bbl)**
Perkins Lake Gas	0	0	0
Pierce Road Gas	0	33,726	3,015

Putah Sink Gas	0	0	0
Rancho Capay Gas	0	55,504	19
Rice Creek Gas	0	308,270	2,799
Rice Creek, East, Gas	0	159,702	289
Rindge Tract Gas	0	0	0
Rio Vista Gas	10,834	4,751,144	251,098
River Island Gas	0	39,712	173
Robbins Gas	0	0	0
Roberts Island Gas	0	0	0
Ryer Island Gas	177	119,394	300
Sacramento Airport Gas	0	0	0
Stegeman Gas	0	1,086	0
Oakley, South, Gas	0	0	0
Sugarfield Gas	0	0	0
Suisun Bay Gas	0	48,782	3,077
Sutter Buttes Gas	0	1,646,975	23,027
Sutter City Gas	0	200,451	3,680
Sycamore Gas	0	601,653	12,570
Sycamore Slough Gas	0	3,515	0
Thornton, W.-Walnut Grove Gas	0	0	0
Tisdale Gas	0	174,597	4,351
Todhunters Lake Gas	0	35,270	31
Tompkins Hill Gas	0	370,566	7,061
Union Island Gas	0	419,793	28,604
Van Sickle Island Gas	207	117,787	1,308
Vernalis Gas	0	69,709	325
West Butte Gas	0	110,054	1,682
Williams Gas	0	52,968	580
Willow Slough Gas	0	0	0
Willows-Beehive Bend Gas	0	2,912,646	59,639
Winchester Lake Gas	0	0	0
Winters Gas	0	40,040	77
District 6 Production Total	**11,670**	**18,387,218**	**506,890**

District	Condensate (bbl)	Net Gas (Mcf)	Water (bbl)
District 1	0	2,247	0
District 2	432	4,724	24,799

District 3	460	448	67,311
District 4	24,666	1,467,923	199,526
District 5	0	407,445	1,082
District 6	11,670	18,387,218	506,890
State Total	**37,228**	**20,270,005**	**799,608**

STEAM AND WATER INJECTION BY DISTRICT AND FIELD

District 1 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Belmont Offshore	0	0	0	2,639,980	2,639,980
Beverly Hills	0	0	39,662	1,113,458	1,153,120
Brea-Olinda	0	0	17,718	2,307,488	2,325,206
Cheviot Hills	0	0	7,327	0	7,327
Chino-Soquel	0	0	0	0	0
Coyote, East	0	0	0	2,443,768	2,443,768
El Segundo	0	0	14,700	0	14,700
Huntington Beach	0	0	0	28,715,197	28,715,197
Inglewood	0	0	0	41,729,160	41,729,160
Las Cienegas	0	0	0	891,302	891,302
Long Beach	0	0	0	6,399,560	6,399,560
Long Beach Airport	0	0	10,624	0	10,624
Los Angeles Downtown	0	0	0	238,654	238,654
Mahala	0	0	0	0	0
Montebello	0	0	0	10,273,893	10,273,893
Newport, West	5,706	8,833	0	96,260	110,799
Playa Del Rey	0	0	1,431	0	1,431
Richfield	0	0	0	1,959,244	1,959,244
Rosecrans	0	0	0	465,398	465,398
San Vicente	0	0	0	0	0
Sansinena	0	0	0	4,072	4,072
District 1 Field Name	**Cyclic Steam (bbl)**	**Steam Flood (bbl)**	**Water Disposal (bbl)**	**Water Flood (bbl)**	**Total (bbl)**
Santa Fe Springs	0	0	0	14,948,146	14,948,146
Sawtelle	0	0	0	191,707	191,707
Seal Beach	0	0	0	318,547	318,547
Torrance	0	0	3,704	1,612,534	1,616,238
Whittier	0	0	0	0	0
Wilmington	0	0	90,333	203,380,846	203,471,179

District 2 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Aliso Canyon	0	0	308,658	79,132	387,790
Bardsdale	0	0	218,469	1,695	220,164

Big Mountain	0	0	0	0	0
Cascade	0	0	0	45,134	45,134
Castaic Hills	0	0	0	0	0
Chaffee Canyon	0	0	0	0	0
Del Valle	0	0	57,412	0	57,412
Eureka Canyon	0	0	6,296	0	6,296
Hasley Canyon	0	0	0	0	0
Holser	0	0	2,943	0	2,943
Honor Rancho	0	0	35,718	0	35,718
Hopper Canyon	0	0	0	0	0
Montalvo, West	0	0	176,203	80,334	256,537
Newhall	0	0	0	0	0
Newhall-Potrero	0	0	30,805	0	30,805
Oak Canyon	0	0	44,620	0	44,620
Oak Park	0	0	17,588	0	17,588
Oakridge	0	0	0	226,007	226,007
Ojai	0	0	150,969	0	150,969
Oxnard	41,875	0	203,651	0	245,526
Placerita	799,231	1,768,784	6,228,468	0	8,796,483
Ramona	0	0	19,421	0	19,421
Rincon	0	0	4,935	466,029	470,964
San Miguelito	0	0	0	1,195,975	1,195,975
Santa Clara Avenue	0	0	14,976	0	14,976
District 2 Field Name	**Cyclic Steam (bbl)**	**Steam Flood (bbl)**	**Water Disposal (bbl)**	**Water Flood (bbl)**	**Total (bbl)**
Santa Susana	0	0	0	0	0
Saticoy	0	0	0	23,408	23,408
Sespe	0	0	107,427	0	107,427
Shiells Canyon	0	0	30,348	0	30,348
South Mountain	0	0	35,723	93,320	129,043
Tapia	0	0	293,975	0	293,975
Tapo, North	0	0	0	0	0
Temescal	0	0	71,391	0	71,391
Timber Canyon	0	0	0	0	0
Torrey Canyon	0	0	0	0	0
Ventura	0	0	0	20,134,453	20,134,453
West Mountain	0	0	0	0	0

District 3 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Any Field	0	0	2,565,163	0	2,565,163
Arroyo Grande	18,100	1,228,059	395,917	0	1,642,076
Barham Ranch	0	0	40,500	0	40,500
Careaga Canyon	0	0	103,994	0	103,994
Casmalia	0	0	1,935,086	0	1,935,086
Cat Canyon	729,895	0	2,492,235	388,338	3,610,468
Cuyama, South	0	0	0	4,503,528	4,503,528
Elwood	0	0	332	0	332
Elwood, South, Offshore	0	0	0	0	0
Gaviota Offshore Gas (ABD)	0	0	10,275	0	10,275
Jesus Maria	0	0	0	0	0
Lompoc	0	0	6,748,590	0	6,748,590
Lynch Canyon	246,379	353,880	1,208,714	0	1,808,973
McCool Ranch	0	0	349,940	0	349,940
Monroe Swell	0	0	0	0	0
Orcutt	264,408	0	2,062,535	10,461,512	12,788,455
Paris Valley	0	0	0	0	0
Russell Ranch	0	0	0	399,029	399,029
San Ardo	1,325,344	15,595,924	15,980,117	2,122,657	35,024,042
District 3 Field Name	**Cyclic Steam (bbl)**	**Steam Flood (bbl)**	**Water Disposal (bbl)**	**Water Flood (bbl)**	**Total (bbl)**
Santa Maria Valley	0	0	167,418	819,570	986,988
Sargent	0	0	13,076	0	13,076
Zaca	0	0	2,804,192	0	2,804,192

District 4 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Ant Hill	0	0	588,180	0	588,180
Antelope Hills, North	56,162	422,445	256,262	0	734,869
Any Field	0	0	0	0	0
Asphalto	0	0	3,109,001	0	3,109,001
Belgian Anticline	0	0	0	18,680	18,680
Bellevue	0	0	160,077	0	160,077
Bellevue, West	0	0	81,597	0	81,597

Belridge, North	0	0	131,580	14,871,355	15,002,935
Belridge, South	1,204,415	30,576,027	61,136,536	49,343,907	142,260,885
Blackwells Corner	0	0	18,557	0	18,557
Bowerbank	0	0	290	0	290
Buena Vista	0	0	4,066,971	11,728,009	15,794,980
Cal Canal Gas	0	0	45,234	0	45,234
Canal	0	0	16,653	0	16,653
Canfield Ranch	0	0	156,538	0	156,538
Chico-Martinez	0	0	0	0	0
Cienaga Canyon	0	0	0	0	0
Coles Levee, North	0	0	0	355,127	355,127
Coles Levee, South	0	0	22,413	0	22,413
Comanche Point	0	0	191,455	0	191,455
Cymric	19,025,632	6,811,102	1,388,551	0	27,225,285
Deer Creek	0	0	638,075	0	638,075
Devils Den	0	0	330	0	330
Edison	445,057	217,811	2,305,315	0	2,968,183
Edison, Northeast	0	0	0	0	0
Elk Hills	0	0	21,882,988	27,952,193	49,835,181
English Colony	0	0	0	0	0
Fruitvale	0	0	3,008,990	85,635	3,094,625
District 4 Field Name	**Cyclic Steam (bbl)**	**Steam Flood (bbl)**	**Water Disposal (bbl)**	**Water Flood (bbl)**	**Total (bbl)**
Greeley	0	0	787,997	0	787,997
Jasmin	0	0	270,100	0	270,100
Kern Bluff	0	0	412,600	0	412,600
Kern Front	524,796	7,496,306	641,422	0	8,662,524
Kern River	2,578,038	25,202,212	2,495,918	0	30,276,168
Landslide	0	0	0	263,675	263,675
Lost Hills	376,060	7,583,279	4,564,475	27,610,275	40,134,089
Lost Hills, Northwest	0	0	57,027	0	57,027
McDonald Anticline	0	0	258,878	0	258,878
McKittrick	1,024,146	3,943,587	14,076,671	0	19,044,404
Midway-Sunset	18,269,692	26,987,320	18,841,291	0	64,098,303
Mount Poso	34,475	1,564	4,337,412	1,431,861	5,805,312
Mountain View	0	0	48,403	530	48,933
Paloma	0	0	3,309	0	3,309
Pleito	0	0	262,050	0	262,050

Poso Creek	2,694,097	6,462,144	49,012,638	0	58,168,879
Rio Bravo	0	0	0	1,941,740	1,941,740
Rio Viejo	0	0	27,999	0	27,999
Rose	0	0	314,605	0	314,605
Rosedale	0	0	6,318	0	6,318
Rosedale Ranch	0	0	1,833,371	0	1,833,371
Round Mountain	0	3,783,920	262,811	52,604,222	56,650,953
San Emidio Nose	0	0	0	0	0
Semitropic	0	0	0	0	0
Shafter, North	0	0	540,160	0	540,160
Strand	0	0	0	0	0
Tejon	0	0	88,774	4,462,544	4,551,318
Tejon Hills	0	0	76,713	6,294	83,007
Tejon, North	0	0	0	20,335	20,335
Temblor Ranch	0	0	26,427	0	26,427
Ten Section	0	0	735,634	0	735,634
Trico Gas	5,706	8,833	185,499	319,729,214	319,929,252
Union Avenue	0	0	0	0	0
Wheeler Ridge	0	0	93,041	29,021	122,062
Yowlumne	0	0	0	386,208	386,208

District 5 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Any Field	0	0	85,530	0	85,530
Burrel	0	0	616,993	0	616,993
Burrel, Southeast	0	0	0	0	0
Coalinga	1,023,791	12,162,684	784,544	4,831,624	18,802,643
Coalinga, East, Extension	0	0	5,645,924	0	5,645,924
Gill Ranch Gas	0	0	3	0	3
Helm	0	0	164,871	0	164,871
Jacalitos	0	0	32,499	309,218	341,717
Kettleman Middle Dome	0	0	27,218	0	27,218
Kettleman North Dome	0	0	250,673	0	250,673
Pleasant Valley	0	0	0	0	0
Pyramid Hills	0	0	0	54,672	54,672
Raisin City	0	0	1,677,286	0	1,677,286

Riverdale	0	0	77,822	0	77,822
San Joaquin	0	0	34,500	0	34,500
Tulare Lake	0	0	0	0	0
Vallecitos	0	0	873	0	873
Van Ness Slough	0	0	0	0	0

District 6 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Any Field	0	0	68	0	68
French Camp Gas	0	0	0	0	0
Grimes Gas	0	0	0	0	0
Kirkwood Gas	0	0	0	0	0
La Honda	0	0	0	0	0
Lathrop Gas	0	0	0	0	0
Lindsey Slough Gas	0	0	88,795	0	88,795
Livermore	0	0	8,317	0	8,317
Lodi Gas	0	0	4,934	0	4,934
Malton-Black Butte Gas	0	0	0	0	0
Oil Creek	0	0	0	0	0
District 6 Field Name	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
Princeton Gas	0	0	0	0	0
Rice Creek Gas	0	0	900	0	900
Rio Vista Gas	0	0	91,510	0	91,510
Sutter Buttes Gas	0	0	0	0	0
Sutter City Gas	0	0	9,237	0	9,237
Union Island Gas	0	0	0	0	0
Willows-Beehive Bend Gas	0	0	0	0	0

District	Cyclic Steam (bbl)	Steam Flood (bbl)	Water Disposal (bbl)	Water Flood (bbl)	Total (bbl)
District 1 Injection	16,054	21,945	527,006	958,881,051	959,446,056
District 2 Injection	2,064,682	4,097,829	20,175,030	55,079,254	81,426,795
District 3 Injection	6,997,767	41,673,810	99,055,422	55,145,997	202,872,996
District 4 Injection	121,726,890	320,438,711	550,252,265	539,579,799	1,531,997,665
District 5 Injection	2,362,624	29,713,906	23,834,239	10,909,336	66,820,105

District 6 Injection	0	0	458,433	0	458,433
State Total	**133,168,017**	**395,946,201**	**694,302,395**	**1,619,595,437**	**2,843,012,050**

CALIFORNIA 2017 NEW WELL OPERATIONS

The table below summarizes drilling activity in 2017. After a decrease in wells drilled between 2015 and 2016, an increase was noted between 2016 and 2017 totals. The number of wells completed was largely unchanged between 2016 and 2017. Increases were noted in the footage drilled and the number of drilling, rework and abandonment notices filed.

	2017	2016	2015	2014	2013
Wells Drilled	996	759	1,016	3,249	2,723
Wells Completed	1,108	1,111	1,346	3,647	3,037
Footage Drilled (ft)	2,085,937	1,587,498	2,022,697	8,366,634	6,920,062
Drilling Notices Filed	5,208	3,917	4,976	4,456	4,536
Rework Notices Filed	2,547	1,715	3,082	3,481	3,158
Abandonment Notices Filed	2,153	1,798	2,120	2,176	2,785

Division of Oil, Gas, and Geothermal Resources
OIL AND GAS DISTRICT BOUNDARIES AND OFFICES
2017

DISTRICT OFFICES

Headquarters	801 K St., 18th Floor, MS 18-05, Sacramento, CA 95814-3530 Phone: 916-445-9686, TDD 916-324-2555 Fax: 916-323-0424
District No. 1	5816 Corporate Ave., Suite 200, Cypress, CA 90630-4731 Phone: 714-816-6847 Fax: 714-816-6853
District No. 2	1000 S. Hill Rd., Suite 116, Ventura, CA 93003-4458 Phone: 805-654-4761 Fax: 805-654-4765
District No. 3	195 S. Broadway, Suite 101, Orcutt, CA 93455 Phone: 805-937-7246 Fax: 805-937-0673
District No. 4	4800 Stockdale Hwy., Suite 100, Bakersfield, CA 93309 Phone: 661-322-4031 Fax: 661-861-0279
District No. 5	4800 Stockdale Hwy., Suite 100, Bakersfield, CA 93309 Phone: 661-322-4031 Fax: 661-861-0279
District No. 6	801 K St., 20th Floor, MS 18-05, Sacramento, CA 95814-3530 Phone: 916-322-1110 Fax: 916-445-3319

EXHIBIT 6

VENTURA COUNTY
AIR POLLUTION CONTROL DISTRICT

669 County Square Drive
Ventura, CA 93003
805/645-1400

PART 70 PERMIT No. 00012

Permit Term: May 14, 2019 to December 31, 2023

Company Name / Address
California Resources Production Corporation
2575 Vista Del Mar Drive, Suite 101
Ventura, CA 93001

Facility Name / Address
Tenby Production Facility
3450 East Fifth St.
Oxnard, CA 93030

Responsible Officials
Mr. Chad Jones (VP Northern Operations)
Mr. Anibal Araya (Manager Operations)
Mr. James Robinson (VP HSE)
Mr. Raymond Rodriguez (Environmental Director)
661/869-8000

Title V Contact
Mr. Jeff Nobriga
Environmental Advisor
2575 Vista Del Mar Drive, Suite 101
Ventura, CA 93001
805/232-9622

The Part 70 permit consists of this page and the tables, attachments and conditions listed in the attached table of contents. The Part 70 permit application is included for reference only and is not a part of the Part 70 permit.

Pursuant to Rule 33.1, the Part 70 permit shall also serve as a permit to operate issued to fulfill the requirements of Rule 10.B.

Kerby E. Zozula, Manager
Engineering Division

For:

Michael Villegas
Air Pollution Control Officer

May 14, 2019

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PART 70 PERMIT NO. 00012
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13. Part 70 Permit Application Package

Note: The Part 70 permit application is included for reference only and is not a part of the Part 70 permit.

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1.a. PERMIT REVISONS TABLE

Application No.	Issue Date	Description / Category	Revised Permit Sections
00012-151	03/09/2000	Modified Storage Tank Description / Minor Part 70 Permit Modification	• Signature Cover Page • Table of Contents • Permit Revisions Table • Table No. 2 • Table No. 3 • Table No. 4
00012-161	01/13/03	Permit Reissuance for Term: January 1, 2003 to December 31, 2007	See "Stationary Source Description"
00012-ADM1	02/09/04	Administrative Amendment to revise the permitted emissions to reflect updated EPA-AP42 emissions factors for natural gas external combustion	• Signature Cover Page • Permit Revisions Table • Table No. 4
00012-171	08/04/04	Designate Steam Generator No. 3 as Out of Service / Minor Part 70 Permit Modification	• Signature Cover Page • Table of Contents • Permit Revisions Table • Periodic Monitoring Table • Table No. 2 • Table No. 3 • Table No. 4 • Attachment PO00012PC5 • Attachment PO00012PC8
00012-181	05/03/05	Add Existing Emergency Engines to Permitted Equipment Tables	• Signature Cover Page • Table of Contents • Permit Revisions Table • Periodic Monitoring Table • Table No. 2 • Applicable Requirement Code Key • Table No. 3 • Table No. 4 • Insignificant Activities Table • ATCM Engine N1 • ATCM Engine N2
00012-191	01/15/08	Permit Reissuance for Term January 1, 2008 to December 31, 2012	See "Permit Summary and Statement of Basis"
00012-201	02/01/12	Transfer of Ownership / Administrative Amendment	• Signature Cover Page

Application No.	Issue Date	Description / Category	Revised Permit Sections
00012-211	07/18/12	Designate Various Emissions Units as Out of Service / Minor Part 70 Permit Modification	• Signature Cover Page • Permit Revisions Table • Table No. 2 • Table No. 3 • Table No. 4 • Attachment PO00012PC8
00012-231	10/18/12	Administrative Amendment to change responsible official	• Signature Cover Page • Permit Revisions Table
00012-271	05/28/13	Revise Responsible Officials /Administrative Amendment	• Signature Cover Page • Permit Revisions Table
00012-221 00012-241 00012-242 00012-243 00012-244 00012-291 00012-301	12/03/13	App -221: Permit Reissuance for Term Ending December 31, 2018 Apps -241,-242,-243,-244: Well Replacements App -291: Administrative Amendment to change Company Name and Responsible Official App -301: Administrative Amendment to change Responsible Official	See "Permit Summary and Statement of Basis"
00012-281	07/10/14	Permit backup flare / Minor Part 70 Permit Modification	• Signature Cover Page • Table of Contents • Permit Revisions Table • Permit Summary and Statement of Basis • Periodic Monitoring Summary • Table No. 2 • Table No. 3 • Table No. 4 • Attachment PO00012PC9 *(new)* • Attachment 54.B.1 • Attachment 54.B.2
00012-245 00012-331	01/21/15	App -245: Well Replacements App - 331: Company Name Change	• Signature Cover Page • Permit Revisions Table • Oil Well List • Attachment PO00012PC1

Application No.	Issue Date	Description / Category	Revised Permit Sections
00012-351	07/07/15	Remove Emergency Engine From Permit / Revise Engine Description	• Signature Cover Page • Table of Contents • Permit Revisions Table • Periodic Monitoring Summary • Table No. 2 • Table No. 3 • Table No. 4 • *Remove* Attachment ATCM Engine N2
00012-321	01/19/16	Replacement of Steam Generator No. 0 / Minor Part 70 Permit Modification	• Signature Cover Page • Table of Contents • Permit Revisions Table • Periodic Monitoring Summary • Table No. 2 • Table No. 3 • Table No. 4 • Attachment PO00012PC5 • Attachment SHIELD-Steam Generator • Attachment 40CFR60OOOO
00012-361	02/17/16	Revise Responsible Officials and Title V Contact/Administrative Amendment	• Signature Cover Page • Permit Revisions Table
00012-371	04/04/18	Administrative Amendment to designate stationary source as non-operational per Rule 42	• Signature Cover Page • Permit Revisions Table
00012-381	05/14/19	Permit Reissuance for Term Ending December 31, 2023	See "Permit Summary and Statement of Basis"

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1.b. PERMIT SUMMARY AND STATEMENT OF BASIS

Stationary Source Description

This stationary source is a crude oil production and storage facility. This source has a Standard Industrial Classification (SIC) Code of 1311, Crude Oil Production. The source operates various oil production and processing equipment, including wells, crude oil storage tanks, produced water and slop tanks, gas oil (diluent) storage tanks, nitrite solution vessels, boilers, steam generators, asphalt heaters, asphalt storage tanks, and various loading racks. This stationary source extracts heavy crude oil from tar sands and blends the material into asphalt products. Steam generators are used to inject steam into the tar sand formation to heat the heavy crude and help it flow into the well pump. Diluent is injected into the well casing to enable the well pump to bring the heavy crude to the surface. The diluent is then removed from the crude and recycled for continued heavy crude recovery. This stationary source is subject to the Part 70 permit program based upon the potential to emit nitrogen oxides (NOx).

As discussed in more detail throughout this Permit Summary and Statement of Basis, this permit applies to emissions units that are required to have a permit to operate pursuant to District Rule 10, "Permits Required", and District Rule 23, "Exemptions from Permit". These emissions units are listed in Table No. 2 in Section No. 2 of this permit. However, as discussed below, some equipment that is exempt from permit pursuant to District Rule 23, "Exemptions from Permit", may be subject to District rules such as District Rule 50, "Opacity". This includes "Insignificant Activities" as listed in Section No. 6 of the permit. In addition, "Short Term Activities" as listed in Section No. 10 of the permit are subject to certain rules and regulations. This permit does not regulate or restrict the use of motor vehicles and mobile equipment such as cars, trucks, bulldozers, and forklifts, however, any smoke or dust emissions generated from the use of such equipment is subject to District Rule 50, "Opacity". This permit does not shield the permittee from complying with any Federal, State, or District rule or regulation that is not specifically addressed in the permit or any rule or regulation that may come into effect during the term of the permit.

Stationary Source Emissions

In Ventura County, the Part 70 permit thresholds are 50 tons per year for ROC and NOx and 100 tons per year for PM, SOx, and CO, pursuant to Rule 33.B.2 and Ventura County's "Serious" nonattainment classification with the federal ozone standard. The purpose of Table No. 4 is to document the permitted emissions of the criteria pollutants ROC, NOx, PM, SOx, and CO for this stationary source. District Rule 29, "Conditions on Permits", requires permitted emissions to be included on each Permit to Operate. District Rule 29 requires that annual permitted emissions be based on a 12 calendar month rolling period and be expressed in units of tons per year. Hourly permitted emissions are required to be expressed in units of pounds per hour. Permitted emissions for a stationary source are required to be determined by aggregating the permitted emissions for each emissions unit at the stationary source.

Criteria pollutant emissions (ROC, NOx, PM, SOx, and CO) result from the combustion of natural gas and diesel fuel in the boilers and steam generators. Reactive Organic Compound

(ROC) emissions result from the storage, handling, and loading of crude oil in the tanks and loading racks.

This stationary source is not a major source of federal Hazardous Air Pollutants (HAPs). The source is well below the HAP major source levels of 10 tons per year of a single HAP or 25 tons per year of combined HAPs. There are no Maximum Achievable Control Technology (MACT) major-source standards that apply to this facility. As described below, there are some applicable area-source MACT standards for this stationary source. The Part 70 Permit re-issuance application includes a summary (in the units of pounds per year and pounds per hour) of pollutants that are subject to the State of California AB2588 Air Toxics "Hot Spot" Program. All HAPS are subject to "Hot Spots" reporting. The goal of the Air Toxics "Hot Spots" Information and Assessment Act of 1987 (California Health and Safety Code Section 44300) is to collect air toxics emission data, to identify facilities having localized adverse health impacts, to ascertain health risks, to notify nearby workers and residents of significant risks, and to reduce significant risks if they exist. Under state law, motor vehicles (on-road and off-road) are not subject to the "Hot Spots" program. This facility has been subject to the "Hot Spots" program since 1989. Based on the quantity of toxic air contaminants released from the facility as determined by source testing, material balance calculations, and other engineering estimates, the potency and toxicity of materials released, and the proximity to sensitive receptors, this facility has been classified as "low level". As a low level facility, the stationary source is exempt from toxics reporting requirements unless any changes are made; such as facility changes, receptor changes, or toxicity calculation changes, which would put the facility in the "intermediate" category. The most recent data submitted was for the calendar year 1994.

The United States EPA has added greenhouse gases (GHGs) to the list of regulated air pollutants. As of January 2, 2011, EPA has required that GHGs be calculated for each Title V stationary source and included in the Part 70 Permit. However, in a Federal Register notice dated August 19, 2015, EPA ruled that GHG emissions alone cannot be used to determine Title V applicability. This ruling was based on the U.S. Supreme Court decision of June 23, 2015. Greenhouse gases are defined as the aggregate group of six greenhouse gases: carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (by category), perfluorocarbons (by category), and sulfur hexafluoride. Carbon dioxide equivalent emissions (CO_{2e}) is the amount of greenhouse gases emitted relative to the global warming potential of each pollutant.

The CO_2 potential to emit for this stationary source has been calculated to be 86,239.3 tons per year. The District's potential to emit is based on the permitted annual combustion and operational (hours per year) limits listed in Table No. 3 of the permit. The District has used emission factors of 10.14 kg CO_2/gallon diesel (22.33 lb CO_2/gallon diesel) and 53.02 kg CO_2/MMBTU natural gas (116.78 lb CO_2/MMBTU natural gas) from the *Regulation For The Mandatory Reporting of Greenhouse Gas Emissions*, California Code of Regulations, title 17, Subchapter 10, Article 2, sections 95100 to 95133; Appendix A, Table 4. This CO_2 potential to emit does not include insignificant activities or equipment exempt from permit pursuant to Rule 23, "Exemptions From Permit".

Compliance History

Upon reissuance of this Part 70 permit, the facility was determined to be in compliance with all applicable requirements. For the time period January 1, 1996 to December 31, 2018, the facility received twelve (12) Notices of Violation (NOV) as detailed in the "NOV by Facility" history for Facility No. 00012 located at the end of this section of the Part 70 permit.

Equipment Description and Applicable Requirements - General

Applicable requirements for this stationary source are listed throughout the permit. The Table of Contents in the front of the permit summarizes the applicable requirements including the equipment specific requirements, the general applicable requirements, and the applicable requirements for short-term activities. Table No. 2 in Section No. 2 of this Permit to Operate details the applicable requirements for specific emissions units at the facility. Permit conditions that enforce these requirements are listed in Section No. 7, "Specific Applicable Requirements" and Section No. 8, "Permit Specific Conditions" of this permit.

In addition to the emission unit specific requirements in Section No. 7 and Section No. 8, there are additional general requirements that may apply to the emissions units listed in this table, or to the stationary source as a whole. Furthermore, some general requirements may apply to emissions units or short-term activities not required to be specifically listed on the permit. These general requirements are contained in the following sections of the Permit: Section No. 9, "General Applicable Requirements"; Section No. 10, "General Requirements for Short-Term Activities"; Section No. 11, "General Permit Conditions"; and Section No. 12, "Miscellaneous Federal Program Conditions". A detailed applicability discussion and additional legal basis for the permit condition(s) is included with each attachment or set of permit conditions.

Equipment Description and Applicable Requirements - Specific

The crude oil, gas oil (diluent), and asphalt storage tanks and processing tanks at this facility are subject to Rule 71.1, "Crude Oil Production and Separation". The tanks are equipped with vapor recovery for Rule 71.1 compliance. The gas oil and crude oil loading racks are equipped with vapor recovery and primary and secondary overfill protection for Rule 71.3, "Transfer of Reactive Organic Compound Liquids", compliance. The gas oil and crude oil loading rack vapor recovery systems are also required for Rule 26, "New Source Review", compliance. The asphalt loading racks are exempt from the requirements of Rule 71.3 since the ROC liquid transferred has a modified Reid vapor pressure of less than 0.5 psia; however, pursuant to Rule 51, "Nuisance", the units are equipped with a vapor collection system that passes vapors through a water scrubber and filtration system.

The 20.0 MMBTU/Hr Erie City boiler, the six (6) 20.0 MMBTU/Hr steam generators, and the 20.0 MMBTU/Hr Natco Crude oil process heater are equipped with Lo NOx burners for Rule 74.15, "Boilers, Steam Generators and Process Heaters", compliance. Some of these units are also equipped with flue gas recirculation (FGR) and the capability to burn fuel oil. The 20.0 MMBTU/Hr Erie City boiler, the 20.0 MMBTU/Hr Natco crude oil process heater, and the 20.0

MMBTU/hr PCL Steam Generator (No. 0) have NOx concentration emission limits that are Rule 26, "New Source Review", limits which are more stringent than the Rule 74.15 requirements.

The facility includes a 5.0 MMBTU/hr flare (PROS Model FLTR-1) which is used for the combustion of gases pursuant to Rules 71.1.B.1.a or 71.1.C.1 by burning excess gas that cannot be combusted in the steam generators or asphalt heaters. The flare is required to be operated properly pursuant to Rules 71.1 and 71.3. The sulfur content of the gas prior to flaring is treated for compliance with Rules 26 and 54.

This stationary source is subject to the fugitive leak and inspection requirements of Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities". The stationary source is also subject to the California "Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities. This is a state regulation that is enforced by the District via a Memorandum of Understanding between the District and the California ARB.

A substantial amount of the emissions units listed on this permit are identified as Out of Service (OOS). As stated in Attachment PO00012PC8, the tanks designated as OOS shall not contain any liquids; and the combustion units shall not be connected to a fuel source. Demonstrations of compliance for the Out of Service emissions units are at the discretion of the VCAPCD Compliance Division.

The diesel-fired emergency engines greater than 50 BHP are subject to the requirements of Rule 74.9, "Stationary Internal Combustion Engines"; the California Air Toxic Control Measure (ATCM) For Stationary Compression Ignition Engines; and 40 CFR Part 63, Subpart ZZZZ, NESHAPS for Stationary Reciprocating Internal Combustion Engines (RICE MACT). Since the engines are emergency use only, the requirements of these regulations are limited to fuel use, maintenance, and recordkeeping. There are engines listed in the Insignificant Activities Table that are subject to applicable rules. The fire water pump engine that is exempt because it is rated less than 50 HP is subject to the RICE MACT; the fire water pump engine that is exempt because it is a spark ignited emergency use engine is subject the RICE MACT and to Rule 74.9.

This stationary source has stated that 40 CFR Part 68, "Chemical Accident Prevention Provisions", is not an applicable requirement. The facility does not store any specified materials in sufficient quantities to make them subject to 40 CFR Part 68. Therefore, a federal Risk Management Plan, pursuant to section 112(r) of the federal Clean Air Act as amended, is not required.

This stationary source does not have any emission units subject to 40 CFR Part 64, "Compliance Assurance Monitoring" (CAM). There are no "control devices" on emissions units, as defined in the CAM regulation.

This Part 70 Permit contains a permit shield from 40 CFR Part 60, Subpart Dc, "Standards of Performance for Small Industrial – Commercial – Institutional Steam Generating Units". The shield applies to the six (6) 20.0 MMBTU/Hr steam generators (Units Nos. 0, 1, 2, 3, 4, 5), the one (1) 20.0 MMBTU/Hr Erie City boiler, and the one (1) 20.0 MMBTU/Hr Natco crude oil heater. Except for Unit No. 0, all of these units were constructed prior to the applicability date of

June 9, 1989. Unit No. 0 is subject to Subpart Dc; but since it combusts natural gas only, it is only subject to recordkeeping requirements.

This Part 70 Permit also contains permit shields from 40 CFR Part 60, Subpart J, "Standards of Performance for Petroleum Refineries"; 40 CFR Part 60, Subpart UU, "Standards of Performance for Asphalt Processing and Asphalt Roofing Manufacture"; 40 CFR Part 60, Subpart GGG, "Standards of Performance for Equipment Leaks of VOC in Petroleum Refineries"; and 40 CFR Part 60, Subpart QQQ, "Standards of Performance for VOC Emissions from Petroleum Refinery Wastewater Systems". These New Source Performance Standards do not apply to this stationary source because the source does not meet the applicable definitions of a petroleum refinery, asphalt roofing plant, or asphalt processing plant.

Permit Revisions Summary

The Permit Revisions Table (located in Section No. 1 of the permit) is a list of all permit revisions since Part 70 Permit No. 00012 was initially issued on January 1, 1998. A detailed list of a portion of the permit revisions is described below. The District's Engineering Analysis for each application can also be consulted for further details.

Application No. 00012-161: Application No. 00012-161 is for the reissuance of Part 70 Permit No. 00012 for the period January 1, 2003 to December 31, 2007. The following items summarize the changes from the initial Part 70 Permit No. 00012 (January 1, 1998 to December 31, 2002):

- This "Stationary Source Description" has been added to the permit. It was not included in the initial Part 70 Permit No. 00012.
- The number of oil wells on the permit has been reduced from 86 to 70 wells; thereby reducing the permitted emissions by 5.84 tons per year ROC and 1.33 pounds per hour ROC.
- An attachment detailing the requirements of Rule 74.9, "Stationary Internal Combustion Engines", that apply to emergency standby stationary internal combustion engines rated at 50 or more horsepower and operated during an emergency or maintenance operation has been added to the permit. These exempt units have been specifically listed in the Insignificant Activities Table and now are also generally listed in Tables 2, 3, and 4 of the permit.
- Attachments detailing the applicable requirements for Rule 74.11.1, "Large Water Heaters and Small Boilers", and Rule 74.22, "Natural Gas-Fired Central Furnaces", have been added to the permit.
- The following District rules have been revised and/or revisions of the rule have been adopted into the State Implementation Plan (SIP) since the initial issuance of Part 70 Permit No. 00012:
  a) Rule 54, "Sulfur Compounds"
  b) Rule 57, "Combustion Contaminants – Specific"

c) Rule 64, "Sulfur Content of Fuels"
d) Rule 68, "Carbon Monoxide"
e) Rule 74.2, "Architectural Coatings"
f) Rule 74.6, "Surface Cleaning and Degreasing"
g) Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities"
h) Rule 74.15.1, "Boilers, Steam Generators, and Process Heaters (1 to 5 MMBTUs)"
i) Rule 74.16, "Oilfield Drilling Operations"
j) Rule 74.29, "Soil Decontamination Operations"

<u>Application No. 00012-191:</u> Application No. 00012-191 is for the reissuance of Part 70 Permit No. 00012 for the period January 1, 2008 to December 31, 2012. The following items summarize the revisions to the permit since the January 1, 2003 to December 31, 2007 reissuance:

- The Permit Summary and Statement of Basis for the permit has been expanded.
- Attachment PO0012PC1, Condition No. 3 has been revised to reflect the November 11, 2003 changes to Rule 23, "Exemptions From Permit", Section F.10, regarding solvent cleaning operations.
- Attachment PO0012PC2 was revised pursuant to revisions to Rule 64, "Sulfur Content of Fuels".
- The following District rules have been revised and/or revisions of the rule have been adopted into the State Implementation Plan (SIP) since the last reissuance of Part 70 Permit No. 00012:
  a) Rule 51, "Nuisance"
  b) Rule 52, "Particulate Matter – Concentration (Grain Loading)" – The rule was revised such that it no longer is applicable to the emissions units at this stationary source.
  c) Rule 57, "Combustion Contaminants – Specific" – The rule has been replaced by Rule 57.1, "Particulate Matter Emissions From Fuel Burning Equipment"
  d) Rule 68, "Carbon Monoxide" – The rule was revised such that it no longer is applicable to the emissions units at this stationary source.
  e) Rule 74.6, "Surface Cleaning and Degreasing"
  f) Rule 74.9, "Stationary Internal Combustion Engines"

<u>Application No. 00012-221:</u> Application No. 00012-221 is for the reissuance of Part 70 Permit No. 00012 for the five-year period ending December 31, 2018. This permit revision also includes Application No. 00012-241, -242, -243, and -244 which are for well replacements. Application No. 00012-291 is also included; and is an Administrative Amendment to change the company name, Responsible Official, and Title V Contact. Application No. 00012-301 is also included; and is an Administrative Amendment to replace a Responsible Official. The following items summarize the revisions to the permit since the January 1, 2008 to December 31, 2012 reissuance:

- A discussion of Greenhouse Gases has been included.
- Attachment PO0012PC1 has been revised to name the wells which are required to operate as BACT wells, pursuant to Application Nos. 00012-241, -242, -243, and -244.
- A permit condition attachment has been added for 40 CFR Part 63, Subpart ZZZZ, National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines (RICE MACT).
- A permit condition attachment for Rule 55, "Fugitive Dust", has been added to the permit.
- The following District rules have been revised and/or revisions of the rule have been adopted into the State Implementation Plan (SIP) since the last reissuance of Part 70 Permit No. 00012:
  a) California Air Toxic Control Measure (ATCM) For Stationary Compression Ignition Engines
  b) Rule 74.2, "Architectural Coatings"
  c) Rule 74.15.1, "Boilers, Steam Generators, and Process Heaters"
  d) Rule 74.11.1, "Large Water Heaters and Small Boilers"
  e) Rule 74.29, "Soil Decontamination Operations"

Application No. 00012-381 Application No. 00012-381 is for the reissuance of Part 70 Permit No. 00012 for the five-year period ending December 31, 2023. The following items summarize the revisions to the permit since the January 1, 2014 to December 31, 2018 reissuance:

- A condition attachment for the California ARB Greenhouse Gas Emissions Standards for Crude Oil and Natural Gas Facilities has been added to the permit.

- A condition attachment for 40 CFR Part 60, Subpart OOOOa, Standards of Performance (NSPS) for Crude Oil and Natural Gas Facilities for which Construction, Modification, or Re-Construction Commenced After September 18, 2015 has been added to the permit.

- The District has revised some monitoring requirements to exclude the phrase "routine surveillance" from the permit. The following attachments have been revised to reflect this change:
  a) Attachment 50
  b) Attachment 71.3N4
  c) Attachment 71.3N6
  d) Attachment 74.1
  e) Attachment 74.2
  f) Attachment 74.6
  g) Attachment 74.15.1N1
  h) Attachment 74.15.1N4
  i) Attachment 74.26
  j) Attachment 74.29N3
  k) Attachment PO00012PC6

- The following District and EPA rules have been revised and/or revisions of the District rule have been adopted into the State Implementation Plan (SIP):
  a) Rule 54, "Sulfur Compounds"
  b) Rule 74.11.1, "Large Water Heaters and Small Boilers"
  c) Rule 74.15.1, "Boilers, Steam Generators, and Process Heaters"
  d) 40 CFR Part 63, Subpart ZZZZ, "NESHAPS for Stationary Reciprocating Internal Combustion Engines (RICE MACT)

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NOV by Facility

Since January 1, 1996

Facility selected

00012

Facility No 00012 Tenby Production Facility

NOV Date	NOV No	Rule Number	Comment	Settlement	Date Closed
10/01/1996	018259	74.15	Failure To Meet Emissions - Steam Generator Viol. 74.15.B.1. Paid $500.00	$500.00	11/11/1996
10/01/1996	018260	29.C	Permit Condition Not Met - Boiler Emissions Viol. 29.C. Paid $0.00	$0.00	11/11/1996
09/25/1997	018287	29.C	Permit Condition Not Met - Boiler Viol. 29.C. Paid $750.00	$750.00	11/10/1997
03/24/1999	019059	74.10.C.2	Exceeding Leak Rate Threshold - Two Open Ended Lines	$2,000.00	05/04/1999
09/20/1999	019080	29.C	Permit Condition Not Met - Exceeded Gas Oil Tanks Throughput	$0.00	10/04/1999
05/02/2001	019522	74.15.B.1	Failure To Meet Boiler Emissions - CO Emissions	$0.00	05/30/2001
04/07/2004	020259	71.1.B.1	Improper Vapor Recovery System - Vapor Recovery	$1,000.00	05/18/2004
04/20/2005	021063	71.1.B.1	Improper Vapor Recovery System - Vapor Recovery System	$3,500.00	06/01/2005
07/06/2011	022626	74.15.B.1	Failure To Meet Boiler Emissions - Heater	$500.00	09/08/2011
03/22/2012	022852	74.10	Exceeding Leak Rate Threshold - Oilfield	$3,500.00	04/27/2012
04/04/2013	022873	29.C	Permit Condition Not Met - Failure To Conduct VEE Survey	$5,000.00	05/23/2013
02/23/2016	023307	71.1.B.1.a	Improper Vapor Recovery System - Vapor Recovery System	$1,000.00	03/16/2016

Total for 12 NOVs $17,750.00

1.c. PERIODIC MONITORING SUMMARY

This periodic monitoring summary is intended to aid the permittee in quickly identifying key monitoring, recordkeeping, and reporting requirements. It is not intended to be used as a "stand alone" monitoring guidance document that completely satisfies the requirements specifically applicable to this facility. The following tables are included in the periodic monitoring summary:

- Table 1.c.1. - Specific Applicable Requirements
- Table 1.c.2. - Permit-Specific Conditions
- Table 1.c.3. - General Applicable Requirements
- Table 1.c.4. - General Requirements for Short-Term Activities

1.c.1. Specific Applicable Requirements

The Specific Applicable Requirements Table includes a summary of the monitoring requirements, recordkeeping requirements, reporting requirements, and test methods associated with the attachments contained in Section No. 7 of this permit.

Attachment No./ Condition No.	Applicable Rule or Requirement	Monitoring	Recordkeeping	Semi-annual Reports	Test Methods	Comments
71.1N1	Rules 71.1.B.1.a, 74.10	•Quarterly inspection of the following components for proper operation: gas compressor, hatches, relief valves, pressure regulators, flare, as applicable •Verbal notice of maintenance activities •Rule 74.10 inspections •Annual compliance certification including verification that tanks are equipped with a vapor recovery system	•Records of quarterly inspections and tank maintenance activities •Rule 74.10 records	None	None	
71.3N4	Rules 71, 71.3.B.2.a.1, 71.3.B.2.b.2	•Annual compliance certification •Annually monitor one complete loading operation for leaks and for proper operation of the loading equipment and delivery vessel vapor recovery and overfill protection systems •Visual inspection of truck tank level after each liquid loading	•Records of annual inspections of the loading operations	None	•Leak Detection - Appropriate analyzer calibrated with methane or alternative screening procedure in EPA Reference 21	

1.c.1. Specific Applicable Requirements (Continued)

Attachment No./ Condition No.	Applicable Rule or Requirement	Monitoring	Recordkeeping	Semi-annual Reports	Test Methods	Comments
71.3N6	Rule 71.3.E.1	•Annual compliance certification with records of data to ensure modified Reid vapor pressure of liquid is < 0.5 psia	•Records of vapor pressure determinations	None	•VP of petroleum products - ASTM Method D-323-82 Volume 5.01, Section 5	Organic liquids listed in Attachment 1 of Rule 71.2 w/ a transfer temp not exceeding the max. temp listed corresponding w/ 0.5 psia are exempt from Rule 71.3.
74.9N7	Rule 74.9.D.3	•Annual compliance certification •Hours of operation	•Records of operating hours •Date, time, duration, and reason for emergency operation •Records of engine data	None	None	
74.15N1	Rule 74.15.B.1	•Annual compliance certification •Biennial Source Test (NO_x, CO)	•Records of source tests •Daily records of alternate fuel consumption	None	•NO_x-ARB Method 100 •CO-ARB Method 100	
74.15.1N1	Rule 74.15.1.B.1	•Annual compliance certification •Source test every 24 or 48 months (NO_x, CO) •Annual screening analysis (NOx, CO) with a portable analyzer	•Records of source tests •Daily records of alternate fuel consumption	•Submit report of annual screening analysis within 45 days	•NO_x-ARB Method 100 •CO-ARB Method 100	
74.15.1N4	Rules 74.15.1.D.1 and 74.15.B.1 or2	•Annual compliance certification •Notice to the District and fuel records if operating	•Notice to the District and fuel records if operating	None	None	
ATCM Engine N1	California ATCM for Stationary Compression Engines – fuel requirements	•Maintain records of fuel type •Maintain records of hours of operation •Maintain records of fuel used	•Maintain records of fuel type •Maintain records of hours of operation •Maintain records of fuel used	None	None	
40CFR63ZZZZN3	RICE MACT for emergency diesel engines – oil change and inspections	•Maintenance records •Annual compliance certification	•Maintenance records •Hours of operation records	None	None	
40CFR63ZZZZN9	RICE MACT for emergency spark ignited engines – oil change and inspections	•Maintenance records •Annual compliance certification	•Maintenance records •Hours of operation records	None	None	

1.c.2. Permit-Specific Conditions

The Permit-Specific Conditions Table includes a summary of the monitoring requirements, recordkeeping requirements, reporting requirements, and test methods associated with the attachments contained in Section No. 8 of this permit.

Attachment No./ Condition No.	Applicable Rule or Requirement	Monitoring	Recordkeeping	Semi-annual Reports	Test Methods	Comments
PO00012PC1 - Condition No. 1	Rules 26 and 29 General Recordkeeping	•Annual compliance certification •Monthly records of throughput and consumption	•Monthly records	None	None	
PO00012PC1 - Condition No. 2	Rule 29 Maximum Number of Oil Wells	•Annual compliance certification	None	None	None	
PO00012PC1 – Condition No. 3	Rule 26 – BACT wells	•Annual compliance certification	None	None	None	
PO00012PC1 - Condition No.4	Rule 29 Solvent Recordkeeping	•Monthly records of solvent purchase and usage •Annual compliance certification	•Records of solvent purchase and usage	None	None	
PO00012PC2	Rule 64 Nitrite Solution Vessel Operation	•Weekly tests of H_2S content in gases •Annual analysis of sulfur content in fuel gas •Annual compliance certification	•Records of H_2S test information •Records of fuel gas sulfur analysis tests	None	H_2S content - detector tubes Sulfur content - SCAQMD Method 307-94	
PO00012PC3	Rules 26 and 74.15 Boiler Emission Limits and FGR Settings	•Monthly records of FGR valve opening setting •Biennial Source Test (NO_x) •Annual compliance certification	•Records of FGR valve settings •Records of emissions source test	None	•NO_x-ARB Method 100	
PO00012PC4	Rules 26 and 74.15 Process Heater Emission Limits and FGR Settings	•Monthly records of FGR valve opening setting •Biennial Source Test (NO_x) •Annual compliance certification	•Records of FGR valve settings •Records of emissions source test	None	•NO_x-ARB Method 100	
PO00012PC5 - Condition Nos. 1, 5, 6,7, and 8	Rules 26, 29, and 74.15 Steam Generator Nos. 4 and 5 Max. Fuel Oil Rate, Sulfur and Nitrogen Concentration Limits, Emission Limits , and FGR Settings	•Monthly records of FGR valve opening setting •Monthly records of oxygen trim controller settings •Source Test (NO_x) while burning fuel oil during curtailment when > 118.2 gal/hr •Source Test (NO_x, CO) while burning fuel oil during periods of other than curtailment •Biennial Source Test (NO_x, CO) while burning natural gas •Fuel supplier's certification, or fuel test per each delivery documenting nitrogen and sulfur content of fuel •Amount of fuel consumed •Annual compliance certification	•Records of FGR valve settings •Records of oxygen trim controller settings •Records of emissions source tests •Records of fuel tests •Fuel consumption records	None	•NO_x-ARB Method 100 •CO - ARB Method 100	

1.c.2. Permit-Specific Conditions (Continued)

PO00012PC5 - Condition Nos. 2, 3, and 8	Rules 26, 29, 54, 64, and 74.15 Steam Generator No. 0 Emission Limits and fuel limits	•Source Test (NO_x and CO) every 24 months •Annual monitoring of fuel sulfur content •Annual compliance certification	•Records of emissions source test •Fuel sulfur content measurements	None	•NO_x-ARB Method 100 •CO - ARB Method 100 •SCAQMD Method 307-91	
PO00012PC5 - Condition Nos. 4, 6, 7, and 8	Rules 26, 29, and 74.15 Steam Generator Nos. 1 and 2 Emission Limits and FGR Settings	•Monthly records of FGR valve opening setting •Monthly records of oxygen trim controller settings •Source Test (NO_x) prior to burning fuel oil during curtailment •Source Test (NO_x, CO) while burning fuel oil during periods of other than curtailment •Biennial Source Test (NO_x, CO) while burning natural gas •Amount of fuel consumed •Monthly records of oxygen trim controller settings •Annual compliance certification	•Records of FGR valve settings •Records of oxygen trim controller settings •Records of emissions source tests •Fuel consumption records	None	•NO_x-ARB Method 100 •CO - ARB Method 100	
PO00012PC6	Rule 51 Asphalt Loading Rack Odor Control	•Annual certification that the vapor collection and scrubbing system is operating properly	None	None	None	•District-enforceable only
PO00012PC7	Rules 26 and 71.3 Crude Oil and Gas Oil Loading Rack Vapor Control	•Annual compliance certification including monitoring one complete loading operation for leaks and for proper operation of the loading equipment and delivery vessel vapor recovery and overfill protection systems	•Records of annual inspections of the loading operations	None	•Leak Detection - Appropriate analyzer calibrated with methane or alternative screening procedure in EPA Reference 21	
PO00012PC8	Rule 29 Out of Service Emissions Units	•Annual compliance certification to ensure that emissions unit is shut down and not being operated	None	None	None	
PO00012PC9 Condition Nos. 1, 2, 3, and 4	Rules 26, 71.1, 71.3 Flare ignition system operation, Smokeless	•Annual compliance certification •Monthly test of flare's ignition system	•Records of monthly tests and maintenance activities	None	None	
PO00012PC9 Condition No. 5	Rules 26 and 54 20 ppm sulfur content	•Annual testing of sulfur content of gas	•Records of annual testing	None	•Detector tubes, SCAQMD Method 307-91, or EPA Method 16	

1.c.3. General Applicable Requirements

The General Applicable Requirements Table includes a summary of the monitoring requirements, recordkeeping requirements, reporting requirements, and test methods associated with the attachments contained in Section No. 9 of this permit.

Attachment No./ Condition No.	Applicable Rule or Requirement	Monitoring	Recordkeeping	Semi-annual Reports	Test Methods	Comments
50	Rule 50	•Periodic visual inspections •Annual compliance certification, including a formal survey •Opacity readings upon request •Notification required for uncorrectable visible emissions	•All occurrences of visible emissions for periods>3min in any one hour •Annual formal survey of all emissions units	None	•Opacity - EPA Method 9	
54.B.1	Rule 54.B.1	•Annual compliance certification •Follow monitoring requirements under Rule 64 •Upon request, source test for sulfur compounds at point of discharge	None	None	•Sulfur Compounds - EPA Test Method 6, 6A, 6C, 8, 15, 16A,16B, or SCAQMD Method 307-94, as appropriate	•Compliance with Rule 64 ensures compliance with this rule based on District analysis
54.B.2	Rule 54.B.2	•Annual compliance certification •Determine ground or sea level concentrations of SO_2, upon request	•Representative fuel analysis or exhaust analysis and compliance demonstration	None	•SO_2 - BAAQMD Manual of Procedures, Vol.VI, Section 1, Ground Level Monitoring for H_2S and SO_2	
55	Rule 55	•Annual compliance certification	•Specific activity records as applicable	None	•EPA Method 9 with modifications	
57.1	Rule 57.1	•Annual compliance certification	None	None	None	•Not required based on District analysis
64.B.1	Rule 64.B.1	•Annual compliance certification •None for PUC-quality gas •Annual test for non PUC-quality gas (submit with annual compliance certification)	•Annual fuel gas analysis for non PUC-quality gas	None	•SCAQMD Method 307-94	
64.B.2	Rule 64.B.2	•Annual compliance certification •Fuel supplier's certification, or fuel test per each delivery (submit with annual compliance certification)	•Fuel supplier's certification, or fuel test per each delivery	None	•ASTM Method D4294-83 or D2622-87	
71.1.C	Rules 71.1.C and 74.10	•Annual compliance certification •Rule 74.10 inspections •Visual inspection to ensure collection system is closed •Quarterly inspection of flare to ensure proper operation	•Records of inspections of flare •Rule 74.10 records	None	None	Compliance with Rule 74.10 ensures compliance with the gas collection system's maintenance requirements

1.c.3. General Applicable Requirements (Continued)

Attachment No./ Condition No.	Applicable Rule or Requirement	Monitoring	Recordkeeping	Semi-annual Reports	Test Methods	Comments
71.4.B.1	Rule 71.4.B.1	•Annual compliance certification to ensure there are no first stage sumps	None	None	None	
71.4.B.3	Rule 71.4.B.3	•Annual compliance certification	•Records of maintenance or well workover activity during periods of crude oil storage	None	None	
74.6	Rule 74.6	•Conduct periodic facility inspections •Annual compliance certification •Maintain current solvent information •Upon request, solvent testing	•Records of current solvent information	None	•ROC content-EPA Test Method 24 or 24A •Identity of solvent components-ASTM E168-67, ASTM E169-87, or ASTM E260-85 •True vapor pressure or composite partial pressure -ASTM D2879-86 •Initial boiling point-ASTM 1078-78 or published source •Spray gun active/passive solvent losses-SCAQMD Method (10-3-89)	
74.10	Rule 74.10	•Annual compliance certification •Identify leaking components •Inspections every shift or 8 hours at natural gas processing plants •Daily and/or weekly inspections for specified equipment •Quarterly inspections for specified components •Pressure relief valve inspections •Annual update to Operator Management Plan •Notification of major leaks in critical components •Notification of repeat leaks	•Records of leak inspections in inspection log	None	•Gas Leaks - EPA Method 21 •ROC Concentration of Gas Streams - ASTM E168-88, ASTM E169-87, or ASTM E260-85 •Weight percentage of evaporated compounds of liquids - ASTM Method D 86-82 •API Gravity - ASTM Method D287	
74.11.1	Rule 74.11.1	•Annual compliance certification •Maintain identification records of large water heaters and small boilers	•Records of current information of large water heaters and small boilers	None	None	•Rule only applies to future installation of large water heaters and small boilers
74.22	Rule 74.22	•Annual compliance certification •Maintain furnace identification records	•Records of current furnace information	None	None	•Rule only applies to future installation of natural gas-fired, fan-type furnaces

1.c.4. General Requirements for Short-Term Activities

The General Requirements for Short-Term Activities Table includes a summary of the monitoring requirements, recordkeeping requirements, reporting requirements, and test methods associated with the attachments contained in Section No. 10 of this permit.

Attachment No./ Condition No.	Applicable Rule or Requirement	Monitoring	Recordkeeping	Semi-annual Reports	Test Methods	Comments
74.1	Rule 74.1	•Monitor each abrasive blasting operation •Annual compliance certification •Abrasive blasting records	•Abrasive blasting records	None	•Visible emission evaluation-Section 92400 of CCR	
74.2	Rule 74.2	•Conduct periodic inspections •Annual compliance certification •Maintain VOC records of coatings used	•Maintain VOC records of coatings used	None	•Pursuant to Rule 74.2.G	
74.4.D	Rule 74.4.D	•Annual compliance certification •Test ROC content of oil sample being proposed for usage	•Records of oil analyses	None	•ASTM D402	
74.16	Rule 74.16	•Annual compliance certification to ensure grid power being used, and/or •Annual compliance certification to ensure drilling engine has a valid APCD Permit to Operate, and meets NO_x limit, or •Maintain cost analysis documentation as verification to grid power exemption, if applicable •Annual source tests (NO_x) or engine manufacturer certification	•Records of source tests or engine manufacturer certification •Records of cost analysis documentation	None	•NO_x-ARB Method 100	
74.26	Rule 74.26	•Annual compliance certification •Record vapor concentration and gas flow rate of control device •Record vapor concentration of tank •Vapor destruction or removal efficiency upon request •Insure subcontractor has valid permit for portable equipment, if applicable •Notification req'd for degassing	•Vapor concentration and gas flow rate of control device •Vapor concentration of tank being degassed	None	•Liquid mRVP-ASTM Method D 323-82 •Vapor concentration-EPA Method 21 •Vapor flow-EPA Method 2A •Vapor destruction or removal efficiency-EPA Method 25A	

1.c.4. General Requirements for Short-Term Activities (Continued)

74.29N3	Rule 74.29	•Annual compliance certification •Weekly measurements of in-situ soil bioventing or bioremediation •Weekly measurements of soil aeration •Date and quantity of soil aerated •Notification req'd for excavation	•Weekly measurements of soil decontamination operation vapor concentration •Date and quantity of soil aerated	None	•Vapor concentration- EPA Method 21 •Wt. % of contaminant in soil-EPA Method 8015B	

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2. PERMITTED EQUIPMENT AND APPLICABLE REQUIREMENTS TABLE

Purpose

The purpose of this table is to list the emissions units at this stationary source that are permitted to operate pursuant to Rule 10, "Permits Required" and Rule 23, "Exemptions From Permit". The table also provides a list of requirements that are specifically applicable to these emissions units. Permit conditions that enforce these requirements are listed in Section No. 7, "Specific Applicable Requirements" and Section No. 8, "Permit Specific Conditions" of this permit.

In addition to the emission unit specific requirements in Section No. 7 and Section No. 8, there are additional general requirements that may apply to the emissions units listed in this table, or to the stationary source as a whole. Furthermore, some general requirements may apply to emissions units or short-term activities not required to be specifically listed on the permit. These general requirements are contained in the following sections of the Permit: Section No. 9, "General Applicable Requirements"; Section No. 10, "General Requirements for Short-Term Activities"; Section No. 11, "General Permit Conditions"; and Section No. 12, "Miscellaneous Federal Program Conditions".

Equipment Description

This portion of the table provides a brief description of the permitted equipment at this stationary source. Attached to the table is a "Title V Equipment List Description Key" that contains definitions and explanations for some of the standard terminology used in the equipment description.

Applicable Requirements

The applicable requirements portion of the table is a matrix of applicability for the specific requirements that apply to the listed emissions units. The columns are labeled with APCD rule numbers or references to federal requirements. An "X" in the row corresponding to the emissions unit indicates the requirement is specifically applicable to that unit. For cases where a rule has multiple compliance options, a number appears instead of an "X". The number is a code key that corresponds to the "Title V Applicable Requirement Code Key" attached to the table. The code key table contains specific citations for the portions of the rule that are applicable. The code key is also used to identify the permit attachment in Section No. 7 , "Specific Applicable Requirements", that contains the associated permit conditions. For example, code key "1" under Rule 71.1 is associated with Attachment 71.1N1 in Section No. 7.

Permit specific conditions are identified with a "PC" followed by a number in the column labeled "ADD REQ" (additional requirements). A "PC#" in the row corresponding to the emissions unit indicates that the permit specific condition is specifically applicable to that unit. The "PC#" also corresponds to the permit attachment in Section No. 8, "Permit Specific Conditions", that contains the permit specific requirements.

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TABLE NO. 2

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
Permit to Operate No. 00012
Permitted Equipment and Applicable Requirements

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Equipment		71.1	71.3	74.9	74.15	74.15.1	ATCM Engine	RICE MACT	Additional Requirements
Indirect Process Heat									
1 - 20.0 MMBTU/Hr NG/FO Erie City Boiler (7) Lo Nox (36 PPM)	OOS				1				PC1, PC3, PC8
1 - 4.0 MMBTU/Hr NG/FO Boiler (5) Standby UNC	OOS					4			PC1, PC8
1 - 4.5 MMBTU/Hr NG/FO Boiler (6) Standby UNC	OOS					4			PC1, PC8
1 - 3.0 MMBTU/Hr NG/FO Boiler (1) Standby UNC	OOS					4			PC1, PC8
1 - 3.0 MMBTU/Hr NG/FO Boiler (4) Standby UNC	OOS					4			PC1, PC8
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC (3500 Tank Farm)	OOS					4			PC1, PC8
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC (3500 Tank Farm)	OOS					4			PC1, PC8
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC (3500 Tank Farm)	OOS					4			PC1, PC8
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC (3500 Tank Farm)	OOS					4			PC1, PC8
Solids Recycling and Disposal System									
1 - 150 BBL Slop Tank (TC-14) VR	OOS	1							PC1, PC8
1 - 500 BBL PWT (501) VR	OOS	1							PC8
1 - 500 BBL PWT (502) VR	OOS	1							PC8
Produced Gas Sweetening System									
1 (or More) - Nitrite Solution Vessels									PC2
Flare									
1 - 5.0 MMBTU/Hr Flare, PROS, Inc., Model FLTR-1, 45 scf/hr pilot, 26' high, electronic auto ignition pilot, sulfur pre-treatment system, used as backup VR system									PC9
Portable Steam Generators for Thermally EOR									
1 - 20.0 MMBTU/Hr NG PCL Industrial Services, Inc. Steam Generator (0), equipped with Coen QLN-II Low NOx burner, automatic FGR, fired on PUC Natural gas, with PUC natural gas mixed with produced gas as secondary fuel					1				PC1,PC5
1 - 20.0 MMBTU/Hr NG Steam Generator (1) Lo NOx					1				PC1,PC5
1 - 20.0 MMBTU/Hr NG Steam Generator (2) Lo NOx	OOS				1				PC1,PC5,PC8
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (3) Lo NOx	OOS								PC1, PC8
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (4) Lo NOx					1				PC1, PC5
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (5) Lo NOx	OOS				1				PC1,PC5,PC8
Production Tank System									
1 - 2000 BBL COST (2001) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2002) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2003) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2004) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2005) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2006) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2008) VR		1							PC1
1 - 2000 BBL COST (2009) VR		1							PC1
1 - 2000 BBL COST (2011) VR	OOS	1							PC1,PC8
1 - 2000 BBL COST (2012) VR		1							PC1
1 - 2500 BBL COST (C-1) VR (Transamerica Lease)	OOS	1							PC1,PC8
1 - 2000 BBL COST (C-2) VR (Transamerica Lease @ Texcon)	OOS	1							PC1,PC8
1 - 2000 BBL COST (C-3) VR (Transamerica Lease @ Texcon)	OOS	1							PC1,PC8
1 - 30000 BBL COST (30001) VR	OOS	1							PC1,PC8
1 - 2500 BBL PWT (2501) VR	OOS	1							PC1,PC8
1 - Crude Oil Loading Rack BL VR (Transamerica @ C-1 Tank)	OOS		4						PC1,PC7,PC8
1 - Crude Oil Loading Rack BL VR (Texcon @ C-2,C-3 Tanks)	OOS		4						PC1,PC7,PC8
1 - Crude Oil Loading Rack BL VR (2005-2006 Tank Area)	OOS		4						PC1,PC7,PC8

TABLE NO. 2

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
Permit to Operate No. 00012
Permitted Equipment and Applicable Requirements

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Equipment		71.1	71.3	74.9	74.15	74.15.1	ATCM Engine	RICE MACT	Additional Requirements
Process Heater Prior to Separation Tower									
1 - 20.0 MMBTU/Hr NG/FO Natco Crude Oil Process Heater Lo NOx	OOS				1				PC1,PC4,PC8
Gas Oil (Diluent) Storage & Injection System									
1 - 1500 BBL Gas Oil Storage Tank (1501) VR	OOS	1							PC1, PC8
1 - 1500 BBL Gas Oil Storage Tank (1502) VR		1							PC1
1 - 1500 BBL Gas Oil Storage Tank (1503) VR	OOS	1							PC1,PC8
1 - 700 BBL Gas Oil Storage Tank (701) VR	OOS	1							PC1,PC8
1 - 700 BBL Gas Oil Storage Tank (702) VR	OOS	1							PC1,PC8
1 - 3500 BBL Gas Oil Storage Tank (3500) VR		1							PC1
1 - 3000 BBL Gas Oil Storage Tank (3001) VR	OOS	1							PC1,PC8
1 - 3000 BBL Gas Oil Storage Tank (3003) VR	OOS	1							PC1,PC8
1 - 1500 BBL Gas Oil Storage Tank (1506) VR	OOS	1							PC1,PC8
1 - 1500 BBL Gas Oil Storage Tank (1507) VR		1							PC1
1 - 1000 BBL Gas Oil Storage Tank (1505) VR	OOS	1							PC1,PC8
1 - 2000 BBL Gas Oil Storage Tank (2000) VR	OOS	1							PC1,PC8
1 - Gas Oil Loading Rack BL VR (1501 -1503 Tank Area)	OOS		4						PC1,PC7,PC8
1 - Gas Oil Loading Rack BL VR (3500 Tank Area)			4						PC1
Asphalt Tank Heating and Storage									
1 - 4.9 MMBTU/Hr Asphalt Heater (Tank12001) Lo NOx	OOS					1			PC1,PC8
1 - 4.9 MMBTU/Hr Asphalt Heater (P-1) Lo NOx						1			PC1
1 - 1.0 MMBTU/Hr Asphalt Heater (506) UNC (stndby)	OOS					4			PC1,PC8
1 - 1.0 MMBTU/Hr Asphalt Heater (Shell 1 & 2) UNC (stndby)	OOS					4			PC1,PC8
1 - 12000 BBL Asphalt Storage Tank (12001) VR	OOS	1							PC1,PC8
1 - 2000 BBL Asphalt Storage Tank (2007) VR	OOS	1							PC1,PC8
1 - 2000 BBL Asphalt Storage Tank (2010) VR	OOS	1							PC1,PC8
1 - 800 BBL Asphalt Storage Tank (1001) VR	OOS	1							PC1,PC8
1 - 1000 BBL Asphalt Storage Tank (1002) VR	OOS	1							PC1,PC8
1 - 1000 BBL Asphalt Storage Tank (1003) VR	OOS	1							PC1,PC8
1 - 1000 BBL Asphalt Storage Tank (1004) VR	OOS	1							PC1,PC8
1 - 500 BBL Asphalt Storage Tank (505) VR	OOS	1							PC1.PC8
1 - 500 BBL Asphalt Storage Tank (506) VR	OOS	1							PC1,PC8
1 - 600 BBL Asphalt Storage Tank (Shell 1 & 2) VR	OOS	1							PC1,PC8
1 - 3500 BBL Asphalt Storage Tank (3501) VR	OOS	1							PC1,PC8
1 - Asphalt Loading Rack SF VR (Shell Tanks)	OOS		6						PC1,PC6,PC8
1 - Asphalt Loading Rack SF VR (12001 Tank Farm)	OOS		6						PC1,PC6,PC8
1 - Asphalt Loading Rack SF VR (12001 Tank Farm)	OOS		6						PC1,PC6,PC8
1 - Asphalt Loading Rack SF VR (@ 1002 Tank)	OOS		6						PC1,PC6,PC8
1 - Asphalt Loading Rack SF VR (@ 3501 Tank)	OOS		6						PC1,PC6.PC8
Diesel-Fired Emergency Standby Engine									
1 - 160 BHP Detroit, Model PTA-1SD-50, Serial No. 292084, used for fire suppression	OOS			7			1	3	PC8
For Use Throughout Leases									
70 - Oil Wells									PC1
Exempt Emissions Units									
1 - 40 BHP Perkins Diesel Fired Fire Water Pump Engine	OOS							3	PC8
1 - 130 BHP Gasoline Fired Fire Water Pump Engine	OOS			7				9	PC8
OOS - Out of Service									

TITLE V EQUIPMENT LIST DESCRIPTION KEY

For Title V permits, the Permitted Equipment and Applicable Requirements Table contains a number of terms, abbreviations, and acronyms that have been standardized for oilfield facilities. The following list describes many of the terms on an oilfield equipment list:

BHP The output of an internal combustion engine as measured in brake horsepower.

BL A crude oil loading facility that is equipped with bottom loading capabilities.

Condensate Tank A tank that is used for the purpose of storing water and hydrocarbon liquids recovered from natural gas scrubbers. This tank is assumed to operate with a variable liquid level and has an associated throughput limit.

COST A crude oil storage tank that generally operates with a variable liquid level and has an associated throughput limit. An oil shipping tank that has a truck loading rack is a COST by definition. These tanks may also be known as shipping tanks.

Cover Indicates that a petroleum sump, pit, or pond is equipped with a properly installed and maintained cover which complies with Rule 71.4.

EXEMPT A tank, pit, or sump that processes produced water with an ROC content of less than 5 milligrams per liter and is exempt from Rule 71.1 or Rule 71.4.

Gauge or Test Tank A tank that is used for the purpose of production testing a well or group of wells. This tank is assumed to operate with a variable liquid level and has an associated throughput limit.

LACT Tank A Lease Automated Custody Transfer tank that operates at a constant or near constant liquid level and does not have an associated throughput limit. This tank is generally equipped with a LACT pump for pipeline oil shipping. A shipping tank with a truck loading rack is not by definition a LACT tank, but is a COST.

Loading Facility A crude oil loading rack or loading valve used for the transfer of crude oil from a storage tank or group of tanks to a delivery vessel.

Lo-NOx Device has equipment to control the emissions of NOx and CO to meet the requirements of Rules 74.15 or 74.15.1, or best available control technology requirements.

MMBTU/Hr The heat input of an external combustion device as measured in millions of British Thermal Units per hour.

NG Indicates that the equipment is permitted to be fired on natural gas only.

NG/FO Indicates that equipment is permitted to be fired on natural gas with fuel oil or diesel as a backup fuel.

NSCR Engine that is equipped with non-selective catalytic reduction to meet its Rule 74.9 compliance requirements.

Pit Device used to receive emergency or intermittent flows.

PSC Engine that is equipped with a pre-stratified charge to meet its Rule 74.9 compliance requirements.

PWT A produced water tank that generally operates with a constant liquid level and does not have an associated throughput limit. These tanks may also be known as free water knock out (FWKO) tanks.

Rich Burn or Lean Burn A designation associated with a gas-fired internal combustion engine that determines its Rule 74.9 compliance requirements.

SCR Engine or turbine that is equipped with selective catalytic reduction and ammonia injection to meet its Rule 74.9 or Rule 74.23 compliance requirements.

SF A crude oil loading facility that is equipped with submerged fill loading capabilities.

Sump Device used for separation, generally in constant use.

UNC Indicates that the equipment is uncontrolled. For example, a tank that is not equipped with a vapor recovery system, or an engine or heater that is not equipped with NOx controls are labeled UNC.

VR A vapor recovery system that is installed on a tank, loading rack or loading facility, glycol dehydrator, or other piece of process equipment.

Wash Tank A tank that stores and separates oil and water that generally operates with a constant liquid level. It does not have an associated throughput limit.

TITLE V APPLICABLE REQUIREMENT CODE KEY

Rule 71.1, "Crude Oil Production and Separation"

1. Storage tanks shall be equipped with a vapor recovery system that directs all vapors to a gas gathering system or flare (71.1.B.1.a)
2. Storage tanks shall be equipped with a vapor recovery system that directs all vapors to some other control system with a minimum destruction or removal efficiency of 90% by weight (71.1.B.1.b)
3. Tank batteries installed prior to June 20, 1978 are exempt from vapor recovery when processing crude oil having a modified Reid vapor pressure of less than 0.5 psia. Solid roof and pressure-vacuum relief valve is required. (71.1.B.2/71.1.D.1.a)
4. Storage tanks are exempt from the solid roof and vapor recovery requirements if the ROC content of the liquid entering the tank is less than 5 milligrams per liter. (71.1.D.3)
5. Storage tanks are exempt from the solid roof and vapor recovery requirements if a BACT Cost Analysis indicates that maximum emission reduction has already taken place. (71.1.D.4)
6. Portable tanks shall be equipped with closed covers and pressure vacuum valves and have limited exemptions from vapor recovery requirements. (71.1.B.3/71.1.D.1.c)

Rule 71.3, "Transfer of Reactive Organic Compound Liquids"

1. Requirement for submerged fill pipe or bottom loading and exemption from vapor recovery based on low throughput. (71.3.B.1) Requirement for leak-free equipment. (71.3.B.3)
2. Requirement for bottom loaded vapor recovery system which connects to a gas pipeline recovery and distribution system with automatic primary and secondary overfill protection. (71.3.B.2.a.1 and 71.3.B.2.b.1) Requirement for leak-free equipment. (71.3.B.3)
3. Requirement for bottom loaded vapor recovery system which connects to a 90% vapor disposal system with automatic primary and secondary overfill protection. (71.3.B.2.a.2 and 71.3.B.2.b.1) Requirement for leak-free equipment. (71.3.B.3)
4. Requirement for bottom loaded vapor recovery system which connects to a gas pipeline recovery and distribution system and APCO-approved alternative primary and secondary overfill protection. (71.3.B.2.a.1 and 71.3.B.2.b.2) Requirement for leak-free equipment. (71.3.B.3)
5. Requirement for bottom loaded vapor recovery system which connects to a 90% vapor disposal system and APCO-approved alternative primary and secondary overfill protection (71.3.B.2.a.2 and 71.3.B.2.b.2) Requirement for leak-free equipment. (71.3.B.3)
6. Exemption from Rule 71.3 because the crude oil has a modified Reid vapor pressure of less than 0.5 psia. (71.3.E.1)
7. Requirement for submerged fill pipe or bottom loading and exemption from vapor recovery when transfer is from a tank exempt from the vapor recovery requirements of Rule 71.1. (71.3.B.1 and 71.3.E.2) Requirement for leak-free equipment. (71.3.B.3)

8. Requirement for submerged fill pipe or bottom loading and exemption from vapor recovery when transfer is from a tank that is located more than 1200 feet from a loading facility constructed prior to July 1, 1990. (71.3.B.1 and 71.3.E.3) Requirement for leak-free equipment. (71.3.B.3)
9. Exemption from Rule 71.3 because the crude oil is being transferred into a vacuum truck, and not into a ROC liquid delivery vessel as defined in Rule 71.B.26. (71.B.26)

Rule 74.9, "Stationary Internal Combustion Engines"

1. Pre-January 1, 2002 emission limits and post-January 1, 2002 emission limits for natural gas rich burn engines with existing emission controls installed after September 5, 1989. (74.9.B.1 or 74.9.B.2, and 74.9.B.3)
2. Pre-January 1, 2002 emission limits and post-January 1, 2002 emission limits for natural gas lean burn engines with existing emission controls installed after September 5, 1989. (74.9.B.1 or 74.9.B.2, and 74.9.B.3)
3. Post-January 1, 1997 emission limits for natural gas rich burn engines with emission controls installed before September 5, 1989; or installed after March 5, 1992. (74.9.B.1 or 74.9.B.2)
4. Post-January 1, 1997 emission limits for natural gas lean burn engines with emission controls installed before September 5, 1989; or installed after March 5, 1992. (74.9.B.1 or 74.9.B.2) Post-January 1, 1997 emission limit for ammonia, if applicable. (74.9.B.5)
5. Post-January 1, 1997 emission limits for diesel engines. (74.9.B.1 or 74.9.B.2) Post-January 1, 1997 emission limit for ammonia, if applicable. (74.9.B.5)
6. Exemption from Rule 74.9 for engines operated less than 200 hours per calendar year (74.9.D.2)
7. Exemption from Rule 74.9 for emergency standby engines operated during either an emergency or maintenance operation. (74.9.D.3)
8. Exemption from Rule 74.9 for diesel engines with a permitted capacity factor of less than or equal to 15%. (74.9.D.8)
9. Exemption from Rule 74.9 for diesel engines used to power cranes and welding equipment. (74.9.D.9)

Rule 74.15, "Boilers, Steam Generators and Process Heaters"

1. NOx and CO emission limits for units with an annual heat input rate greater than or equal to 9,000 MMBTU per calendar year (74.15.B.1)
2. Tuning and fuel metering requirements for units with an annual heat input rate of less than 9,000 MMBTU per calendar year. (74.15.B.2 and 74.15.D.1)

Rule 74.15.1, "Boilers, Steam Generators and Process Heaters"

1. NOx and CO emission limits for units with an annual heat input greater than or equal to 1,800 MMBTU. (74.15.1.B.1)
2. Tuning and fuel metering requirements for units with an annual heat input rate of greater than or equal to 300 MMBTU and less than 1,800 MMBTU. (74.15.1.B.2 and 74.15.1.D.1)

3. Exemption from tuning requirements for units with an annual heat input rate less than 300 MMBTU and requirement for metering. (74.15.1.B.2 and 74.15.1.D.1)
4. Equipment is currently shut-down and not operating. Upon operation will install fuel meter (74.15.1.D.1). Based on annual heat input will perform tuning (74.15.1.B.2) or will comply with NOx and CO emission limits (74.15.1.B.1).

Section 93115, Title 17, California Code of Regulations California Airborne Toxic Control Measure For Stationary Compression Ignition (CI) Engines

1. In-use emergency fire pump assembly engines
2. In-use emergency engines operated not more than 20 hours per year for maintenance and testing purposes.
3. Engines operated solely on OCS Platforms
4. In-use emergency engines – 50 hours per year
5. Emergency engines installed after January 1, 2005

40 CFR Part 63, Subpart ZZZZ, National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engine (RICE MACT)

1. Existing compression ignition and spark ignition engine compliance dates
2. Existing landfill gas engines – area source
3. Existing emergency diesel engines – area source
4. Existing non-emergency diesel engines ≤ 300 HP – area source
5. Existing non-emergency diesel engines 300 HP < X ≤ 500 HP – area source
6. Existing non-emergency diesel engines < 500 HP – area source
7. Existing non-emergency spark-ignited remote engine > 500 HP – area source
8. Existing non-emergency diesel engines greater than 300 HP at an area source of HAPs that qualify under the national security exemption
9. Existing emergency spark ignited engines

3. PERMITTED THROUGHPUT AND CONSUMPTION LIMIT TABLE

Purpose

The purpose of this table is to list the emissions units at this stationary source that have limitations on throughput, fuel consumption, raw material usage, hours of operation, or other parameters that limit the potential to emit of the emissions unit. In some cases, the limit on the potential to emit is expressed directly as a set of pollutants and emission limits in tons per year.

These limitations are applied pursuant to Rule 26, "New Source Review" or Rule 29, "Conditions on Permits." Two sets of limits are listed in this table. The "Throughput Permit Limit" is the enforceable limit pursuant to this permit. Permit conditions that enforce these limits are listed in Section No. 7, "Permit Specific Conditions" of this permit.

The "Calculation Throughput" is used only to calculate permitted emissions pursuant to Rule 29, "Conditions on Permits."

Equipment Description

This portion of the table is the same as the equipment description in the "Permitted Equipment and Applicable Requirements Table."

Throughput Permit Limit

The throughput or consumption limit listed in this column of the table is an enforceable limit on the emissions unit's potential to emit. In the column labeled "District (D)/ Federal (F) Enforceable," a "D" or an "F" denotes whether the limit is only enforceable by the District or whether the limit is a federally-enforceable limit. District-enforceable limits are limits applied solely pursuant to Rule 29, "Conditions on Permits." Limits that have been applied pursuant to Rule 26, "New Source Review" are federally enforceable.

The throughput permit limit may apply to a single emissions unit or to a set of emission units. When the limit applies to set of emissions units, the set consists of the emissions unit with which the limit is listed and the emissions units which follow that have an asterisk in the throughput permit limit column.

Pursuant to Rule 26 and Rule 29, the throughput permit limit is an annual limit which is enforceable based on a period of any twelve (12) consecutive calendar months.

Note that when the calculation throughput (discussed below) corresponds to using the emissions unit full time (8760 hours per year) at maximum rated capacity, the throughput permit limit column contains the notation "No Limit." When District emission calculation procedures do not involve throughput or consumption data, both the throughput permit limit and the calculation throughput column are left blank.

Calculation Throughput

The throughput or consumption limit listed in this column of the table is the throughput used in the District calculation procedures to calculate permitted emissions for the emissions unit. The calculation throughput may apply to a single emissions unit or to a set of emissions units denoted as discussed above. The calculation throughput is not an enforceable permit limit.

Abbreviations

The following abbreviations have been used in the "Permitted Throughput and Consumption Limit Table" for the "Throughput Permit Limit" column and for the "Calculation Throughput Limit" column:

BBL/Yr: barrels per year
Days/Yr: days per year
FO: fuel oil or diesel fuel
Gal/Yr: gallons per year
Hrs/Day: hours per day
Hrs/Yr: hours per year
Lbs/day: pounds per day
Lbs ROC/Yr: pounds of reactive organic compounds per year
MBBL/Yr: thousands of barrels per year
MGal/Yr: thousands of gallons per year
MMBTU/Yr: million British Thermal Units of heat input per year
MMCF/Yr: million standard cubic feet of natural gas per year
MMGal/Yr: million gallons per year
NG: natural gas
TPY: tons per year

TABLE NO. 3

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
Permit to Operate No. 00012
Permitted Throughput/Consumption Limits

M:\TITLEV\TV PERMITS\PO0012\PERMITV\Tables_00012-321 Equipment		Permit Throughput Limit	District (D)/ Federal(F) Enforceable	Calculation Throughput Limit
Indirect Process Heat				
1 - 20.0 MMBTU/Hr NG/FO Erie City Boiler (7) Lo NOx	OOS	144.0 MMCF/Yr NG & 7.1 MGal/Yr FO & 152,201.1 MMBTU/Yr Total Fuel	F	144 MMCF/Yr NG & 7.09 Mgal/Yr FO
1 - 4.0 MMBTU/Hr NG/FO Boiler (5) Standby UNC	OOS	76.6 MMCF/Yr NG & 13.8 Mgal/Yr FO & 82,320 MMBTU/Yr Total Fuel	D	15.8 MMCF/Yr NG & 10.3 MGal/Yr FO
1 - 4.5 MMBTU/Hr NG/FO Boiler (6) Standby UNC	OOS	*	D	*
1 - 3.0 MMBTU/Hr NG/FO Boiler (1) Standby UNC	OOS	*	D	*
1 - 3.0 MMBTU/Hr NG/FO Boiler (4) Standby UNC	OOS	*	D	*
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	*	D	*
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	*	D	*
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	*	D	*
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	*	D	*
Solids Recycling and Disposal System				
1 - 150 BBL Slop Tank (TC-14) VR	OOS	21.9 MBOPY	D	21.9 MBOPY
1 - 500 BBL PWT (501) VR	OOS			
1 - 500 BBL PWT (502) VR	OOS			
Produced Gas Sweetening System				
1 (or More) - Nitrite Solution Vessels (No PE)				
Flare				
1 - 5.0 MMBTU/Hr Flare, PROS, Inc., Model FLTR-1, 45 scf/hr pilot, 26' high, electronic auto ignition pilot, sulfur pre-treatment system, used as backup VR system		No Limit	F	43,800 MMBTU/yr
Portable Steam Generators for Thermally EOR				
1 - 20.0 MMBTU/Hr NG PCL Industrial Services, Inc. Steam Generator (0) w/ Coen QLN-II low NOx burner, automatic FGR, fired on PUC natural gas, with PUC natural gas mixed with produced gas as secondary fuel		163.3 MMCF/Yr NG & 0 MGal/Yr FO	F	163.3 MMCF/Yr NG
1 - 20.0 MMBTU/Hr NG Steam Generator (1) Lo NOx		163.3 MMCF/Yr NG & 0 MGal/Yr FO	F	163.3 MMCF/Yr NG
1 - 20.0 MMBTU/Hr NG Steam Generator (2) Lo NOx	OOS	163.3 MMCF/Yr NG & 0 MGal/Yr FO	F	163.3 MMCF/Yr NG
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (3) Lo NOx	OOS	163.3 MMCF/Yr NG & 5.91 MGal/Yr FO	F	163.3 MMCF/Yr NG & 5.91 MGal/Yr FO
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (4) Lo NOx		163.3 MMCF/Yr NG & 5.91 MGal/Yr FO	F	163.3 MMCF/Yr NG & 5.91 MGal/Yr FO
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (5) Lo NOx	OOS	163.3 MMCF/Yr NG & 5.91 MGal/Yr FO	F	163.3 MMCF/Yr NG & 5.91 MGal/Yr FO
Production Tank System				
1 - 2000 BBL COST (2001) VR	OOS	2,241.0 MBBL/Yr	D	547.0 MBBL/Yr
1 - 2000 BBL COST (2002) VR	OOS	*	D	547.0 MBBL/Yr
1 - 2000 BBL COST (2003) VR	OOS	*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2004) VR	OOS	*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2005) VR	OOS	*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2006) VR	OOS	*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2008) VR		*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2009) VR		*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2011) VR	OOS	*	D	143.4 MBBL/Yr
1 - 2000 BBL COST (2012) VR		*	D	143.4 MBBL/Yr
1 - 2500 BBL COST (C-1) VR (Transamerica Lease)	OOS	136.3 MBBL/Yr	D	136.3 MBBL/Yr
1 - 2000 BBL COST (C-2) VR (Transamerica Lease@Texcon)	OOS	356.0 MBBL/Yr	D	178.0 MBBL/Yr
1 - 2000 BBL COST (C-3) VR (Transamerica Lease@Texcon)	OOS	*	D	178.0 MBBL/Yr
1 - 30000 BBL COST (30001) VR	OOS	110.0 MBBL/Yr	D	110.0 MBBL/Yr
1 - 2500 BBL PWT (2501) VR	OOS			
1 - Crude Oil Loading Rack BL VR (Transamerica@C-1 Tank)	OOS	191.4 MBBL/Yr	D	191.4 MBBL/Yr
1 - Crude Oil Loading Rack BL VR (Texcon@C-2,C-3 Tanks)	OOS	227.9 MBBL/Yr	D	227.9 MBB;L/Yr
1 - Crude Oil Loading Rack BL VR (2005-2006 Tank Area)	OOS	529.2 MBBL/Yr	D	529.2 MBBL/Yr
Process Heater Prior to Separation Tower				
1 - 20.0 MMBTU/Hr NG/FO Natco Crude Oil Process Heater Lo NOx	OOS	136.1 MMCF/Yr NG & 7.1 MGal/Yr FO & 143,801.1 MMBTU/Yr Total Fuel	F	136.1 MMCF/Yr NG and 7.09 MGal/Yr FC
Gas Oil (Diluent) Storage & Injection System				
1 - 1500 BBL Gas Oil Storage Tank (1501) VR	OOS	702.4 MBBL/Yr	F	115.0 MBBL/Yr
1 - 1500 BBL Gas Oil Storage Tank (1502) VR		*	F	91.4 MBBL/Yr

TABLE NO. 3

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT Permit to Operate No. 00012 Permitted Throughput/Consumption Limits				
M:\TITLEV\TV PERMITS\PO0012\PERMITV\Tables_00012-321 Equipment		Permit Throughput Limit	District (D)/ Federal(F) Enforceable	Calculation Throughput Limit
1 - 1500 BBL Gas Oil Storage Tank (1503) VR	OOS	*	F	70.0 MBBL/Yr
1 - 700 BBL Gas Oil Storage Tank (701) VR	OOS	*	F	100.0 MBBL/Yr
1 - 700 BBL Gas Oil Storage Tank (702) VR	OOS	*	F	100.0 MBBL/Yr
1 - 3500 BBL Gas Oil Storage Tank (3500) VR		*	F	20.0 MBBL/Yr
1 - 3000 BBL Gas Oil Storage Tank (3001) VR	OOS	*	F	20.0 MBBL/Yr
1 - 3000 BBL Gas Oil Storage Tank (3003) VR	OOS	*	F	20.0 MBBL/Yr
1 - 1500 BBL Gas Oil Storage Tank (1506) VR	OOS	*	F	146.0 MBBL/Yr
1 - 1500 BBL Gas Oil Storage Tank (1507) VR		*	F	10.0 MBBL/Yr
1 - 1000 BBL Gas Oil Storage Tank (1505) VR	OOS	*	F	5.0 MBBL/Yr
1 - 2000 BBL Gas Oil Storage Tank (2000) VR	OOS	*	F	5.0 MBBL/Yr
1 - Gas Oil Loading Rack BL VR (1501 -1503 Tank Area)	OOS	345.2 MBBL/Yr	F	345.2 MBBL/Yr
1 - Gas Oil Loading Rack BL VR (3500 Tank Area)		*	F	*
Asphalt Tank Heating and Storage				
1 - 4.9 MMBTU/Hr Asphalt Heater (Tank 12001) Lo NOx	OOS	**	D	60.8 MMCF/Yr NG and 3.5 MGal/Yr FO
1 - 4.9 MMBTU/Hr Asphalt Heater (P-1) Lo NOx		**	D	*
1 - 1.0 MMBTU/Hr Asphalt Heater (506) UNC (stndby)	OOS	**	D	***
1 - 1.0 MMBTU/Hr Asphalt Heater (Shell 1 & 2) UNC (stndby)	OOS	**	D	***
1 - 12000 BBL Asphalt Storage Tank (12001) VR	OOS	1,034.9 MBBL/Yr	D	300.0 MBBL/Yr
1 - 2000 BBL Asphalt Storage Tank (2007) VR	OOS	*	D	150.0 MBBL/Yr
1 - 2000 BBL Asphalt Storage Tank (2010) VR	OOS	*	D	150.0 MBBL/Yr
1 - 800 BBL Asphalt Storage Tank (1001) VR	OOS	*	D	10.0 MBBL/Yr
1 - 1000 BBL Asphalt Storage Tank (1002) VR	OOS	*	D	50.0 MBBL/Yr
1 - 1000 BBL Asphalt Storage Tank (1003) VR	OOS	*	D	30.0 MBBL/Yr
1 - 1000 BBL Asphalt Storage Tank (1004) VR	OOS	*	D	30.0 MBBL/Yr
1 - 500 BBL Asphalt Storage Tank (505) VR	OOS	*	D	0.0 MBBL/Yr
1 - 500 BBL Asphalt Storage Tank (506) VR	OOS	*	D	0.0 MBBL/Yr
1 - 600 BBL Asphalt Storage Tank (Shell 1 & 2) VR	OOS	*	D	21.9 MBBL/Yr
1 - 3500 BBL Asphalt Storage Tank (3501) VR	OOS	*	D	293.0 MBBL/Yr
1 - Asphalt Loading Rack SF VR (Shell Tanks)	OOS	17,178.0 MGal/Yr	D	17,178 MGal/Yr
1 - Asphalt Loading Rack SF VR (12001 Tank Farm)	OOS	*	D	*
1 - Asphalt Loading Rack SF VR (12001 Tank Farm)	OOS	*	D	*
1 - Asphalt Loading Rack SF VR (@ 1002 Tank)	OOS	*	D	*
1 - Asphalt Loading Rack SF VR (@ 3501 Tank)	OOS	*	D	*
Diesel-Fired Emergency Standby Engine				
1 - 160 BHP Detroit, Model PTA-1SD-50, Serial No 292084, used for fire suppression	OOS	20 Hr/yr****	D	20 Hr/yr
For Use Throughout Leases				
70 - Oil Wells				

* - Included in Limit Above
** - Included in Permit Throughput Limit Abovefor Standby Boiler (5)
*** - Included in Calculation Throughput Limit for standby Boiler (5)
**** - Limit for maintenance and testing, does not include emergency operation
OOS - Out of Service
Note: The MMBtu/Yr values were calculated based on Heating Values of 1050 Btu/Scf for NG and 141,000 Btu/Gal for FO

4. PERMITTED EMISSIONS TABLE

Purpose

The purpose of this table is to document the permitted emissions for this stationary source. Rule 29, “Conditions on Permits,” requires permitted emissions to be included on each Permit to Operate. Rule 29 is not federally enforceable.

The permitted emissions table also characterizes the amount and type of criteria air pollutants emitted by this stationary source.

Rule 29 requires that annual permitted emissions be based on a 12 calendar month rolling period and be expressed in units of tons per year. Hourly permitted emissions are required to be expressed in units of pounds per hour. Permitted emissions for a stationary source are required to be determined by aggregating the permitted emissions for each emissions unit at the stationary source.

In general, permitted emissions are calculated based on throughput or consumption data for an emission unit, specific physical characteristics of the emission unit, and emission factors. The emission factors may be standard published emission factors, or they may be derived from source test data or specific emission limits that apply to the emissions unit. In some cases, permitted emissions are expressed directly as a set of pollutants and emission limits in tons per year without reference to any calculation method.

Section No. 3, “Permitted Throughput and Consumption Limit Table,” contains information on the throughput and consumption limits that are enforceable at this stationary source. In addition, other sections of this permit contain conditions that act to enforce specific portions of the permitted emissions table.

Equipment Description

This portion of the table is the same as the equipment description in the "Permitted Equipment and Applicable Requirements Table."

Tons Per Year

This column of the table represents the permitted emissions in units of tons per year for ROC (reactive organic compounds), NOx (nitrogen oxides), PM (particulate matter), SOx (sulfur oxides), and CO (carbon monoxide). In some cases, emissions of non-criteria pollutants of interest may also be listed. Pursuant to Rule 29, annual permitted emissions shall be the annual emissions used to determine compliance for issuance of any new or revised permit issued after October 22, 1991. For emissions units for which no new or revised permit has been issued since

October 22, 1991, annual permitted emissions generally reflect actual historical emissions from the emissions unit.

The permitted emissions limit may apply to a single emissions unit or to a set of emission units. When the limit applies to set of emissions units, the set consists of the emissions unit with which the limit is listed and the emissions units which follow that have an asterisk in the pollutant columns.

Pounds Per Hour

This column of the table represents the permitted emissions in units of pounds per hour for ROC (reactive organic compounds), NOx (nitrogen oxides), PM (particulate matter), SOx (sulfur oxides), and CO (carbon monoxide). Pursuant to Rule 29, hourly permitted emissions shall be calculated based on the maximum quantity of each air pollutant which may be emitted from the emissions unit during a one-hour period, as limited by any applicable rules or permit conditions.

Hazardous Air Pollutants

This permit does not provide information that characterizes the emissions of hazardous air pollutants (HAPS) from this facility. This information can be obtained from the reissuance application or the facility's AB-2588, Air Toxics "Hot Spots," Report referenced at the bottom of the "Permitted Emissions Table." For Outer Continental Source (OCS) sources and other sources not subject to AB-2588, HAP emissions information is included in the permit reissuance application and is maintained by the stationary source.

TABLE NO. 4

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
Permit to Operate No. 00012
Permitted Emissions

M:\TITLEV\TV PERMITS\PO0012\PERMIT V\Tables_00012-321		TONS PER YEAR					POUNDS PER HOUR				
Equipment		ROC	NOx	PM	SOx	CO	ROC	NOx	PM	SOx	CO
Indirect Process Heat											
1 - 20.0 MMBTU/Hr NG/FO Erie City Boiler (7) Lo NOx	OOS	0.40	3.33	0.56	3.15	7.34	0.10	2.84	0.28	10.18	1.93
1 - 4.0 MMBTU/Hr NG/FO Boiler (5) Standby UNC	OOS	0.04	0.89	0.07	0.69	0.69	0.02	0.57	0.06	2.04	0.32
1 - 4.5 MMBTU/Hr NG/FO Boiler (6) Standby UNC	OOS	**	**	**	**	**	0.02	0.64	0.06	2.29	0.36
1 - 3.0 MMBTU/Hr NG/FO Boiler (1) Standby UNC	OOS	**	**	**	**	**	0.02	0.43	0.04	1.53	0.24
1 - 3.0 MMBTU/Hr NG/FO Boiler (4) Standby UNC	OOS	**	**	**	**	**	0.02	0.43	0.04	1.53	0.24
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	**	**	**	**	**	0.02	0.45	0.04	1.60	0.25
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	**	**	**	**	**	0.02	0.45	0.04	1.60	0.25
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	**	**	**	**	**	0.02	0.45	0.04	1.60	0.25
1 - 3.15 MMBTU/Hr NG/FO Boiler Standby UNC(3500TF)	OOS	**	**	**	**	**	0.02	0.45	0.04	1.60	0.25
Solids Recycling and Disposal System											
1 - 150 BBL Slop Tank (TC-14) VR	OOS	0.01					0.00				
1 - 500 BBL PWT (501) VR	OOS	0.01					0.00				
1 - 500 BBL PWT (502) VR	OOS	0.03					0.01				
Produced Gas Sweetening System											
1 (or More) - Nitrite Solution Vessels (No PE)											
Flare											
1 - 5.0 MMBTU/Hr Flare, PROS, Inc., Model FLTR-1, 45 scf/hr pilot, 26' high, electronic auto ignition pilot, sulfur pre-treatment system, used as backup VR system		1.13	1.49	0.11	0.07	8.10	0.26	0.34	0.03	0.02	1.85
Portable Steam Generators for Thermally EOR											
1 - 20.0 MMBTU/Hr NG PCL Industrial Services, Inc. Steam Generator (0) w/ Coen QLN-II Low NOx burner, automatic FGR, fired on PUC natural gas, with PUC natural gas mixed with produced gas as secondary fuel		0.45	0.27	0.62	0.27	2.73	0.10	0.06	0.14	0.06	0.63
1 - 20.0 MMBTU/Hr NG Steam Generator (1) Lo NOx		4.53	4.08	0.62	3.29	4.59	1.05	0.95	0.14	0.77	1.07
1 - 20.0 MMBTU/Hr NG Steam Generator (2) Lo NOx	OOS	0.45	4.08	0.62	3.29	3.69	0.10	0.95	0.14	0.77	0.86
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (3) Lo NOx	OOS	1.79	4.16	0.63	3.40	8.25	0.42	3.14	0.24	4.26	1.92
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (4) Lo NOx		0.45	4.17	0.63	3.40	6.87	0.10	3.74	0.24	4.26	1.60
1 - 20.0 MMBTU/Hr NG/FO Steam Gen. (5) Lo NOx	OOS	0.45	4.17	0.63	3.40	6.87	0.10	3.74	0.24	4.26	1.60
Production Tank System											
1 - 2000 BBL COST (2001) VR	OOS	0.37					0.09				
1 - 2000 BBL COST (2002) VR	OOS	0.37					0.09				
1 - 2000 BBL COST (2003) VR	OOS	0.50					0.11				
1 - 2000 BBL COST (2004) VR	OOS	0.50					0.11				
1 - 2000 BBL COST (2005) VR	OOS	0.50					0.11				
1 - 2000 BBL COST (2006) VR	OOS	0.50					0.11				
1 - 2000 BBL COST (2008) VR		0.81					0.18				
1 - 2000 BBL COST (2009) VR		0.81					0.18				
1 - 2000 BBL COST (2011) VR	OOS	0.81					0.18				
1 - 2000 BBL COST (2012) VR		0.81					0.18				
1 - 2500 BBL COST (C-1) VR (Transamerica Lease)	OOS	0.13					0.03				
1 - 2000 BBL COST (C-2) VR (Transamerica Lease@Texcon)	OOS	0.15					0.03				
1 - 2000 BBL COST (C-3) VR (Transamerica Lease@Texcon)	OOS	0.15					0.03				
1 - 30000 BBL COST (30001) VR	OOS	0.58					0.14				
1 - 2500 BBL PWT (2501) VR	OOS	0.05					0.01				
1 - Crude Oil Loading Rack BL VR (Transamerica@C-1 Tank)	OOS	1.10					2.30				
1 - Crude Oil Loading Rack BL VR (Texcon@C-2,C-3 Tanks)	OOS	1.31					2.30				
1 - Crude Oil Loading Rack BL VR (2005-2006 Tank Area)	OOS	0.44					0.34				
Process Heater Prior to Separation Tower											
1 - 20.0 MMBTU/Hr NG/FO Natco Crude Oil Process Heater Lo NOx	OOS	0.37	2.96	0.53	2.99	5.73	0.10	2.84	0.28	10.18	1.60

TABLE NO. 4

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
Permit to Operate No. 00012
Permitted Emissions

M:\TITLEV\TV PERMITS\PO0012\PERMITV\Tables_00012-321		TONS PER YEAR					POUNDS PER HOUR				
Equipment		ROC	NOx	PM	SOx	CO	ROC	NOx	PM	SOx	CO
Gas Oil (Diluent) Storage & Injection System											
1 - 1500 BBL Gas Oil Storage Tank (1501) VR	OOS	0.35					0.08				
1 - 1500 BBL Gas Oil Storage Tank (1502) VR		0.33					0.08				
1 - 1500 BBL Gas Oil Storage Tank (1503) VR	OOS	0.32					0.07				
1 - 700 BBL Gas Oil Storage Tank (701) VR	OOS	0.20					0.04				
1 - 700 BBL Gas Oil Storage Tank (702) VR	OOS	0.2					0.04				
1 - 3500 BBL Gas Oil Storage Tank (3500) VR		0.21					0.05				
1 - 3000 BBL Gas Oil Storage Tank (3001) VR	OOS	0.19					0.04				
1 - 3000 BBL Gas Oil Storage Tank (3003) VR	OOS	0.19					0.04				
1 - 1500 BBL Gas Oil Storage Tank (1506) VR	OOS	0.38					0.09				
1 - 1500 BBL Gas Oil Storage Tank (1507) VR		0.09					0.02				
1 - 1000 BBL Gas Oil Storage Tank (1505) VR	OOS	0.05					0.02				
1 - 2000 BBL Gas Oil Storage Tank (2000) VR	OOS	0.09					0.03				
1 - Gas Oil Loading Rack BL VR (1501 -1503 Tank Area)	OOS	1.98					4.60				
1 - Gas Oil Loading Rack BL VR (3500 Tank Area)		*					*				
Asphalt Tank Heating and Storage											
1 - 4.9 MMBTU/Hr Asphalt Heater (Tank 12001) Lo NOx	OOS	0.17	1.18	0.23	1.36	2.56	0.03	0.70	0.07	2.50	0.39
1 - 4.9 MMBTU/Hr Asphalt Heater (P-1) Lo NOx		*	*	*	*	*	0.03	0.70	0.07	2.50	0.39
1.0 MMBTU/Hr Asphalt Heater (506) UNC (stndby)	OOS	**	**	**	**	**	0.01	0.14	0.01	0.51	0.08
1.0 MMBTU/Hr Asphalt Heater (Shell 1 & 2) UNC (stndby)	OOS	**	**	**	**	**	0.01	0.14	0.01	0.51	0.08
1 - 12000 BBL Asphalt Storage Tank (12001) VR	OOS	0.27					0.06				
1 - 2000 BBL Asphalt Storage Tank (2007) VR	OOS	0.07					0.01				
1 - 2000 BBL Asphalt Storage Tank (2010) VR	OOS	0.07					0.01				
1 - 800 BBL Asphalt Storage Tank (1001) VR	OOS	0.02					0.00				
1 - 1000 BBL Asphalt Storage Tank (1002) VR	OOS	0.04					0.01				
1 - 1000 BBL Asphalt Storage Tank (1003) VR	OOS	0.03					0.00				
1 - 1000 BBL Asphalt Storage Tank (1004) VR	OOS	0.03					0.00				
1 - 500 BBL Asphalt Storage Tank (505) VR	OOS	0.01					0.00				
1 - 500 BBL Asphalt Storage Tank (506) VR	OOS	0.01					0.00				
1 - 600 BBL Asphalt Storage Tank (Shell 1 & 2) VR	OOS	0.01					0.00				
1 - 3500 BBL Asphalt Storage Tank (3501) VR	OOS	0.12					0.03				
1 - Asphalt Loading Rack SF VR (Shell Tanks)	OOS	0.23					0.49				
1 - Asphalt Loading Rack VR (12001 Tank Farm)	OOS	*					*				
1 - Asphalt Loading Rack SF VR (12001 Tank Farm)	OOS	*					*				
1 - Asphalt Loading Rack SF VR (@ 1002 Tank)	OOS	*					*				
1 - Asphalt Loading Rack SF VR (@ 3501 Tank)	OOS	*					*				
Diesel-Fired Emergency Standby Engine											
1 - 160 BHP Detroit, Model PTA-1SD-50, Serial No. 292084, used for fire suppression	OOS	0.00	0.05	0.00	0.00	0.01	0.04	0.53	0.04	0.01	0.12
For Use Throughout Leases											
70 - Oil Wells		25.55					5.84				
* - Included in Emissions Above ** - Boiler (5) Includes All Standby Boilers and Heaters OOS - Out of Service											
Total Permitted Emissions		51.21	30.83	5.25	25.31	57.43	20.79	24.68	2.29	54.58	16.28

HAP Emissions Ref.: AB 2588 Air Toxics Report — Reporting Year: 1994 — Submittal Date: July 17, 1996

5. OIL WELL LIST

This permit authorizes the operation of a maximum number of wells for the production of oil or natural gas. This section of the permit contains a list of the wells currently authorized to be operated. When changes to the list are desired, the permit holder is required to submit an application to modify the Part 70 Permit.

An Authority to Construct is also required prior to adding a well that is newly drilled to the oil well list or prior to increasing the number of wells on the oil well list.

Section No. 8, "Permit Specific Conditions", includes a condition that limits the maximum number of producing wells at this stationary source. If applicable, Section No. 8 also includes a condition that requires best available control technology (BACT) on specific wells that were subject to Rule 26, "New Source Review".

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Ventura County Air Pollution Control District

OIL WELL LIST

Part 70 Permit No. 00012

The following oil wells are on permit with at the Tenby Production Facility:

Philtom Lease Wells

Janet   Culberson 2

Chase Lease Wells

El-Rio 1	Chase 14	Chase 28
El-Rio 2	Chase 15	Chase 29
El-Rio 5	Chase 16	Chase 30
El-Rio 7	Chase 17	Chase 31
Chase 1	Chase 18	Chase 32
Chase 2	Chase 20	Chase 33
Chase 3	Chase 21	Chase 34
Chase 5	Chase 22	Chase 35
Chase 6	Chase 23	Chase C8
Chase 8	Chase 24	Chase E9
Chase 9	Chase 25	Chase D11
Chase 11	Chase 26	Chase F12
Chase 12	Chase 27	

Transamerica Lease Wells

Texcon 1	Texcon 213	Texcon 711
Texcon 203	Texcon 214	Texcon 713
Texcon 204	Texcon 215	Texcon 715
Texcon 205	Texcon 216	Texcon 716
Texcon 206	Texcon 217	Texcon 717
Texcon 207	Texcon 218	Texcon 718
Texcon 208	Texcon 219	Texcon 719
Texcon 209	Texcon 702	Transamerica D10
Texcon 210	Texcon 709	TA B5
Texcon 212	Texcon 710	TA C2

Total Number of Wells: 70

6. EXEMPT EQUIPMENT LIST

Rule 33.2.A.3 (Part 70 Permits - Application Contents) requires the applicant to provide a list of all emissions units located at the stationary source that are exempt pursuant to Rule 23 based on size or production rate. Pursuant to Rule 33.2.A.3, emissions from insignificant activities do not need to be included in the permit application.

This section of the permit contains a table entitled "Insignificant Activities (Exempt Equipment)". This table is a list of insignificant activities (exempt equipment) at the facility that are exempt from permit based on a size or production rate exemption in Rule 23, "Exemptions From Permit". Insignificant Activity is defined in Rule 33.1 (Part 70 Permits – Definitions). The permittee shall provide calculations, usage records, emission records, and/or operational data as necessary to substantiate an activity as insignificant.

This table is presented for informational purposes only. Any changes to this list are not considered to be permit modifications, nor is the list considered to be enforceable. As detailed in Rule 33.2.A.3, this list is required to be submitted with an application for permit reissuance. The general requirements listed in Section No. 9 of this permit may apply to these insignificant activities.

Ventura County Air Pollution Control District

INSIGNIFICANT ACTIVITIES (EXEMPT EQUIPMENT)

Part 70 Permit No. 00012

INSIGNIFICANT ACTIVITIES (EXEMPT EMISSION UNITS)	BASIS FOR EXEMPTION (Size/Production Rate)	RULE 23 CITATION
Ajax Boiler at Texcon	< 1 MMBTU/Hr	23.C.1
40 BHP Perkins Diesel Fired Fire Water Pump Engine	< 50 BHP	23.D.6
130 BHP Gasoline Fire Water Pump	Spark-ignited engine used for emergency pumping of water for fire protection, and engine maintenance operation is < 50 hr/yr	23.D.7.a

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7. SPECIFIC APPLICABLE REQUIREMENTS (ATTACHMENTS)

As discussed in Section No. 2, "Permitted Equipment and Applicable Requirements Table", the emissions units at this stationary source listed in the table have requirements that are specifically applicable to them. The applicable requirements are based on the District's prohibitory rules, federal NSPS (40 CFR Part 60), federal NESHAPS (40 CFR Part 61), and federal NESHAPS/MACT (40 CFR Part 63).

In this section of the permit, the permit conditions that are associated with each specific applicable requirement are listed in an individual attachment. The attachment is identified with the label "Attachment (APCD Rule No. or CFR No.) #" in the lower left corner. Each attachment has an applicability section that describes how and why this attachment applies to the specific emissions unit. The attachment may apply to one or more of the emissions units listed in the Permitted Equipment and Applicable Requirements Table in Section No. 2.

Ventura County Air Pollution Control District
Rule 71.1.B.1.a Applicable Requirements
Tanks Equipped with Vapor Recovery

Rule 71.1, "Crude Oil Production and Separation"
Adopted 06/16/92, Federally-Enforceable

Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities"
Adopted 03/10/98, Federally-Enforceable

Applicability:

This attachment applies to tanks at this stationary source equipped with a vapor recovery system which directs all vapors to a fuel gas system, a sales gas system, or to a flare. Specifically, this attachment applies to all storage tanks in a tank battery including wash tanks, produced water tanks, and wastewater separators, that are used in the production, gathering, storage, processing, and separation of crude oil and natural gas from any petroleum production permit unit prior to custody transfer. This attachment does not apply to portable tanks or other tanks not equipped with vapor recovery.

A tank is defined as a container, constructed primarily of nonearthen materials, used for the purpose of storing or holding petroleum material, or for the purpose of separating water and/or gas from petroleum material. A tank battery is defined as any tank or aggregation of tanks. An aggregation of tanks is considered a tank battery only if the tanks are located so that no one tank is more than 150 feet from any other tank, edge to edge.

The tank's hatches and other inlet and outlet liquid and gas piping connections are considered to be components subject to the leak requirements of APCD Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities".

Conditions:

1. Pursuant to Rule 71.1.B.1.a, all tanks shall be equipped with a properly installed, maintained and operated vapor recovery system. The vapor disposal portion of the vapor recovery system shall consist of either a system which directs all vapors to a fuel gas system, a sales gas system, or to a flare that combusts reactive organic compounds.

2. Pursuant to Rule 71.1.D.2, the vapor recovery provisions of Rule 71.1.B.1.a shall not apply during maintenance operations on vapor recovery systems or tank batteries, including wash tanks, produced water tanks and wastewater separators, if the Air Pollution Control District is notified verbally at least 24 hours prior to the maintenance operation and if the maintenance operation will take no more than 24 hours to complete.

3. The tank's hatches and other inlet and outlet gas and liquid piping connections are components subject to the leak requirements of Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities".

4. On a quarterly basis, permittee shall monitor the storage tank vapor recovery system to ensure that compliance with Rule 71.1.B.1.a is being maintained. This shall include an inspection of the following components, as applicable, for proper operation: gas compressor, hatches, relief valves, pressure regulators, flare. Permittee shall keep dated records of the quarterly inspections and tank maintenance activities. These records shall be maintained at the facility and submitted to the District upon request.

5. On an annual basis, permittee shall certify that storage tanks at the facility are complying with Rule 71.1.B.1.a. This annual compliance certification shall include verifying that the tanks are equipped with a vapor recovery system.

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Ventura County Air Pollution Control District
Rules 71.3.B.2.a.1 and 71.3.B.2.b.2 Applicable Requirements
ROC Liquid Loading Facilities
Bottom Loaded Vapor Recovery System To Gas Pipeline
District-Approved Alternative
Primary and Secondary Overfill Protection

Rule 71.3, "Transfer of Reactive Organic Compound Liquids"
Adopted 6/16/92, Federally-Enforceable

Applicability:

This attachment applies to equipment used to transfer reactive organic compound (ROC) liquids with a Modified Reid Vapor Pressure (MRVP) greater than or equal to 0.5 psia. This attachment does not apply to the transfer of gasoline, or to the transfer of ROC liquids via pipeline.

Specifically, this attachment applies to loading facilities that are equipped with a bottom-loaded vapor recovery system that connects to a gas pipeline recovery and distribution system and are equipped with a District-approved alternative primary and secondary overfill protection system.

A loading facility is defined as any aggregation or combination of organic liquid loading equipment which is located so that all the organic liquid loading outlets for such aggregation or combination of loading equipment can be encompassed within any circle of 300 feet in diameter.

Conditions:

1. Pursuant to Rule 71.3.B.2.a.1, no person shall transfer ROC liquids into any ROC liquid delivery vessel without utilizing a bottom-loaded vapor recovery system that prevents the displaced vapors during loading from being released into the atmosphere. The vapor recovery system shall be capable of collecting all ROC vapors, and shall have a vapor return or condensation system that connects to a gas pipeline recovery and distribution system.

2. Pursuant to Rule 71.3.B.2.b.2, no person shall transfer ROC liquids into any ROC liquid delivery vessel without utilizing a combination of overfill devices and/or procedures, submitted in writing to the APCO, that is at least as effective in preventing overfill spillage as the system in Rule 71.3.B.2.b.1. Permittee has submitted an alternative overfill protection system and shall comply with Rule 71.3.B.2.b in the following manner:

    In order to meet primary overfill protection requirements, the applicable loading racks shall be equipped with meters that automatically shut off when the preset volume in gallons is loaded. This preset gallon amount is based on the maximum weight of ROC liquid that can be legally loaded into the delivery vessel. The maximum weight of liquid that can be loaded shall be determined by first weighing the delivery vessel prior to loading, then subtracting its weight from the total legal weight limit, and then dividing the maximum weight by the liquid density (weight per gallon) to get this amount in gallons.

In order to meet secondary overfill protection requirements, the operator shall set the meter initially to a volume in gallons less than that which would indicate a maximum load, and then the operator shall visually check the truck tank level after the meter shuts off the liquid transfer process. The driver shall then determine how much more liquid, if any, can be loaded. The preset fill meter shall also be used for any additional liquid loading.

As an additional precaution, the maximum weight of liquid that can be legally loaded in the delivery vessel shall still allow for additional volume to load more liquid before an overfill condition would occur. This additional volume can equate up to 3500 gallons or more, depending on the type of liquid and delivery vessel being loaded.

3. Pursuant to Rule 71.3.B.2.c, no person shall transfer ROC liquids into any ROC liquid delivery vessel without utilizing either a block and bleed valve system or other connectors with equivalent spill prevention characteristics.

4. Pursuant to Rule 71.3.B.3, any loading operation equipment, vapor recovery system, or other equipment required by Rule 71.3 shall not leak. The vapor recovery system shall be operated and maintained so that it does not cause the pressure in any delivery vessel to exceed 18 inches water gauge or the vacuum to exceed 6 inches water gauge.

5. Pursuant to Rule 71.3.C.1, no person shall transfer ROC liquids into a delivery vessel using loading equipment having a vapor recovery system unless the delivery vessel is leak free and is permanently equipped with:

   a. A properly installed vapor recovery system that is compatible with the loading facility.

   b. A pressure-vacuum relief device for each compartment that is set at 90 percent of the maximum, safe pressure and vacuum ratings of the vessel.

   c. A secondary overfill protection system compatible with the loading operation APCO-approved secondary overfill protection system.

   d. A loading connector/adapter that is compatible with those required at the loading facility.

6. Pursuant to Rule 71.3.C.2, no person shall fill an ROC liquid delivery vessel unless the vapor recovery system is properly operating, properly maintained, does not leak, and all hatches are closed during transfer operations.

7. Pursuant to Rule 71.3.D.1, permittee shall annually monitor one complete loading operation for leaks and for proper operation of the loading equipment and delivery vessel vapor recovery and overfill protection systems. In order to detect leaks during the annual operator inspection, the permittee shall utilize an appropriate analyzer calibrated with methane or the alternative screening procedure in EPA Reference Method 21, as detailed in Rule 71.3.G.3.

8. Pursuant to Rule 71.3.D.2, permittee shall notify the District Enforcement Section of the following problems no later than 72 hours after the annual inspection required by Rule 71.3.D.1:

    a. If any leaks were detected,
    b. If the vapor recovery system, including any flare or incinerator, was not operating properly,
    c. If any hatches were opened during the filling operation,
    d. If the overfill prevention systems malfunctioned, or
    e. If any spillage of ROC liquid occurred.

9. Pursuant to Rule 71.3.D.3, any leak detected shall be repaired to a leak free state and any vapor recovery system or overfill prevention system found malfunctioning shall be restored to a properly operating condition. These repairs shall be done as soon as practicable but no later than 5 calendar days from the detection date.

10. Pursuant to Rule 71.3.F.1, the operator of any loading equipment equipped with a bottom-loaded vapor recovery system shall maintain a record of the inspection required by Rule 71.3.D.1 and submit this record to the District upon request. These records shall, at a minimum, include the following:

    a. Date of inspection and operator's initials.
    b. Name and location of loading equipment and amount of ROC liquid transferred.
    c. Description of any leak or malfunction of the vapor recovery or overfill prevention systems.
    d. Date component was repaired and type of repair, if applicable.
    e. Whether or not delivery vessels hatches are closed during filling and if any spillage occurred.
    f. Delivery vessel identification and name of delivery company.

Ventura County Air Pollution Control District
Rule 71.3.E.1 Applicable Requirements
ROC Liquid Loading Facilities
Low Vapor Pressure Exemption

Rule 71.3, "Transfer of Reactive Organic Compound Liquids"
Adopted 6/16/92, Federally-Enforceable

Applicability:

This attachment applies to ROC liquid loading facilities that are exempt from Rule 71.3 requirements, pursuant to the exemption of Rule 71.3.E.1. The exemption states that the provisions of this rule shall not apply to any equipment that transfers an ROC liquid with a modified Reid vapor pressure of less than 0.5 psia. This attachment does not apply to the transfer of gasoline, or to the transfer of ROC liquids via pipeline.

A loading facility is defined as any aggregation or combination of organic liquid loading equipment which is located so that all the organic liquid loading outlets for such aggregation or combination of loading equipment can be encompassed within any circle of 300 feet in diameter.

Conditions:

1. Pursuant to Rule 71.3.E.1, the loading facility shall not be used to transfer an ROC liquid with a modified Reid vapor pressure of greater than or equal to 0.5 psia.

2. Permittee shall annually determine the liquid vapor pressure of all products at the loading facility in order to certify that the modified Reid vapor pressure is less than 0.5 psia. Records of the vapor pressure determinations shall be maintained at the facility and submitted to the District with the annual compliance certification.

3. Pursuant to Rule 71.3.G.1 the method for determining the vapor pressure shall be as follows:

   a. For petroleum products, the modified Reid vapor pressure shall be measured at the product transfer temperature using ASTM Method No. D-323-82 Volume 5.01, Section 5.

   b. For an organic liquid, if the liquid is listed in Attachment 1 of Rule 71.2, and if the transfer temperature of the liquid does not exceed the maximum temperature listed corresponding to 0.5 psia, then it shall be deemed exempt from Rule 71.3 requirements.

Ventura County Air Pollution Control District
Rule 74.9.D.3 Applicable Requirements
Emergency Standby Stationary Internal Combustion Engines
Operated During Either an Emergency or Maintenance Operation

Rule 74.9, "Stationary Internal Combustion Engines"

Adopted 11/08/05, Federally-Enforceable

Applicability:

This attachment applies to emergency standby stationary internal combustion engines rated at 50 or more horsepower, not subject to the provisions of APCD Rule 74.16, "Oilfield Drilling Operations," and operated during an emergency or maintenance operation. Maintenance operation is limited to 50 hours per calendar year. Pursuant to Rule 74.9.D.3, emergency standby stationary internal combustion engines operated during an emergency or during maintenance operation of no more than 50 hours per calendar year are exempt from all provisions of Rule 74.9.

As detailed in Rule 74.9.I.2 an emergency standby engine is defined as an internal combustion engine used only when normal power line or natural gas service fails, or for the emergency pumping of water for either fire protection or flood relief. An emergency standby engine may not be operated to supplement a primary power source when the load capacity or rating of the primary power source has been either reached or exceeded.

Conditions:

1. Pursuant to Section D.3 of Rule 74.9, an applicable emergency standby stationary internal combustion engine shall only be operated during an emergency or during maintenance operation of not more than 50 hours per calendar year.

   Pursuant to Section I.5 of Rule 74.9, a maintenance operation is defined as the use of an emergency standby engine and fuel system during testing, repair and routine maintenance to verify its readiness for emergency standby use.

2. Pursuant to Section D.3 of Rule 74.9, each emergency standby engine shall be equipped with an operating, non-resettable, elapsed hour meter.

3. Pursuant to Section F.1 of Rule 74.9, the Annual Compliance Certification shall include the following records for each emergency standby engine: Engine manufacturer, model number, operator identification number, and location.

4. Pursuant to Section F.2 of Rule 74.9, the annual engine hours of maintenance operation shall be reported annually. A report shall be provided to the District after every calendar year by February 15.

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Ventura County Air Pollution Control District
Rule 74.15.B.1 Applicable Requirements
Boilers, Heater Treaters, Steam Generators, and Process Heaters
NOx and CO Emission Limits
Annual Heat Input ≥ 9,000 MMBTU

Rule 74.15, "Boilers, Steam Generators, and Process Heaters"
Adopted 11/08/94, Federally-Enforceable

Applicability:

This attachment applies to boilers, heater treaters, steam generators and process heaters with a maximum heat input rating of greater than or equal to 5 MMBTU/Hr that have operated with an annual heat input rate of greater than or equal to 9,000 MMBTU during any twelve (12) calendar month rolling period. This attachment also applies to any unit operated with an annual heat input rate of less than 9,000 MMBTU that is equipped with low NOx burners or other such equipment to comply with the NOx and CO requirements of Rule 74.15.B.1. A heat input of 9,000 MMBTU is equivalent to 90,000 therms and equivalent to 8.57 million cubic feet of natural gas at a higher heating value of 1,050 BTU/cf.

A boiler, steam generator or process heater is any external combustion equipment fired with liquid and/or gaseous fuel. A boiler or a steam generator is further defined as equipment used to produce steam or to heat water. Boiler or steam generator does not include any unfired waste heat recovery boiler that is used to recover sensible heat from the exhaust of any combustion equipment. A process heater is further defined as equipment that transfers heat from combustion gases to water or process streams. Process heater does not include any kiln or oven used for drying, baking, cooking, calcinating or vitrifying, or any fuel-fired degreasing or metal finishing equipment. Annual heat input is defined as the actual amount of heat released by fuels burned in a unit during a twelve (12) calendar month rolling period, based on the higher heating value of the fuel. The annual heat input shall be calculated as the sum of the previous 12 monthly fuel use rates multiplied by the higher heating value of the fuel.

Conditions:

1. Pursuant to Rule 74.15.B.1, emissions from an applicable emission unit shall not exceed the following limits:

   a. Oxides of Nitrogen (NOx expressed as NO_2): 40 ppmvd
   b. Carbon Monoxide (CO): 400 ppmvd

   These limits shall be referenced at three (3) percent volume stack gas oxygen on a dry basis averaged over 15 consecutive minutes. Compliance with this condition shall be verified every 24 months by source testing.

2. Pursuant to Rule 74.15.B.1, an applicable emission unit shall be source tested not less than once every 24 months (biennially) utilizing the following methods as detailed in Rule 74.15.E:

a.	NOx	ARB Method 100
b.	CO	ARB Method 100
c.	Stack Gas Oxygen	ARB Method 100

Pursuant to Rule 74.15.E.2, emission tests shall be conducted on units in "as-found" operating condition. However, no emission test for Rule 74.15 shall be conducted during start-up, shutdown or under breakdown conditions. Prior to conducting a biennial emissions test, permittee shall notify the District Compliance Division. Written notification, and a source test protocol subject to District approval, shall be received no less than 15 calendar days prior to the test. The emissions test report and results shall be submitted to the District Compliance Division within 45 days after the test.

3. Pursuant to Rule 74.15.C.2, the emission limits of Rule 74.15.B.1 shall not apply to any unit operated on alternate fuel under the following conditions:

   a. Alternate fuel is required due to the curtailment of natural gas service to the individual unit by the natural gas supplier. Alternate fuel use in this case shall not exceed the period of natural gas curtailment.

   b. Alternate fuel use is required to maintain the alternate fuel system. Alternate fuel use in this case shall not exceed 50 hours per year.

4. Pursuant to Rule 74.15.C.4, the emission limits of Rule 74.15.B.1 shall not apply during the cold startup of an applicable unit. For units with a rated heat input capacity of equal to, or greater than, one hundred (100) million BTUs per hour, the duration of this exemption shall not exceed three (3) hours. For units with a rated heat input capacity of less than one hundred (100) million BTUs per hour, the duration of this exemption shall not exceed one (1) hour.

5. Permittee shall record and maintain the following information:

   a. Daily records of alternate fuel consumption as required by Rule 74.15.D.3. Each record shall include the type of fuel, the quantity of fuel, and the duration of the occurrence; and

   b. The biennial source test report.

This information shall be submitted to the District upon request.

6. If the emission unit is equipped with an external flue gas recirculation (FGR) system for the control of nitrogen oxides, permittee shall also comply with the FGR monitoring and recordkeeping requirements in the Permit Specific Conditions (Attachments) presented in Section No. 7 of this permit.

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Ventura County Air Pollution Control District
Rule 74.15.1.B.1 Applicable Requirements
Boilers, Heater Treaters, Steam Generators, and Process Heaters
Heat Inputs ≥ 1 MMBTU/hr and < 5 MMBTU/hr
NOx and CO Emission Limits
Annual Heat Input ≥ 1,800 MMBTU

Rule 74.15.1, "Boilers, Steam Generators, and Process Heaters"
Adopted 06/23/15, Federally-Enforceable

Applicability:

This attachment applies to boilers, heater treaters, steam generators and process heaters with a rated heat input capacity equal to or greater than 1 MMBTU/Hr and less than 5 MMBTU/Hr that have operated with an annual heat input rate of greater than or equal to 1,800 MMBTU during any twelve (12) calendar month rolling period. This attachment also applies to any unit operated with an annual heat input rate of less than 1,800 MMBTU that is equipped with low NOx burners or other such equipment to comply with the NOx and CO requirements of Rule 74.15.1.B.1. A heat input of 1,800 MMBTU is equivalent to 18,000 therms and equivalent to 1.71 million cubic feet of natural gas at a higher heating value of 1,050 BTU/cf. This attachment specifically applies to units installed prior to January 1, 2013 for units with a heat input capacity of equal to or greater than 1 MMBTU/hr and less than or equal to 2 MMBTU/hr; and installed prior to January 1, 2016 for units with a heat input capacity of greater than 2 MMBTU/hr and less than 5 MMBTU/hr. These units have a Rule 74.15.1.B.1 limit of 30 ppmvd NOx at 3% oxygen.

A boiler, steam generator or process heater is any external combustion equipment fired with liquid and/or gaseous fuel. A boiler or a steam generator is further defined as equipment used to produce steam or to heat water. Boiler or steam generator does not include any unfired waste heat recovery boiler that is used to recover sensible heat from the exhaust of any combustion equipment. A process heater is further defined as equipment that transfers heat from combustion gases to water or process streams. A process heater does not include any of the following combustion sources: kiln, oven, open heated tank, dehydrator, dryer, crematory, incinerator, calciner, cooker, roaster, furnace; unfired waste heat recovery heater that is used to recover sensible heat from the exhaust of any combustion equipment; fuel-fired degreasing or metal finishing equipment including parts washers and metal heat treating or metal furnaces; afterburner, vapor incinerator, thermal or catalytic oxidizers used as an emission control device; glass melting furnace; tenter frame, fabric, or carpet dryer. Annual heat input is defined as the actual amount of heat released by fuels burned in a unit during a twelve (12) calendar month rolling period, based on the higher heating value of the fuel. The annual heat input shall be calculated as the sum of the previous 12 monthly fuel use rates multiplied by the higher heating value of the fuel.

Conditions:

1. Pursuant to Rule 74.15.1.B.1, emissions from an applicable emission unit shall not exceed the following limits:

   a. Oxides of Nitrogen (NOx expressed as NO_2): 30 ppmvd
   b. Carbon Monoxide (CO): 400 ppmvd

   These limits shall be referenced at three (3) percent volume stack gas oxygen on a dry basis averaged over 15 consecutive minutes. Compliance with this condition shall be verified by source testing as detailed below.

2. Source testing:

   a. Pursuant to Rule 74.15.1.B.4.a, units with a rated heat input capacity greater than 2 MMBTU/hr shall be source tested for compliance not less than once every 24 months.
   b. Pursuant to Rule 74.15.1.B.4.c, units with a rated heat input capacity of less than or equal to 2 MMBTU/hr shall be source tested for compliance not less than once every 48 months.

3. Required source testing shall utilize the following methods as detailed in Rule 74.15.1.E:

a.	NOx	ARB Method 100
b.	CO	ARB Method 100
c.	Stack Gas Oxygen	ARB Method 100

   Pursuant to Rule 74.15.1.E.2, emission tests shall be conducted on units in "As-found" operating condition. Prior to conducting a required emissions test, permittee shall notify the District Compliance Division. Written notification shall be received no less than 15 calendar days prior to the test. The emissions test report and results shall be submitted to the District Compliance Division within 45 days after the test.

4. Pursuant to Rule 74.15.1.B.4.d, an annual screening analysis of NOx and CO emissions shall be performed on the unit. The screening analysis is not required if the source testing required by Rule 74.15.1.B.4.a or 74.15.1.B.4.c (Condition No. 2) is required that year. The permittee shall notify the VCAPCD Compliance Division by telephone, fax, or email 24 hours prior to any screening analysis. Pursuant to Rule 74.15.1.D.3, the permittee shall submit a report to the District Compliance Division within 45 days after each screening analysis.

5. Pursuant to Rule 74.15.1.C.1, the emission limits of Rule 74.15.1.B.1 shall not apply to any unit operated on alternate fuel under the following conditions:

a. Alternate fuel is required due to curtailment of natural gas service to the individual unit by the natural gas supplier. Alternate fuel use in this case shall not exceed the period of natural gas curtailment.

b. Alternate fuel use is required to maintain the alternate fuel system. Alternate fuel use in this case shall not exceed 50 hours per year.

6. The permittee shall record and maintain the following information:

a. Daily records of alternate fuel consumption as required by Rule 74.15.1.D.4. Each record shall include the type of fuel, the quantity of fuel, and the duration of the occurrence; and

b. Required source test reports.

c. Annual screening analysis logs and reports as required by Rule 74.15.1.D.3.

This information shall be submitted to the District upon request.

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Ventura County Air Pollution Control District
Rule 74.15.1 Applicable Requirements
Boilers, Heater Treaters, Steam Generators, and Process Heaters
Equipment Currently Shut Down and Not Operating

Rule 74.15.1, "Boilers, Steam Generators, and Process Heaters"
Adopted 06/23/15, Federally-Enforceable

Applicability:

This attachment applies to boilers, heater treaters, steam generators and process heaters with a rated heat capacity equal to or greater than 1 MMBTU/Hr and less than 5 MMBTU/Hr that are currently shut down and not operating.

A boiler, steam generator or process heater is any external combustion equipment fired with liquid and/or gaseous fuel. A boiler or a steam generator is further defined as equipment used to produce steam or to heat water. Boiler or steam generator does not include any unfired waste heat recovery boiler that is used to recover sensible heat from the exhaust of any combustion equipment. A process heater is further defined as equipment that transfers heat from combustion gases to water or process streams. A process heater does not include any of the following combustion sources: kiln, oven, open heated tank, dehydrator, dryer, crematory, incinerator, calciner, cooker, roaster, furnace; unfired waste heat recovery heater that is used to recover sensible heat from the exhaust of any combustion equipment; fuel-fired degreasing or metal finishing equipment including parts washers and metal heat treating or metal furnaces; afterburner, vapor incinerator, thermal or catalytic oxidizers used as an emission control device; glass melting furnace; tenter frame, fabric, or carpet dryer. Annual heat input is defined as the actual amount of heat released by fuels burned in a unit during a twelve (12) calendar month rolling period, based on the higher heating value of the fuel. The annual heat input shall be calculated as the sum of the previous 12 monthly fuel use rates multiplied by the higher heating value of the fuel.

Conditions:

1. Prior to operating an applicable emission unit, permittee shall:

    a. Notify the District Compliance Division; and
    b. Install a dedicated fuel meter pursuant to Rule 74.15.1.D.1. The meter shall be accurate to ± 1 percent, as certified by the manufacturer in writing.

2. Any applicable emission unit operated with an annual heat input rate of equal to or greater than 300 MMBTU and less than 1800 MMBTU shall comply with the tuning requirements of Rule 74.15.1.B.3.

3. Prior to operating any applicable emission unit with an annual heat input rate of equal to or greater than 1800 MMBTU, the permittee shall demonstrate by source testing, using ARB Method 100 as detailed in Rule 74.15.1.E, that the unit complies with the required nitrogen oxide (NOx) and carbon monoxide (CO) limits of either Rule 74.15.1.B.1 or Rule 74.15.1.B.2, as applicable. If the unit requires physical modifications in order to meet the emission limits, permittee shall apply for and receive an Authority to Construct and Permit to Operate for the modification.

5. The permittee shall annually certify that the subject equipment is shut down and not operating.

6. Upon operating an applicable emission unit, totalizing fuel meter records shall be compiled monthly into a rolling twelve (12) calendar month report. These records shall be submitted to the District upon request.

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Ventura County Air Pollution Control District
California Airborne Toxic Control Measure For
Stationary Compression Ignition Engines
In-Use Emergency Fire Pump Assembly Engines

Section 93115, Title 17, California Code of Regulations, Airborne Toxic Control Measure for Stationary Compression Ignition (CI) Engines
Effective 05/19/11

The District is required to implement and enforce the state ATCM. The ATCM is not federally-enforceable.

Applicability:

This attachment describes the requirements of California Airborne Toxic Control Measure (ATCM) For Stationary Compression Ignition (CI) Engines that apply to in-use stationary diesel-fueled CI engines that drive fire pump assemblies. Section 93115.3(n) of the ATCM exempts such engines from the emission standards for stationary emergency standby diesel-fueled CI engines as listed in Section 93115.6(b)(3) of the ATCM. The exempt engines must only be operated the number of hours necessary to comply the testing requirements of National Fire Protection Association (NFPA) 25 – "Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems," 2002 edition. An "in-use" engine is an engine that was installed at a facility prior to January 1, 2005. Pursuant to Section 93115.4(a)(8) CARB Diesel Fuel means any diesel fuel that meets the specifications of vehicular diesel fuel, as defined in title 13, CCR, sections 2281 and 2282. The Verification Procedure is defined in Section 93115.4(a)(78).

Conditions:

1. Pursuant to subsection 93115.5(a), as of January 1, 2006, the permittee shall not fuel the engine with any fuel unless the fuel is one of the following:

    a. CARB Diesel Fuel, or
    b. An alternative diesel fuel that is:
        1) biodiesel;
        2) a biodiesel blend that does not meet the definition of CARB diesel Fuel
        3) a Fischer-Tropsch fuel; or
        4) an emulsion of water in diesel fuel; or
    c. any alternative diesel fuel that is not identified in section 93115.5(a)(2) and meets the requirements of the Verification Procedure; or
    d. an alternative fuel; or
    e. CARB Diesel Fuel used with fuel additives that meets the requirements of the Verification Procedure; or

f. any combination of the above.

2. Pursuant to subsection 93115.10(f)(1)(E), the permittee shall keep a monthly log of each engine's hours of operation to comply with the requirements of NFPA 25.

3. Pursuant to subsection 93115.5(f)(1)(H), the permittee shall document fuel use in the engines. For engines operated exclusively on CARB Diesel Fuel, the owner or operator shall document the use of CARB Diesel Fuel through the retention of fuel purchase records indicating that the only fuel purchased for supply to an emergency standby engine was CARB Diesel Fuel; or for engines operated on any fuel other than CARB Diesel Fuel, the fuel records demonstrating that the only fuel purchased and added to an emergency standby engine or engines, or to any fuel tank directly attached to an emergency standby engine or engines, meets the requirements of section 93115.5(b).

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Ventura County Air Pollution Control District
National Emission Standards for Hazardous Air Pollutants
For Stationary Reciprocating Internal Combustion Engines
Existing Emergency Diesel Engines at an Area Source of HAPs

40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines" (RICE MACT)
RICE MACT Last Revised 01/30/13

Applicability:

The NESHAP for Stationary Reciprocating Internal Combustion Engines is applicable to all stationary reciprocating internal combustion engines (RICE) at both major and area sources of hazardous air pollutants. The NESHAP is applicable to both compression ignition (CI – diesel) engines and spark ignition (SI – natural gas, landfill gas, gasoline, propane, etc.) engines. The specific conditions below are for existing emergency diesel engines at an area source. An engine is defined as "existing" if it was constructed before June 12, 2006. A stationary source is defined as an "area source" if it is not a major source of HAP (Hazardous Air Pollutants) emissions; meaning the stationary source does not emit or have the potential to emit any single HAP at a rate of 10 tons or more per year or any combination of HAP at a rate of 25 tons or more per year.

Pursuant to Section 63.6640(f) and Section 63.6675, an "emergency engine" is any engine whose operation is limited to emergency situations and required testing and maintenance. An emergency can be the loss of grid power or the stationary source's own power production. An emergency engine may also participate in an emergency demand response program under limited circumstances. Stationary RICE used for peak shaving or as part of a financial arrangement to supply power into the grid, or as a part of a non-emergency demand response program are not considered emergency stationary RICE.

For more up-to-date information regarding RICE NESHAP standards, please refer to the following link: https://www.epa.gov/stationary-engines/national-emission-standards-hazardous-air-pollutants-reciprocating-internal-0

Conditions:

1. Pursuant to Section 63.6603(a), Table 2d, the permittee shall comply with the following operating requirements:

   a. Change oil and filter every 500 hours of operation or annually, whichever comes first. An oil analysis program as described in Section 63.6625(i) can be utilized in order to extend the specified oil change requirement.

   b. Inspect air cleaner every 1,000 hours of operation or annually, whichever comes first, and replace as necessary.

c. Inspect all hoses and belts every 500 hours of operation or annually, whichever comes first, and replace as necessary.

Pursuant to Table 2d, if an emergency RICE is operating during an emergency and it is not possible to perform the above maintenance or if performing the maintenance would otherwise pose an unacceptable risk under federal, state, or local law, the maintenance can be delayed and should be performed as soon as practicable after the emergency has ended or the unacceptable risk has abated. All such maintenance delays shall be reported to the APCD Compliance Division.

2. Pursuant to Section 63.6625(e) and 63.6640(a), Table 6, the permittee shall operate and maintain the stationary RICE according to the manufacturer's emission-related written instructions or develop your own plan which must provide to the extent practicable for the maintenance and operation of the engine in a manner consistent with good air pollution control practice for minimizing emissions.

3. Pursuant to Section 63.6625(f), the RICE shall be equipped with a non-resettable hour meter.

4. Pursuant to Section 63.6625(h), the permittee shall minimize the engine's time spent at idle during startup and minimize the engine's startup time to a period needed for appropriate and safe loading of the engine, not to exceed 30 minutes.

5. Pursuant to Sections 63.6640(f) and 63.6675, the permittee shall operate the emergency RICE in compliance with the following requirements:

   a. There is no time limit on the use of emergency stationary RICE in emergency situations. An emergency can be the loss of grid power or the stationary source's own power production.

   b. The use of the engine is limited to 100 hours per calendar year for maintenance checks and readiness testing, emergency demand response, 5% or greater voltage or frequency deviation situations, and up to 50 hours per year for non-emergency situations as detailed in Section 63.6640(f)(4). The 50 hours are to be counted in the 100 hours limit.

   c. The emergency stationary RICE may be operated up to 50 hours per calendar year in non-emergency situations. The 50 hours of operation in non-emergency situations are counted as part of the 100 hours per calendar year for maintenance and testing and emergency demand response provided above. The 50 hours per year for non-emergency situations cannot be used for peak shaving or non-emergency demand response to generate income for a facility. The 50 hours per year for non-emergency situations can be used to supply power as part of a financial agreement with another entity if all of the requirements of Section 63.6640(f)(4)(ii)(A–E) are met. The 50 hours per year limit is to be counted towards the 100 hours per year limit.

6. Pursuant to Sections 63.6655(e) and 63.6655(f), the permittee shall maintain the following records:

    a. Records of maintenance conducted on the stationary emergency RICE.

    b. Records of the hours of operation of the engine that is recorded through the non-resettable hour meter. The permittee must document how many hours are spent for emergency operation, including what classified the operation as emergency, and how many hours are spent for non-emergency operation.

7. If the engine is contractually obligated to be available for more than 15 hours per year for emergency demand response, 5% or greater voltage or frequency deviation situations, or for non-emergency situations as detailed in Section 63.6640(f)(4)(ii) the engine must use a diesel fuel that meets the requirements in 40 CFR 80.510(b) for non-road diesel fuel. This fuel is commonly known as ultra low sulfur diesel or ULSD. Any diesel fuel purchased (or otherwise obtained) prior to January 1, 2015 may be used until depleted. (Section 63.6604(b))

8. If the engine is contractually obligated to be available for more than 15 hours per year for emergency demand response, 5% or greater voltage or frequency deviation situations, or for non-emergency situations as detailed in Section 63.6640(f)(4)(ii) the permittee is required to compile and submit a report as required by Section 63.6650(h). This report includes, but is not limited to, location information, engine information, hours of operation, and fuel requirement deviations. The first annual report must cover calendar year 2015 and must be submitted no later than March 31, 2016. Subsequent annual reports for each calendar year must be submitted no later than March 31 of the following calendar year. As required by Section 63.6650(h)(3), the annual report must be submitted electronically via EPA's Central Data Exchange (CDX). (Section 63.6650(h))

9. On an annual basis, the permittee shall certify that all engines at this stationary source are operating in compliance with 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Engines" (RICE MACT).

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Ventura County Air Pollution Control District
National Emission Standards for Hazardous Air Pollutants
For Stationary Reciprocating Internal Combustion Engines
Existing Emergency Spark Ignited Engines

40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines" (RICE MACT)

Applicability:

The NESHAP for Stationary Reciprocating Internal Combustion Engines is applicable to all stationary reciprocating internal combustion engines (RICE) at both major and area sources of hazardous air pollutants. The NESHAP is applicable to both compression ignition (CI – diesel) engines and spark ignition (SI – natural gas, landfill gas, gasoline, propane, etc.) engines. The specific conditions below are for existing emergency spark ignited engines at an area source. An engine is defined as "existing" if it was constructed before June 12, 2006. A stationary source is defined as an "area source" if it is not a major source of HAP (Hazardous Air Pollutants) emissions; meaning the stationary source does not emit or have the potential to emit any single HAP at a rate of 10 tons or more per year or any combination of HAP at a rate of 25 tons or more per year.

Pursuant to Section 63.6640(f) and Section 63.6675, an "emergency engine" is any engine whose operation is limited to emergency situations and required testing and maintenance. An emergency can be the loss of grid power or the stationary source's own power production. An emergency engine may also participate in an emergency demand response program under limited circumstances. Stationary RICE used for peak shaving or as part of a financial arrangement to supply power into the grid, or as a part of a non-emergency demand response program are not considered emergency stationary RICE.

Pursuant to Section 63.6595(a)(1), the permittee must comply with the applicable operating requirements on and after May 3, 2013.

Conditions:

1. Pursuant to Section 63.6603(a), Table 2d, the permittee shall comply with the following operating requirements:

    a. Change oil and filter every 500 hours of operation or annually, whichever comes first. An oil analysis program as described in Section 63.6625(i) can be utilized in order to extend the specified oil change requirement.

    b. Inspect spark plugs every 1,000 hours of operation or annually, whichever comes first, and replace as necessary.

c. Inspect all hoses and belts every 500 hours of operation or annually, whichever comes first, and replace as necessary.

Pursuant to Table 2d, if an emergency RICE is operating during an emergency and it is not possible to perform the above maintenance or if performing the maintenance would otherwise pose an unacceptable risk under federal, state, or local law, the maintenance can be delayed and should be performed as soon as practicable after the emergency has ended or the unacceptable risk has abated. All such maintenance delays shall be reported to the APCD Compliance Division.

2. Pursuant to Section 63.6625(e) and 63.6640(a), Table 6, the permittee shall operate and maintain the stationary RICE according to the manufacturer's emission-related written instructions or develop your own plan which must provide to the extent practicable for the maintenance and operation of the engine in a manner consistent with good air pollution control practice for minimizing emissions.

3. Pursuant to Section 63.6625(f), the RICE shall be equipped with a non-resettable hour meter.

4. Pursuant to Section 63.6625(h), the permittee shall minimize the engine's time spent at idle during startup and minimize the engine's startup time to a period needed for appropriate and safe loading of the engine, not to exceed 30 minutes.

5. Pursuant to Sections 63.6640(f) and 63.6675, the permittee shall operate the emergency RICE in compliance with the following requirements:

    a. There is no time limit on the use of emergency stationary RICE in emergency situations. An emergency can be the loss of grid power or the stationary source's own power production.

    b. The use of the engine is limited to 100 hours per calendar year for maintenance checks and readiness testing, emergency demand response, 5% or greater voltage or frequency deviation situations, and up to 50 hours per year for non-emergency situations as detailed in Section 63.6640(f)(4). The 50 hours are to be counted in the 100 hours limit.

    c. The emergency stationary RICE may be operated up to 50 hours per calendar year for peak shaving as part of a financial agreement to supply power into the grid, or as part of a non-emergency demand response program, until May 3, 2014. After May 3, 2014, the 50 hours per year for non-emergency situations can be used to supply power as part of a financial agreement if all of the requirements of Section

63.6640(f)(4)(ii) are met. The 50 hours per year limit is to be counted towards the 100 hours per year limit.

6. Pursuant to Sections 63.6655(e) and 63.6655(f), the permittee shall maintain the following records:

   a. Records of maintenance conducted on the stationary emergency RICE.

   b. Records of the hours of operation of the engine that is recorded through the non-resettable hour meter. The permittee must document how many hours are spent for emergency operation, including what classified the operation as emergency, and how many hours are spent for non-emergency operation.

7. If the engine site rating exceeds 100 brake HP and operates or is contractually obligated to be available for more than 15 hours per year for purposes specified in Section 63.6640(f)(2)(ii) and (iii) or that operates for the purposes specified in Section 63.6640(f)(4)(ii) the permittee is required to compile and submit a report as required by Section 63.6650(h). The annual report must be submitted no later than March 31 of each year. (Section 63.6650(h))

8. On an annual basis, the permittee shall certify that all engines at this stationary source are operating in compliance with 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Engines" (RICE MACT).

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8. PERMIT SPECIFIC CONDITIONS (ATTACHMENTS)

As discussed in Section No. 2, "Permitted Equipment and Applicable Requirements Table", the emissions units at this stationary source listed in the table have requirements that are specifically applicable to them. The applicable requirements are primarily based on Rule 26, "New Source Review" requirements (e.g., BACT and offset requirements), or Rule 29, "Conditions on Permits" requirements (e.g., throughput recordkeeping requirements, specific requirements that limit emissions, etc.). These requirements are in addition to the specific applicable requirements listed in Section No. 7.

In this section of the permit, the permit conditions that are associated with each specific applicable requirement are listed in an individual attachment. The attachment is identified with the label "Attachment PO (Title V Permit No.) PC#" in the lower left corner. Each attachment has an applicability section that describes how and why this attachment applies to the specific emissions unit. The attachment may apply to one or more of the emissions units listed in the Permitted Equipment and Applicable Requirements Table in Section No. 2.

Ventura County Air Pollution Control District
Additional Permit Requirements
Permit No. 00012

Rule 26, "New Source Review"

Rule 29, "Conditions on Permits"

Conditions applied pursuant to Rule 26 are federally enforceable and conditions applied pursuant to Rule 29 are District enforceable only.

Applicability:

This attachment applies to this stationary source. These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. In order to comply with the throughput and consumption limits of this permit, the permittee shall maintain monthly records of throughput and consumption as detailed in Section No. 3, "Permitted Throughput and Consumption Limit Table", of this permit. The monthly records shall be summed for the previous 12 months. Throughput or consumption totals for any of these 12 calendar month rolling periods in excess of the specified limit shall be considered a violation of this permit. This is a general throughput and consumption recordkeeping condition and applies unless another throughput and consumption recordkeeping condition appears in this section of the permit. (Rules 26 and 29)

2. The permitted emissions authorized by this permit are based in part on the fugitive emissions from 70 oil wells. An Authority to Construct is required to be obtained from the District prior to drilling a new oil well. Emission offsets must also be provided with the submittal of any application to increase the number of wells beyond 70 wells. (Rule 29)

3. The following wells shall be shall be free flowing, operated on gas lift, or operated with electric motor driven artificial lift equipment:

   Chase C8, Chase E9, Chase D11, Chase F12, TransAmerica B5, TransAmerica C2, TransAmerica D10

   This condition is applied as Best Available Control Technology. (Rule 26)

4. Pursuant to Rule 23.F.7, the use of solvents, in addition to the use of coatings, adhesives, lubricants, and sealants, for facility and building maintenance and repair is exempt from

permit. However, the use of such materials by contractors for the maintenance and repair of process and industrial equipment is not exempt from permit pursuant to Rule 23.F.7, unless the material is exempted under another specific section of Rule 23. Pursuant to Rule 23.F.6, the use of non-refillable aerosol cans is exempt from permit. Pursuant to Rule 23.F.10, the use of cleaning agents certified by the SCAQMD as Clean Air Solvents (Rule 23.F.10.a) and the use of cleaning agents that contain no more than 25 grams per liter of ROC as used or applied, and no more than 5 percent by weight combined of methylene chloride, perchloroethylene, trichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride, and chloroform (Rule 23.F.10.b), is also exempt from permit. This permit does not limit the usage of acetone. Acetone is exempt from permit and record keeping requirements, as it is not defined as a reactive organic compound.

In order to substantiate the solvent use exemptions listed above, the permittee shall maintain a list of all exempt solvents used at the stationary source and a reference to the specific permit exemption status.

(Rule 29)

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Ventura County Air Pollution Control District
Additional Permit Requirements
Nitrite Solution Vessels

Rule 29, "Conditions on Permits"
Adopted 03/14/06, District Enforceable Only

Rule 64, "Sulfur Content of Fuels"
Adopted 04/13/99, Federally-Enforceable

Applicability:

This attachment applies to the nitrite solution vessels or nitrite solution buffer vessels located at this facility. These vessels are used to sweeten, or remove hydrogen sulfide from, gas produced from wells at this facility. These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. All produced gas and casing gas shall be processed through the nitrite solution produced gas sweetening system. (Rule 64)

2. The produced gas and casing gas shall not be burned as fuel in the boilers, steam generators or process heaters if the gas contains sulfur compounds, calculated as hydrogen sulfide at standard conditions, in excess of 236 ppmv, or the equivalent 15 grains per 100 cubic feet. (Rule 29)

3. On a weekly basis, permittee shall test the hydrogen sulfide content of the gases downstream of the nitrite solution vessels or nitrite solution buffer vessels located throughout the facility. The tests shall be performed using detector tubes that measure hydrogen sulfide. Permittee shall maintain this test information and make it available to the District upon request. (Rule 64)

4. Permittee shall analyze the sulfur content of this fuel gas on an annual basis using South Coast AQMD Method 307-94 - Determination of Sulfur in a Gaseous Matrix. This annual fuel gas analysis shall satisfy the requirements of Permit Condition No. 2 above, as well as the requirements of Rule 64.B.1. Records of the test shall be maintained at the facility and the test results shall be provided to the District with the annual compliance certification. (Rule 64)

Ventura County Air Pollution Control District
Additional Permit Requirements
20 MMBTU/Hr Erie City Boiler

Rule 26, "New Source Review"

Rule 74.15, "Boilers, Steam Generators, and Process Heaters"
Adopted 11/08/94, Federally-Enforceable

Conditions applied pursuant to Rule 26 are federally enforceable.

Applicability:

This attachment applies to the 20 MMBTU/Hr Erie City boiler located at this facility. These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. The stack outlet concentrations of oxides of nitrogen (NOx measured as NO2) shall not exceed 36 parts per million by volume (ppmv) corrected to 3 percent oxygen. This is a requirement of Rule 26 as detailed in Authority to Construct No. 0012-110. (Rule 26)

2. Permittee shall operate the Erie City boiler at a flue gas recirculation (FGR) rate at or above a valve opening setting of 45%, and an excess oxygen rate between 0.5% and 3.0%. These operating parameters shall be monitored, measured, and recorded on a monthly basis. Any deviation from the minimum FGR valve position of 45% or any deviation from the excess oxygen rate range shall be considered a violation of this condition, unless the permittee can demonstrate compliance with the NOx emission limits specified in Permit Condition No. 1 above by emission testing pursuant to Rule 74.15. (Rule 26 and Rule 74.15)

3. Permittee shall have the boiler emissions tested no less than once every 24 months and shall maintain the external flue gas recirculation system (FGR) according to the parameters specified in Permit Condition No. 2 above. Additional monitoring, recordkeeping, reporting, and test method requirements for this unit are included in Attachment 74.15N1 in Section No. 7 of this permit. (Rule 26 and Rule 74.15)

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Ventura County Air Pollution Control District
Additional Permit Requirements
20 MMBTU/Hr Natco Crude Oil Process Heater

Rule 26, "New Source Review"

Rule 74.15, "Boilers, Steam Generators, and Process Heaters"
Adopted 11/08/94, Federally-Enforceable

Conditions applied pursuant to Rule 26 are federally enforceable.

Applicability:

This attachment applies to the 20 MMBTU/Hr Natco crude oil process heater located at this facility. These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. The stack outlet concentrations of oxides of nitrogen (NOx measured as NO2) shall not exceed 34 parts per million by volume (ppmv) corrected to 3 percent oxygen. This is a requirement of Rule 26 as detailed in Authority to Construct No. 0012-110. (Rule 26)

2. Permittee shall operate the Natco crude oil process heater at a flue gas recirculation (FGR) rate at or above a valve opening setting of 50%, and an excess oxygen rate between 0.5% and 2.5%. These operating parameters shall be monitored, measured, and recorded on a monthly basis. Any deviation from the minimum FGR valve position of 50% or any deviation from the excess oxygen rate range shall be considered a violation of this condition, unless the permittee can demonstrate compliance with the NOx emission limits specified in Permit Condition No. 1 above by emission testing pursuant to Rule 74.15. (Rule 26 and Rule 74.15)

3. Permittee shall have the heater emissions tested no less than once every 24 months and shall maintain the external flue gas recirculation system (FGR) according to the parameters specified in Permit Condition No. 2 above. Additional monitoring, recordkeeping, reporting, and test method requirements for this unit are included in Attachment 74.15N1 in Section No. 7 of this permit. (Rule 26 and Rule 74.15)

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Ventura County Air Pollution Control District
Additional Permit Requirements
20 MMBTU/Hr Steam Generators
(Steam Generator Nos. 0, 1, 2, 4, and 5)

Rule 26, "New Source Review"
Federally-Enforceable

Rule 29, "Conditions on Permits"
District Enforceable Only

Rule 54, "Sulfur Compounds"
Adopted 01/14/14, Federally-Enforceable

Rule 64, "Sulfur Content of Fuels"
Adopted 04/13/99, Federally-Enforceable

Rule 74.15, "Boilers, Steam Generators, and Process Heaters"
Adopted 11/08/94, Federally-Enforceable

<u>Applicability:</u>

This attachment applies to the five (5) 20 MMBTU/Hr steam generators in service (Nos. 0, 1, 2, 4, and 5) located at this facility. These requirements are in addition to any other specific or general requirements referenced in this permit.

<u>Conditions:</u>

1. Permittee may burn fuel oil in Steam Generator Nos. 4 and 5 at a maximum rate of 118.2 gallons per hour during periods of mandatory natural gas curtailment by the natural gas supplier. Prior to obtaining approval to burn fuel oil at a higher rate during curtailment, permittee must demonstrate through source testing that these steam generators can meet an oxides of nitrogen (NOx measured as NO2) emission limit of 160 parts per million by volume (ppmv) on a dry basis corrected to 3 percent oxygen while burning fuel oil. (Rule 26)

   If the permittee desires to burn fuel oil during periods of time other than natural gas curtailment, compliance with the 40 ppmv NOx and 400 ppmv CO limits of Rule 74.15.B.1 shall be demonstrated prior to such fuel oil burning. (Rule 74.15)

2. PCL Industrial Services, Inc. 20.0 MMBTU/hr Steam Generator (Unit No. 0) Emission Limitations:

a. Oxides of nitrogen (NOx measured as NO2) emissions from the steam generator shall not exceed 5 ppmvd, corrected to 3% oxygen, when burning PUC natural gas.
b. Oxides of nitrogen (NOx measured as NO2) emissions from the steam generator shall not exceed 6 ppmvd, corrected to 3% oxygen, when burning PUC natural gas mixed with produced gas.
c. Carbon monoxide (CO) emissions from the steam generator shall not exceed 100 ppmvd, corrected to 3% oxygen.

The NOx limitations are applied as BACT (Best Available Control Technology). The CO limit is applied pursuant to Rule 29, "Conditions On Permits". The NOx and CO limits are more stringent than the Rule 74.15.B.1 emission limits. In order to demonstrate compliance with these emission limits, the permittee shall have the unit's emissions tested every 24 months. (Rules 26, 29, 74.15)

3. The PCL Industrial Services, Inc. steam generator (Unit No. 0) shall be fired on PUC natural gas or a mixture of PUC natural gas and produced gas that meets a hydrogen sulfide (H_2S) content limit of 20 ppmvd. This condition is applied as BACT (Best Available Control Technology) and Rule 54, "Sulfur Compounds", compliance.

All oilfield gas combustion shall comply with Rule 64, "Sulfur Content of Fuels". The sulfur content of the oilfield gas burned in the steam generator shall be monitored and recorded on an annual basis as required by Section D of Rule 64. The sulfur content of the oilfield gas shall be determined by SCAQMD Method 307-91.

4. The fuel to be burned during commercial operation of Steam Generator Nos. 1 and 2 shall be limited to utility natural gas only. Prior to obtaining approval to burn fuel oil during periods of mandatory natural gas curtailment by the natural gas supplier, permittee must demonstrate through source testing these steam generators can meet an oxides of nitrogen (NOx measured as NO2) emission limit of 160 parts per million by volume (ppmv) on a dry basis corrected to 3 percent oxygen while burning fuel oil. (Rule 26)

If the permittee desires to burn fuel oil during periods of time other than natural gas curtailment, compliance with the 40 ppmv NOx and 400 ppmv CO limits of Rule 74.15.B.1 shall be demonstrated prior to such fuel oil burning. (Rule 74.15)

5. The fuel oil to be burned in Steam Generator Nos. 4 and 5 shall be limited to a sulfur content not to exceed 0.25%, by weight, and a nitrogen content not to exceed 0.25%, by weight. In order to comply with this condition, permittee shall maintain fuel records, or certification from the fuel supplier, documenting the sulfur content and nitrogen content of each fuel delivery. (Rule 29)

6. A totalizing fuel meter shall be installed and dedicated to each steam generator. The meter shall be accurate to ± one percent and shall be maintained in proper operating condition. (Rule 29)

7. Permittee shall maintain the following flue gas recirculation (FGR) valve opening settings and excess oxygen trim rates:

Steam Generator No.	Valve Opening Setting	Excess Oxygen Rates
1	30 %	0.5 - 2.5 %
2	30 %	0.5 - 2.5 %
4	40 %	0.5 - 2.5 %
5	60 %	0.5 - 2.5 %

These operating parameters shall be monitored, measured, and recorded on a monthly basis. Any FGR valve setting less than the FGR valve position setting above, or any deviation from the excess oxygen rates above shall be considered a violation of this condition, unless the permittee can demonstrate compliance with 40 ppmv NOx by emission testing pursuant to Rule 74.15. (Rule 26 and Rule 74.15)

8. Permittee shall have the steam generators' emissions tested no less than once every 24 months and shall maintain the external flue gas recirculation system (FGR) according to the parameters specified in Permit Condition No. 7 above. Additional monitoring, recordkeeping, reporting, and test method requirements for these units are included in Attachment 74.15N1 in Section No. 7 of this permit.

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Ventura County Air Pollution Control District
Additional Permit Requirements
Asphalt Loading Racks

Rule 51, "Nuisance"
Adopted 04/13/04, District Enforceable Only

Applicability:

This attachment applies to the asphalt loading racks located at this facility. These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. Pursuant to Rule 51, permittee shall operate and maintain a vapor collection and scrubbing system at the asphalt loading racks during all asphalt transfer operations in order to reduce any nuisance created by odor. The vapor collection and filtration system shall minimize displaced vapors from being released into the atmosphere during loading operations by collecting the displaced ROC vapors from the delivery vessel, and passing these vapors through a water scrubber and filtration system prior to release to the atmosphere.

2. The permittee shall annually certify that the vapor collection and scrubbing system is operating properly.

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Ventura County Air Pollution Control District
Additional Permit Requirements
Crude Oil and Gas Oil Loading Racks

Rule 71.3, "Transfer of Reactive Organic Compound Liquids"
Adopted 06/16/92, Federally-Enforceable

Rule 26, "New Source Review"

Conditions applied pursuant to Rule 26 are federally enforceable.

Applicability:

This attachment applies to the crude oil loading racks located at the Transamerica Tank C-1 area, Texcon Tank C-2 and C-3 area, and the Main Facility Tank 2005-2006 area. This attachment also applies to gas oil loading rack at the Main Facility Tank 1501-1503 area. These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. Regardless of the applicability, requirements, or exemptions of Rule 71.3, permittee shall maintain a bottom-loaded vapor recovery system at the crude oil and gas oil loading racks during all transfer operations. The vapor recovery system shall prevent all displaced vapors during loading from being released into the atmosphere. The vapor recovery system shall be capable of collecting all ROC vapors; and shall have a vapor return system that routes all vapors to a continuously operating boiler firebox for incineration or to a gas pipeline recovery and distribution system. Additional monitoring, recordkeeping, reporting, and test method requirements for these units are included in Attachment 71.3N4 in Section No. 7 of this permit.

   This is a requirement of Rule 26 as detailed in Application No. 0011-008 for Emission Reduction Credits as a result of adding vapor recovery to these crude oil and gas oil loading racks.

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Ventura County Air Pollution Control District
Additional Permit Requirements
Out of Service Emissions Units

Rule 29, "Conditions on Permits"

Conditions applied pursuant to Rule 29 are District enforceable only.

Applicability:

This attachment applies to any emissions units on permit at this facility that are currently designated as "Out of Service" in Tables 2, 3, and 4 of this permit.

Conditions:

1. Any tank designated as "Out of Service" in Tables 2, 3, and 4 of this permit is shut down, shall not be operated, and shall not contain any liquids.

2. Any combustion unit designated as "Out of Service" in Tables 2, 3, and 4 of this permit is shut down, shall not be operated, and shall not be connected to a fuel source.

3. For emissions units designated as "Out of Service", compliance with other requirements in this permit, such as source testing, shall be at the discretion of VCAPCD personnel.

4. In order to ensure that compliance with this condition is being maintained, the permittee shall annually certify that an emissions unit designated as "Out of Service" is shut down and not being operated.

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Ventura County Air Pollution Control District
Additional Permit Requirements
Flare

Rule 26, "New Source Review"

Conditions applied pursuant to Rule 26 are federally enforceable.

Rule 54, "Sulfur Compounds"
Adopted 01/14/14, Federally Enforceable

Rule 71.1, "Crude Oil Production and Separation"
Adopted 06/16/92, Federally Enforceable

Rule 71.3, "Transfer of Reactive Organic Compound Liquids"
Adopted 06/16/92, Federally-Enforceable

Applicability:

This attachment applies to the following flare:

1 - 5 MMBTU/hr Flare, PROS, Inc., Model FLTR-1 (trailer mounted), 45 scf/hr Mactronic electric auto ignition pilot, 26' high, Coanda effect technology, equipped with sulfur pre-treatment system

The flare will be used for combustion of gases pursuant to Rules 71.1.B.1.a or 71.1.C.1 by burning excess gas that cannot be combusted in the steam generators or asphalt heaters.

These requirements are in addition to any other specific or general requirements referenced in this permit.

Conditions:

1. There is no annual gas consumption limit at the flare. Permitted emissions for the flare are based on 8,760 hours per year.

2. The flare shall be equipped with a functional, operating automatic ignition system equipped with a gas pilot to ensure combustion disposal of all excess produced or recovered gases. (Rules 71.1 and 71.3)

3. Permittee shall test the flare's ignition system monthly and shall maintain a monthly record of the flare's ignition system tests and maintenance activities, including the test date and operator's initials. (Rules 71.1 and 71.3)

4. The flare shall be smokeless. This condition is applied as BACT. (Rule 26)

5. Flare Oxides of Sulfur (SOx) Emission Requirements:

   a. The sulfur content of the gas entering each emergency flare shall not exceed 20 ppmvd, calculated as hydrogen sulfide (H_2S) at standard conditions.
   b. The flare gas sulfur pre-treatment system shall be operated whenever the flare is operated as necessary to comply with the 20 ppmvd limit above.
   c. Annual testing for sulfur compounds in the flare gas shall be conducted using H_2S detector tubes, SCAQMD Method 307-91, or EPA Method 16, as applicable.

   (Rules 26 and 54)

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9. GENERAL APPLICABLE REQUIREMENTS (ATTACHMENTS)

The general applicable requirements are broadly applicable requirements that apply and are enforced in the same manner for all subject emissions units or activities. These requirements can normally be adequately addressed in the permit application with minimal or no reference to any specific emissions unit or activity, provided that the scope of the requirement and the manner of its enforcement are clear. Examples of such requirements include those that apply identically to all emissions units at a facility (e.g., source-wide opacity limits), general housekeeping requirements, and requirements that apply identical emissions limits to small units (e.g., process weight requirements).

As detailed in the Title V Permit Reissuance Application, general applicable requirements that apply to this facility were determined. The permit conditions associated with each generally applicable requirement are listed in an individual attachment. The attachment is identified with the label "Attachment (APCD Rule No.) ____" in the lower left corner of each attachment. Each attachment has an applicability section that describes the emissions units to which the attachment applies. Each attachment may apply to one or more of the emissions units listed in the Applicable Requirements Table of Section No. 2. Note that these general applicable requirements may also apply to emissions units not required to be listed in the permit, such as those that are short-term.

Ventura County Air Pollution Control District
Rule 50 Applicable Requirements
Opacity

Rule 50, "Opacity"
Adopted 04/13/04, Federally-Enforceable

Applicability:

This attachment applies to all emissions units at this stationary source.

Conditions:

1. Pursuant to Rule 50.A, permittee shall not discharge into the atmosphere from any single source whatsoever any air contaminants for a period or periods aggregating more than three (3) minutes in any one (1) hour which are as dark or darker in shade as that designated as No. 1 on the Ringelmann Chart, or equivalent to 20% opacity and greater, unless specifically exempted by Rule 50.

2. Permittee shall perform periodic visual inspections to ensure that compliance with Rule 50 is being maintained. A record shall be kept of any occurrence of visible emissions other than uncombined water greater than zero percent for a period or periods aggregating more than three (3) minutes in any one (1) hour. These records shall include the date, time, and identity of emissions unit. If the visible emissions problem cannot be corrected within 24 hours, permittee shall provide verbal notification to the District within the subsequent 24 hours. These visible emissions records shall be maintained at the facility and submitted to the District upon request. Records of zero percent visual emissions are not required.

3. On an annual basis, permittee shall certify that all emissions units at the facility are complying with Rule 50. This annual compliance certification shall include a formal survey identifying the date, time, emissions unit, and verification that there are no visible emissions other than uncombined water greater than zero percent for a period or periods aggregating more than three (3) minutes in any one (1) hour. As an alternative, the annual compliance certification shall include a formal survey identifying the date, time, emissions unit, and verification that there are no visible emissions for a period or periods aggregating more than three (3) minutes in any one (1) hour which are as dark or darker in shade as that designated as No. 1 on the Ringelmann Chart, or equivalent to 20% opacity and greater, as determined by a person certified in reading smoke using EPA Method 9, or any other appropriate test method as approved in writing by the District, the California Air Resources Board, and the U.S. Environmental Protection Agency.

4. Upon District request, opacity shall be determined by a person certified in reading smoke using EPA Method 9 or a certified, calibrated monitoring system.

Ventura County Air Pollution Control District
Rule 54 Applicable Requirements
Sulfur Compounds - Sulfur Emissions from
Combustion Operations at Point of Discharge

Rule 54, "Sulfur Compounds"
Adopted 01/14/14, Federally Enforceable

Rule 64, "Sulfur Content of Fuels"
Adopted 04/13/99, Federally-Enforceable

Applicability:

This attachment applies to all combustion emissions units at this stationary source that combust gaseous or liquid fuels. This attachment addresses the requirements of Rule 54 for sulfur emissions at the point of discharge. It can be demonstrated that compliance with the fuel sulfur content limits of Rule 64 ensures compliance with the sulfur emission limits of Rule 54.

Conditions:

1. Pursuant to Rule 54.B.1.a, no person shall discharge sulfur compounds from any combustion operation, which would exist as a liquid or gas at standard conditions, in excess of the following limit at the point of discharge:

300 ppm by vol, on a dry basis, as sulfur dioxide (SO_2), at 3% oxygen	For sources subject to: Rule 74.11, "Natural Gas-Fired Water Heaters" Rule 74.11.1, "Large Water Heaters and Small Boilers" Rule 74.15, "Boilers, Steam Generators, and Process Heaters" Rule 74.15.1, "Boilers, Steam Generators, and Process Heaters" (1 to 5 MMBTUs)
300 ppm by vol, on a dry basis, as sulfur dioxide (SO_2), at 15% O_2	For sources subject to: Rule 74.9, "Stationary Internal Combustion Engines" Rule 74.23, "Stationary Gas Turbines" Flares and all other combustion operations

2. In order to comply with Rule 54, permittee shall comply with the fuel sulfur content limits of Rule 64. No additional periodic monitoring requirements for Rule 54 are required beyond the periodic monitoring requirements of Rule 64.

3. Upon District request, sulfur compounds at the point of discharge shall be determined by source testing using EPA Test Method 6, 6A, 6C, 8, 15, 16A, 16B, or South Coast AQMD Test Method 307-91 (Determination of Sulfur in a Gaseous Matrix), as appropriate.

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Ventura County Air Pollution Control District
Rule 54 Applicable Requirements
Sulfur Compounds - Sulfur Dioxide Concentration at Ground Level

Rule 54, "Sulfur Compounds"
Adopted 01/14/14, Federally Enforceable

Applicability:

This attachment applies to all emissions units at this stationary source that emit sulfur compounds. This attachment addresses the requirements of Rule 54 for sulfur emissions at ground or sea level at or beyond the property line of the stationary source.

Conditions:

1. Pursuant to Rule 54, no person shall discharge sulfur compounds, which would exist as a liquid or gas at standard conditions, as sulfur dioxide which results in average ground or sea level concentrations at any point at or beyond the property line in excess of 0.25 ppmv averaged over any one hour period, or 0.04 ppmv averaged over any 24 hour period.

2. Pursuant to Rule 54.B.2.a, no person shall discharge sulfur compounds, which would exist as a liquid or gas at standard conditions, as sulfur dioxide which results in ground or sea level concentrations at any point at or beyond the property line such that the 1-hour average design value exceeds 0.075 ppm (Vol).

    a) For purposes of Subsection B.2.a, the design value is derived from the 3-year average of annual 99th percentile daily maximum 1-hour values. At the District's discretion, compliance with the ground or sea level concentration limit in Subsection B.2.a of this rule may be demonstrated using EPA-approved dispersion models or ambient air monitoring. If the District requires ambient air monitoring, the test method(s) listed in Subsection D.2 of this rule must be employed.

    b) To demonstrate compliance using dispersion modeling, the annual 99th percentile daily maximum at each receptor is determined from model results as follows: for each year of meteorological data modeled, select from each day the maximum hourly modeled SO_2 concentration value and sort all these daily maximum hourly values by descending value. The 99th percentile is the 4th highest value for each modeled year. Calculate the average of the 99th percentile values for three consecutive years of modeling data for each receptor. Compliance is demonstrated if this average value is less than or equal to the design value concentration limit in Subsection B.2.a of this Rule at each receptor.

    c) Compliance with the limit in subsection B.2.a may also be demonstrated using EPA-approved screen models. Compliance is demonstrated if the 1-hour SO_2

ground or sea level concentration does not exceed 0.075 ppm (Vol) at or beyond the property line.

d) If ambient air monitoring data is used to demonstrate compliance, the design value must be calculated in accordance with 40 CFR Part 50 Appendix T – Interpretation of the Primary National Ambient Air Quality Standards for Oxides of Sulfur (Sulfur Dioxide).

3. Permittee shall maintain a representative fuel analysis or exhaust analysis, along with modeling data or other demonstration to ensure that compliance with Rule 54 is being maintained. This analysis and compliance demonstration shall be provided to the District upon request.

4. Upon District request, ground or sea level concentrations of SO_2 shall be determined by Bay Area Air Quality Management District Manual of Procedures, Volume VI, Section 1, Ground Level Monitoring for Hydrogen Sulfide and Sulfur Dioxide (July 20, 1994) with the following amendments:

   a. The wind direction shall be continuously measured and recorded to within 5 degrees of arc, and wind speed shall be continuously measured and recorded to within 0.25 miles per hour (mph) at wind speeds less than 25 mph and with a threshold no greater than 0.2 mph.

   b. The meteorological instruments and siting requirements shall comply with the guidelines in "Quality Assurance Handbook for Air Pollution Measurements Systems, Volume IV, Meteorological Measurements Version 2.0," EPA-454/B-08-002, March 2008.

   c. The gas standards shall be restandardized against the reference wet chemical method at a minimum of once every 12 months, or be standardized using National Institute of Standards and Technology (NIST) standard gases.

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Ventura County Air Pollution Control District
Rule 55 Applicable Requirements
Fugitive Dust

Rule 55, "Fugitive Dust"
Adopted 06/10/08, District-Enforceable

This permit attachment will become federally enforceable when Rule 55 is approved by EPA as part of the SIP.

Applicability:

This attachment applies to any operation, disturbed surface area, or man-made condition at this stationary source that is capable of generating dust. These operations may include bulk material handling, earth-moving, construction, demolition, storage piles, unpaved roads, track-out, or off-field agricultural operations.

All definitions listed in Section H of Rule 55 are applicable to this attachment. The Rule 55 definition section includes the following definitions: "disturbed surface area", "bulk material", "earth moving activities", "construction/demolition activities", "storage piles", "paved road", "track-out", and "off-field agricultural operations". All exemptions listed in Section D of Rule 55 are applicable to this attachment.

Conditions:

1. Pursuant to Rule 55.B.1, the permittee shall not cause or allow the emissions of fugitive dust from any applicable source such that the dust remains visible beyond the midpoint (width) of a public street or road adjacent to the property line of the emission source or beyond 50 feet from the property line if there is not an adjacent public street or road.

2. Pursuant to Rule 55.B.2, the Permittee shall not cause or allow the emissions of fugitive dust from any applicable source such that the dust causes 20 percent opacity or greater during each observation and the total duration of such observations (not necessarily consecutive) is a cumulative 3 minutes or more in any one (1) hour. Only opacity readings from a single source shall be included in the cumulative total used to determine compliance. Compliance with the opacity limit shall be determined by using EPA Method 9 with the modifications listed in Section F of Rule 55.

3. Pursuant to Rule 55.B.3, the permittee shall not allow track-out to extend 25 feet or more in length unless at least one of the following three control measures is utilized: track-out area improvement, track-out prevention, or track-out removal. These control measures are detailed in Rule 55.B.3.a.

4. Pursuant to Rule 55.B.3.b, notwithstanding other track-out requirements, all track-out shall be removed at the conclusion of each workday or evening shift subject to the conditions listed in Section 55.B.3.b.

5. Pursuant to Rule 55.C, the permittee shall comply with the specific activity requirements detailed in Section C of Rule 55, for earth-moving, bulk material handling, and truck hauling activities, as applicable.

6. The permittee shall comply with the specific recordkeeping requirements listed in Section E of Rule 55, as applicable.

7. On an annual basis, the permittee shall certify that all applicable sources of dust at this stationary source are operating in compliance with Rule 55. The permittee may also certify annually that there are no operations, disturbed surface areas, or man-made conditions at this stationary source that are subject to Rule 55.

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Ventura County Air Pollution Control District
Rule 57.1 Applicable Requirements
Particulate Matter Emissions from Fuel Burning Equipment

Rule 57.1, "Particulate Matter Emissions from Fuel Burning Equipment"
Adopted 01/11/05, Federally Enforceable

Applicability:

This attachment applies to fuel burning equipment such as boilers, steam generators, process heaters, water heaters, space heaters, flares, and gas turbines. This attachment does not apply to internal combustion engines, jet engine test stands and rocket engine test stands, and rocket propellant testing devices and rocket fuel testing devices. This attachment also does not apply to exhaust gas streams containing particulate matter that was not generated by the combustion of fuel; such exhaust gas streams are subject to Rule 52 and Rule 53.

Conditions:

1. Pursuant to Section B of Rule 57.1, emissions of particulate matter shall not exceed 0.12 pounds per million BTU of fuel input.

   Particulate matter is defined as any material, except uncombined water, that exists in a finely divided form as a liquid or solid at standard conditions. Standard conditions are: a gas temperature of 68 degrees Fahrenheit (20 degrees Celsius) and a gas pressure of 14.7 pounds per square inch (760 mm. Hg) absolute.

2. Upon request of the District Compliance Division, compliance shall be determined by independent source test using CARB Method 5. The total particulate catch shall include the filter catch, probe catch, impinger catch, and the solvent extract, as specified in CARB Method 5. Any other appropriate test method may be used with prior written approval by the District, the California Air Resources Board, and the U.S. Environmental Protection Agency.

3. Periodic monitoring is not necessary to certify compliance with Rule 57.1. To certify compliance, a reference to the Rule 57.B District analysis dated December 3, 1997 is sufficient.

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Ventura County Air Pollution Control District
Rule 64 Applicable Requirements
Sulfur Content of Fuels - Gaseous Fuel Requirements

Rule 64, "Sulfur Content of Fuels"
Adopted 04/13/99, Federally Enforceable

Applicability:

This attachment applies to all combustion emissions units at this stationary source while the emissions units are combusting gaseous fuels. Rule 64 shall not apply to any flare gas combustion, where no useful energy is produced, and which is subject to Rule 54, "Sulfur Compounds."

Conditions:

1. Pursuant to Rule 64, no person shall burn at any time gaseous fuel containing sulfur compounds in excess of 50 grains per 100 cubic feet of gaseous fuel (788 ppmv), calculated as hydrogen sulfide at standard conditions, unless specifically exempted by Rule 64.

2. If only Public Utilities Commission-regulated natural gas, propane, or butane is combusted at this facility, it will be assumed that the permittee is complying with Rule 64 without additional periodic monitoring requirements. Any person claiming this exemption shall maintain records sufficient to substantiate the use of these fuels.

3. If other than Public Utilities Commission-regulated natural gas, propane, or butane is being combusted, the permittee shall analyze the sulfur content of the fuel on an annual basis using South Coast AQMD Method 307-94 - Determination of Sulfur in a Gaseous Matrix or by ASTM D1072-90 (1994), Standard Test Method for Total Sulfur in Fuel Gases.

   Alternatively, when measuring the sulfur content of landfill or oilfield gaseous fuel, permittee may use the colorimetric method ASTM D 4810-88 (Reapproved 1994) or the ASTM D4084-94 (Lead Acetate Reaction Rate Method) and may assume that the hydrogen sulfide content of the fuel gas adequately represents the total sulfur content. However, if the sulfur content as measured by ASTM D4810-88 or ASTM D4084-94 equals or exceeds 200 ppmv, then only South Coast AQMD Method 307-94 or ASTM D1072-90 (1994) shall be used to determine compliance.

   The applicable ranges of some ASTM methods mentioned above are not adequate to measure the levels of sulfur in some fuel gases. Dilution of samples before analysis may be used subject to the verification of the dilution ratio.

Permittee may use the colorimetric method ASTM D 4810-88 (Reapproved 1994) for the measurement of the sulfur content of gaseous fuels other than landfill or oilfield gas only if written approval has been granted by the District and by US EPA.

4. Monitoring of the sulfur content of landfill or oilfield gaseous fuel by the permittee shall be at least quarterly if any of the following conditions apply:

   a. Any sulfur measurement exceeds 394 ppmv, calculated as hydrogen sulfide at standard conditions.

   b. A stationary source is new.

   c. The permittee has not reported historical measurements of hydrogen sulfide of the landfill or oilfield gaseous fuel performed within the previous three years in writing to the District for a stationary source.

   An operator may have the sulfur content of landfill or oilfield gaseous fuel monitored annually only, instead of quarterly, by satisfying the following provisions:

   a. During four consecutive calendar quarters, each sulfur content measurement shall not exceed 394 ppmv, calculated as hydrogen sulfide at standard conditions, and

   b. Submit a written request to the District for a reduction in monitoring frequency. This request shall contain backup documentation including monitoring reports that document the above provision. Requests for a reduction in monitoring frequency are not effective until written approval by the District is received by the operator.

   This annual fuel analysis, and the quarterly analyses if applicable, shall be maintained at the facility and a copy of the annual analysis shall be provided to the District with the annual compliance certification.

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Ventura County Air Pollution Control District
Rule 64 Applicable Requirements
Sulfur Content of Fuels - Liquid Fuel Requirements

Rule 64, "Sulfur Content of Fuels"
Adopted 04/13/99, Federally Enforceable

Applicability:

This attachment applies to all combustion emissions units at this stationary source while the emissions units are combusting liquid fuels. This attachment does not apply to any combustion emission unit with sulfur emission controls.

Conditions:

1. Pursuant to Rule 64, no person shall burn any liquid fuels with a sulfur content in excess of 0.5 percent, by weight, unless specifically exempted by Rule 64.

2. If only ARB-quality reformulated gasoline or ARB-certified diesel fuel is combusted at this facility, it will be assumed that the permittee is complying with Rule 64 without additional periodic monitoring requirements. Any person claiming this exemption shall maintain records sufficient to substantiate the use of these fuels.

3. If other than ARB-quality reformulated gasoline or ARB-certified diesel fuel is being combusted, for each liquid fuel delivery permittee shall either obtain the fuel supplier's certification, or shall test the sulfur content of the fuel using ASTM Method D4294-98 or D2622-98, to ensure that compliance with Rule 64 is being maintained. For liquid fuels, operators of electric power generation units may use the sampling and analysis methods prescribed in Code of Federal Regulations 40CFR Part 75 Appendix D.2.2. The fuel supplier's certification may be provided once for each purchase lot, if records are kept of the purchase lot number of each delivery.

   The fuel sulfur content by weight data shall be maintained at the facility and shall be provided with the annual compliance certification.

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Ventura County Air Pollution Control District
Rule 71.1.C Applicable Requirements
Crude Oil Production and Separation - Produced Gas

Rule 71.1, "Crude Oil Production and Separation"
Adopted 06/16/92, Federally-Enforceable

Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities"
Adopted 03/10/98, Federally-Enforceable

Applicability:

This attachment applies to the emissions of produced gas from equipment used in the production, gathering, storage, processing, and separation of crude oil and natural gas from any petroleum production unit prior to custody transfer. Specifically, this attachment applies to gas collection systems that are hard-piped and closed systems that direct all produced gas to a fuel or sales gas system or to a flare.

Conditions:

1. Pursuant to Rule 71.1.C.1, the emissions of produced gas shall be controlled at all times using a properly maintained and operated closed system that directs all gas, except gas used in a tank battery vapor recovery system, to one of the following:

    a. A fuel or sales gas system
    b. A flare that combusts reactive organic compounds

2. Pursuant to Rule 71.1.C.2, the provisions of Rule 71.1.C.1 shall not apply to wells which are undergoing routine maintenance, or to exploratory wells (during the first two weeks of production) if the composition of the produced gas is unknown (i.e., new reservoir) and there are no existing gas handling systems within 150 feet of the well.

3. Permittee shall annually certify the produced gas collection system to ensure that compliance with Rules 71.1.C.1 is being maintained. This annual certification shall include a visual inspection assuring that the produced gas collection system is a closed system.

4. If a flare is used to control the produced gas, permittee shall inspect the flare on a quarterly basis to ensure that it is operating properly. A record of these inspections shall be maintained at the facility and shall be submitted to the District upon request.

5. The gas collection system's gas and liquid piping connections are components subject to the leak requirements of Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities". Compliance with Rule 74.10 at the gas collection system ensures compliance with the maintenance requirements of Rule 71.1.C.1.

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Ventura County Air Pollution Control District
Rule 71.4.B.1 Applicable Requirements
First Stage Sump Prohibition

Rule 71.4, "Petroleum Sumps, Pits, Ponds, and Well Cellars"
Adopted 06/08/93, Federally-Enforceable

Applicability:

This attachment applies to any first stage production sump at this stationary source. A first stage production sump is a sump that receives a stream of petroleum material directly from wells or a field gathering system. A sump is a receptacle, formed primarily of earthen materials, although it may be lined with artificial materials. A sump is further defined as "in continuous use for separating oil, water, sand, or other material in petroleum production operations".

Conditions:

1. Pursuant to Rule 71.4.B.1, no person shall install, maintain, or operate a first stage production sump. A first stage production sump is a sump that receives a stream of petroleum material directly from wells or a field gathering system.

2. In order to ensure that compliance with Rule 71.4.B.1 is being maintained, permittee shall annually certify that there are no first stage production sumps at the facility.

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Ventura County Air Pollution Control District
Rule 71.4.B.3 Applicable Requirements
Well Cellar Storage Prohibition

Rule 71.4, "Petroleum Sumps, Pits, Ponds and Well Cellars"
Adopted 06/08/93, Federally Enforceable

Applicability:

This attachment applies to any well cellar at this stationary source. This attachment addresses the requirements of Rule 71.4.B.3 which prohibits the storage of crude oil or petroleum material in a well cellar. Rule 71.4 applies to well cellars at facilities where crude oil or petroleum material is produced, gathered, separated, processed, or stored.

A well cellar is a lined or unlined area around one or more oil wells, allowing access to the wellhead components for servicing and/or installation of blowout prevention equipment.

Conditions:

1. Pursuant to Rule 71.4.B.3, no person shall store crude oil or petroleum material in a well cellar except during periods of equipment maintenance or well workover. In no case shall storage occur for more than five (5) calendar days.

2. Pursuant to Rule 71.4.C, the provisions of Rule 71.4 shall not apply to well cellars used in an emergency, if clean-up procedures are implemented within 24 hours after each emergency occurrence and if clean-up procedures are completed within fifteen (15) calendar days.

3. Pursuant to Rule 71.4.D.2, any person storing crude oil in a well cellar during periods of equipment maintenance or well workover shall maintain records, which may include but are not limited to, workover invoice documents, indicating the date(s) the material was stored in the well cellar or the date(s) of workover activity. These records shall be submitted to the District upon request.

4. Pursuant to Rule 71.4.D.3, any person claiming exemption to this rule pursuant to emergency use (Condition No. 2 above), shall maintain records to justify the exemption.

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Ventura County Air Pollution Control District
Rule 74.6 Applicable Requirements
Surface Cleaning and Degreasing

Rule 74.6, "Surface Cleaning and Degreasing"
Adopted 11/11/03, Federally Enforceable

Applicability:

This attachment applies to all solvent cleaning activities at this stationary source, except those activities listed in Condition No. 11 that are exempt pursuant to Section E of Rule 74.6. This attachment does not apply to substrate surface preparation regulated by other APCD surface coating, adhesive, ink, resin, and solvent rules. "Solvent" is defined as any ROC-containing liquid used to perform solvent cleaning. "Solvent cleaning" is defined as the use of organic solvent to remove loosely held uncured adhesives, uncured inks, uncured coatings, uncured resins, and other contaminants which include, but are not limited to, dirt, soil, lubricants, coolant, moisture, grease, and fingerprints, from parts, tools, machinery, equipment, and general work areas.

This attachment also contains requirements, pursuant to Rule 74.6, for cold cleaners. A cold cleaner is defined in Rule 74.6 as any batch operated equipment designed to contain liquid solvent that is operated below the solvent's boiling point to carry out solvent cleaning operations. A specific type of cold cleaner is a "remote reservoir cold cleaner" which is a device in which solvent is moved through a sink-like work area for cleaning parts and drains immediately, without forming a pool, through a single drain hole less than 100 square centimeters (15.5 square inches) in area into an enclosed container that is not accessible for soaking parts. The freeboard height for remote reservoir cold cleaners is the distance from the top of the solvent drain to the top of the tank.

This attachment does not apply to solvent cleaning where an emission control system is used pursuant to Rule 74.6.B.5 or where an alternative cleaning system is used pursuant to Rule 74.6.B.6. Pursuant to APCD Rule 23.F.7, solvents used by the permittee for facility, ground, and building maintenance and repair are exempt from the requirement to have a permit. However, unless exempted by Rule 74.6.E, such solvents are required to comply with Rule 74.6.

Conditions:

1. Pursuant to Rule 74.6.B.1, no person shall perform solvent cleaning using solvent that exceeds the following limits:

    a. Solvents used for application equipment cleanup, and all other cleanup of uncured coatings, adhesives, inks, or resins, shall not exceed an ROC content of 900 grams per liter and an ROC composite partial pressure of 33 mmHg at $20^{o}C$, as applied.

b. Solvents used for cleaning of electronic components, electrical apparatus components, medical devices, or aerospace components shall not exceed an ROC content of 900 grams per liter and an ROC composite partial pressure of 33 mmHg at 20°C, as applied.

c. Solvents used for cleaning for purposes other than those listed in (a) and (b) above shall not exceed an ROC content of 25 grams per liter, as applied.

2. Pursuant to Rule 74.6.B.2, no person shall perform solvent cleaning using a solvent with an ROC content greater than 25 grams per liter unless one of the following cleaning devices or methods is used:

   a. Wipe cleaning where solvent is dispensed to wipe cleaning materials from containers that are kept closed to prevent evaporation, except while dispensing solvent or replenishing the solvent supply;

   b. Non-atomized solvent flow, dip, or flush method where pooling on surfaces being cleaned is prevented or drained, and all solvent runoff is collected in a manner that enables solvent recovery or disposal. The collection system shall be kept closed to prevent evaporation except while collecting solvent runoff or emptying the collection system;

      If the cleaning method has a solvent capacity more than one gallon, a cold cleaner or remote reservoir cold cleaner meeting the equipment and operating requirements of Condition Nos. 8, 9, and 10 of this attachment (Sections C and D of Rule 74.6) shall be used to comply with this requirement.

   c. Application of solvent from a hand held spray bottle, squirt bottle or other closed container with a capacity of one liter or less;

   d. A properly used enclosed gun washer or low emission spray gun cleaner.

3. Pursuant to Rule 74.6.B.3.a, no person shall allow liquid cleaning solvent to leak from any equipment or container.

4. Pursuant to Rule 74.6.B.3.b, no person shall specify, solicit, supply, or require any cleaning solvent or solvent cleaning equipment intended for uses governed by Rule 74.6 if such use would violate Rule 74.6. This prohibition applies to all written and oral contracts under which solvent cleaning operations subject to Rule 74.6 are to be conducted at any location in Ventura County.

5. Pursuant to Rule 74.6.B.3.c, no person shall use more than one gallon per week of

solvents containing methylene chloride, perchloroethylene, trichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride, or chloroform, or any combination of these solvents, in a total concentration greater than 5 percent by weight, for cold cleaning except in a cold cleaner operated in accordance with National Emission Standards for Halogenated Solvent Cleaning, 40 CFR Parts 9 and 63, Subpart T, Sections 63.460 through 63.469 (Degreasing MACT Standards). Any person that uses the above solvent in quantities less than one gallon per week shall maintain records of the volume and formulation of such solvent on an as-used basis (recording use each day such material is used). Records shall be saved for at least five (5) years from the date of each record and shall be made available to District personnel upon request.

6. Pursuant to Rule 74.6.B.4.a, all ROC-containing solvents shall be stored in non-absorbent, non-leaking containers that shall be kept closed at all times except when filling or emptying.

7. Pursuant to Rule 74.6.B.4.b, waste solvent and waste solvent residues shall be disposed of in a manner conforming with Division 20, Chapter 6.5 of the California Health and Safety Code.

8. Pursuant to Rule 74.6.C.1, all cold cleaners, except remote reservoir cold cleaners, shall be equipped with the following devices:

   a. A drying rack suspended above the solvent, or other facility for draining cleaned parts such that the drained solvent is returned to the cleaner.

   b. A cover that prevents the solvent from evaporating when not processing work in the cleaner. If high volatility solvent is used, the cover must be a sliding, rolling, or guillotine (bi-parting) type that is designed to easily open and close, or it must be designed to be easily operated with one hand. A high volatility solvent is an unheated solvent with an ROC composite partial pressure of greater than 2 mmHg @ 20^{o}C.

   c. A freeboard height of at least 6 inches (15.2 centimeters), if low volatility solvent is used. A low volatility solvent is an unheated solvent with an ROC composite partial pressure of 2 mmHg or less @ 20^{o}C.

   d. At least one of the following control devices, if high volatility solvent is used:

      1. A freeboard height such that the freeboard ratio is at least 0.75.
      2. A water cover if the solvent is insoluble in and heavier than water.

   e. A permanent conspicuous mark locating the maximum allowable solvent level that conforms with the applicable freeboard height requirement in Condition No. 8.c or 8.d.1.

f. A permanent conspicuous label or sign summarizing the applicable operating requirements appropriate for cold cleaning operations.

9. Pursuant to Rule 74.6.C.2, remote reservoir cold cleaners shall be equipped with the following devices:

   a. A permanent conspicuous label or sign summarizing the applicable operating requirements appropriate for cold cleaning operations.

   b. A sink-like work area that is sloped sufficiently towards the drain to preclude pooling of solvent.

   c. A single drain hole, less than 100 square centimeters (15.5 square inches) in area, for the solvent to flow from the sink into the enclosed reservoir.

   d. A freeboard height of at least 6 inches (15.2 centimeters).

   e. A cover for the drain when no work is being processed in the cleaner and high volatility solvent is used. If low volatility solvent is used, a cover is not required.

10. Pursuant to Rule 74.6.D, any person who operates a cold cleaner shall conform to the following operating requirements:

   a. The operator shall drain cleaned parts of all solvent until dripping ceases to ensure that the drained solvent is returned to the cleaner.

   b. Solvent agitation, where necessary, shall be achieved using pump recirculation, a mixer, or ultrasonics. Air agitation shall not be used.

   c. If a solvent flow is utilized, only a solid fluid stream (not a fine, atomized, or shower type spray) shall be used.

   d. The pressure of the solvent flow system shall be such that liquid solvent does not splash outside the container.

   e. No person shall remove or open any required device designed to cover the solvent unless work is being processed in the cleaner or maintenance is being performed on the cleaner.

   f. The cleaning equipment and emission control equipment shall be operated and maintained in proper working order.

   g. The cleaning of porous or absorbent materials such as cloth, leather, wood, or rope is prohibited. This provision shall not apply to paper gaskets or paper filters.

11. Pursuant to Rule 74.6.E.1, Rule 74.6 (all requirements of this permit attachment) shall not

apply to:

a. Cleaning activities using Clean Air Solvent, or a solvent with an ROC-content no more than 25 grams per liter as applied. A "Clean Air Solvent" is a solvent certified by the South Coast Air Quality Management District as a Clean Air Solvent.

b. The use of up to 160 fluid ounces of non-refillable aerosol cleaning products per day, per facility.

c. Janitorial cleaning including graffiti removal.

d. Cleaning carried out in vapor degreasers or motion picture film cleaning equipment.

e. Any cleaning device or mechanism regulated by National Emission Standards for Halogenated Solvent Cleaning, 40 CFR Parts 9 and 63, Subpart T, Sections 63.460 through 63.469 (Degreasing MACT Standards).

f. Cleaning operations subject to any of the following rules:

Rule 74.3, Paper, Fabric and Film Coating Operations
Rule 74.5.1, Petroleum Solvent Dry Cleaning
Rule 74.5.2, Synthetic Solvent Dry Cleaning
Rule 74.19, Graphic Arts Operations
Rule 74.19.1, Screen Printing Operations
Rule 74.21, Semiconductor Manufacturing

g. Stripping of cured coating (e.g.; stripping), cured adhesive (e.g.; debonding, ungluing), cured ink, or cured resin.

h. The use of solvent for purposes other than solvent cleaning activities.

12. Pursuant to Rule 74.6.E.2, Rule 74.6.B.1 (Condition No. 1 of this attachment) shall not apply to:

a. Cleaning operations required to comply with any ROC content and/or composite vapor pressure limit in any of the following rules:

Rule 74.12, Surface Coating of Metal Parts and Products
Rule 74.13, Aerospace Assembly and Component Manufacturing Operations
Rule 74.14, Polyester Resin Material Operations
Rule 74.18, Motor Vehicle and Mobile Equipment Coating Operations
Rule 74.20, Adhesives and Sealants
Rule 74.24, Marine Coating Operations

Rule 74.24.1, Pleasure Craft Coating Operations
Rule 74.30, Wood Products Coatings

b. Cleaning of ultraviolet lamps used to cure ultraviolet inks coatings, adhesives or resins.

c. Cleaning of solar cells, laser hardware, scientific instruments, or high-precision optics.

d. Cleaning conducted in laboratory tests and analyses including quality assurance/quality control applications, or bench scale or short-term (less than 2 years) research and development programs.

e. Removal of elemental sodium from the inside of pipes and lines.

f. Cleaning of mold release compounds from molds.

g. Cleaning of tools used to cut or abrade cured magnetic oxide coatings.

h. Cleaning of aerospace assembly and subassembly surfaces that are exposed to strong oxidizers or reducers such as nitrogen tetroxide, liquid oxygen or hydrazine.

i. Cleaning of paper gaskets.

j. Cleaning of clutch assemblies where rubber is bonded to metal by means of an adhesive.

k. Cleaning of hydraulic actuating fluid from filters and filter housings.

l. Removal of explosive materials and constituents from equipment associated with manufacturing, testing or developing explosives.

m. Manufacturing cleaning of nuts and bolts designed for automotive racing applications, in a cold cleaner complying with Sections C and D of Rule 74.6 using solvent with an ROC content no more than 900 grams per liter and a ROC composite partial pressure no more than 5 mm Hg @ 20C.

n. Cleaning of precision–lapped mechanical seals in pumps that handle liquefied gasses, in a cold cleaner complying with Sections C and D of Rule 74.6 using solvent with an ROC content no more than 900 grams per liter and a ROC composite partial pressure no more than 5 mm Hg @ 20C.

o. Facility wide use of less than 1 gallon per week of non-compliant solvent where compliant solvents are not available. Any person claiming this exemption shall maintain records of the volume and formulation of non-compliant solvent used on an as-used basis (recording use each day such material is used). Records shall be saved for at least five (5) years from the date of each record and shall be made available to District personnel upon request.

13. Pursuant to Rule 74.6.E.3, Rule 74.6 Sections B.1 and B.2 (Condition Nos. 1 and 2 of this attachment) shall not apply to aircraft engine gas path cleaning or stationary gas turbine gas path cleaning using solvent with an ROC content of 200 g/l or less, as applied.

14. Pursuant to Rule 74.6.F, the permittee shall maintain a current material list showing each ROC containing material used in solvent cleaning activities. The list shall summarize the following information:

    a. Solvent name and manufacturer's description.

    b. All intended uses of the solvent at the facility, classified as follows:

        1. Cleanup, including application equipment cleaning, or
        2. Cleaning of electronic components, electrical apparatus components, medical devices, or aerospace components, or
        3. Solvent used pursuant to an exemption in Rule 74.6.E (specify the exemption claimed).

    c. The ROC content in units of grams per liter of material (and ROC composite partial pressure in units of mm Hg @ 20C, if applicable) of the solvent.

    d. If the solvent is a mix of materials blended by the operator, a record of the mix ratio.

    This information shall be made available to District personnel upon request.

15. Permittee shall maintain the above records and conduct periodic facility inspections, and an annual compliance certification to ensure that compliance with Rule 74.6 is being maintained. Upon request of the District, compliance with Rule 74.6 shall be determined using the following methods:

    a. Pursuant to Rule 74.6.G.1, the ROC content of materials shall be determined by EPA Test Method 24 (40 CFR Part 60, Appendix A).

    b. Pursuant to Rule 74.6.G.4, the identity of components in solvents shall be determined using manufacturer's formulation data or by using ASTM E168-67, ASTM E169-87, or ASTM E260-85.

c. Pursuant to Rule 74.6.G.5, ROC composite partial pressure of a solvent shall be calculated using a widely accepted published source such as: Boublik, T., V. Fried and E. Hala, "The Vapor Pressure of Pure Substances," Elsevier Scientific Publishing Co., New York (1973), Perry's Chemical Engineers Handbook, McGraw-Hill Book Company, CRC Handbook of Chemistry and Physics, Chemical Rubber Publishing Company (1986-1987), and Lange's Handbook of Chemistry, John A. Dean, editor, McGraw-Hill Book Company (1985). The true vapor pressure of a component in a solvent mix may be determined by ASTM Method D2879-86. The ROC composite partial pressure of a solvent mix consisting entirely of ROC may be determined by ASTM Method D2879-86.

d. Pursuant to Rule 74.6.G.6, the active and passive solvent losses from spray gun cleaning systems shall be determined using South Coast Air Quality Management District's "General Test Method for Determining Solvent Losses from Spray Gun Cleaning Systems" dated October 3, 1989. The test solvent for this determination shall be any lacquer thinner with a minimum vapor pressure of 105 mm Hg at 20°C. The minimum test temperature shall be 15°C.

e. Pursuant to Rule 74.6.G.7, initial boiling point of solvent shall be determined by ASTM 1078-78 or by using a published source such as listed in Rule 74.6.G.5.

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Ventura County Air Pollution Control District
Rule 74.10 Applicable Requirements
Components at Crude Oil and Natural Gas Production and Processing Facilities

Rule 74.10, "Components at Crude Oil and Natural Gas Production and Processing Facilities"
Adopted 03/10/98, Federally Enforceable

Applicability:

This attachment applies to the crude oil and gas production facilities, pipeline transfer stations, and to natural gas processing facilities, at this stationary source. This attachment summarizes the fugitive leak and leak inspection requirements of Rule 74.10.

A crude oil and gas production facility is defined as an onshore or offshore facility at which crude petroleum and natural gas production and handling are conducted, as defined in the SIC Code as Industry No. 1311, Crude Petroleum and Natural Gas. A pipeline transfer station is defined as a facility that handles the transfer or storage of crude oil in pipelines. A natural gas processing facility is defined as a facility engaged in the separation of natural gas liquids from field gas and/or fractionation of the liquids into natural gas products, such as ethane, propane, butane, and natural gasoline. Excluded from the definition are compressor stations, dehydration units, sweetening units, field treatment, underground storage facilities, liquefied natural gas units, and field gas gathering systems unless these facilities are located at a natural gas processing plant. This attachment does not apply to petroleum refineries.

Conditions:

1. Pursuant to Rule 74.10.B, the operator shall identify all leaking components that cannot be immediately repaired. This identification shall consist of readily visible labels, tags, or other such system approved by the APCO, in writing, that enables the District and the operator to locate and identify each leaking component. Identification tags and labels shall remain visible for at least one year from the date attached.

   As detailed in Rule 74.10.K.14, a leak is defined as any major gas leak, minor gas leak, major liquid leak or minor liquid leak. A leak is not a gaseous emission from a pneumatic control valve if it occurs when the valve is in the act of opening or closing. As detailed in Rule 74.10.K.3, a component is defined as any valve, stuffing box, dump lever arm, open ended line, fitting, pump seal, compressor seal, pressure relief valve, diaphragm, hatch, sight glass or meter. As detailed in Rule 74.10.K.16, a leak repair is any corrective action taken for the purposes of reducing a component leak to the lowest achievable level or at least below 1,000 ppmv for gas leaks and three drops per minute for liquid leaks using the best modern practices.

2. Pursuant to Rule 74.10.C.1, hatches shall be closed at all times except during sampling, adding of process material through the hatch, or attended maintenance operations.

3. Pursuant to Rule 74.10.C.2, no person shall use a component that emits a major gas leak, major liquid leak or minor liquid leak and the applicable maximum leak threshold for that component category, as listed in Attachment 1 of Rule 74.10, has been exceeded at the facility in any calendar quarter. The provisions of Rule 74.10.C.2 shall not apply to components that are tagged and repaired in accordance with Rules 74.10.D and 74.10.F.

   For the purpose of complying with the operating requirements in Rule 74.10.C.2, any fugitive emissions leak originating at a tank seam, broken pipe or any other nondesigned opening in a process unit shall be considered an "other component" leak for the purpose of Attachment 1 of Rule 74.10.

   A major gas leak, major liquid leak, and minor liquid leak are defined in Subsections K.17, K.18, and K.20 of Rule 74.10, respectively.

4. Pursuant to Rule 74.10.D.1, at natural gas processing plants, operators shall inspect with or without instrumentation all accessible operating pump seals, compressor seals, and pressure relief valves in service for leaks or indications of leaks once during every operating shift or every eight-hour period, whichever is greater.

5. Pursuant to Rule 74.10.D.2, at oil and gas production facilities and pipeline transfer stations, operators shall inspect with or without instrumentation all operating pump seals, compressor seals, pressure relief valves in service, and polished rod stuffing boxes for leaks or indications of leaks as follows:

   a. Inspection frequency at manned facilities shall be at least once per day except when operators do not report to work at a facility at any time during that day.

   b. Inspection frequency at unmanned facilities shall be at least once per week.

6. Pursuant to Rule 74.10.D.3, any gaseous leaks or indications of gaseous leaks discovered by inspection, that cannot be immediately repaired, shall be measured using EPA Method 21. The operator shall perform this leak measurement as follows:

   a. For leaks detected during normal business hours, the leak measurement shall be performed as soon as feasible but no later than 24 hours after detection. If this 24 hour deadline occurs on a weekend or holiday, then the deadline is shifted to the end of the next normal business day.

   b. For leaks detected during holidays, weekends or after business hours, the leak measurement shall be performed as soon as feasible but no later than the end of the next normal business day.

7. Pursuant to Rule 74.10.D.4, immediately after being placed into service, an operator shall inspect all new, replaced or repaired fittings, including flanges and threaded connections, for leaks using EPA Method 21.

8. Pursuant to Rule 74.10.D.5, operators shall inspect all components, except for the following, at least every calendar quarter for gaseous leaks using EPA Method 21.

   a. Inaccessible components or unsafe to monitor components shall be inspected for leaks by the operator at least annually using EPA Method 21.

   b. Threaded connections and flanges shall be inspected for leaks by the operator using EPA Method 21 annually, unless the operator has designated them in the Operator Management Plan as exempt from all inspection requirements and subject to a zero leak threshold.

9. Pursuant to Rule 74.10.D.6, a pressure relief valve shall be inspected using EPA Method 21 within 3 calendar days after every known pressure release.

10. Pursuant to Rule 74.10.D.7, upon detection, operators shall affix a visible, weatherproof tag to all leaking components awaiting repair. The tag shall remain affixed until the component is repaired free of leaks as shown by re-inspection.

    If the leak is gaseous, the operator shall include the following on the tag: date and time of leak detection, date and time of leak measurement; and the concentration (ppmv) measured using EPA Method 21.

    If the leak is liquid, the operator shall include the following on the tag: date and time of leak detection; and whether leak is minor or major.

    A tag may also be some other system approved in writing by the APCO that demonstrates to District personnel that the operator has detected a component leak awaiting repair and contains all of the information required to be on tags by Rule 74.10.D.7.

11. Pursuant to Rule 74.10.D.8, notwithstanding the requirements of Rule 74.10.D.5, operators may inspect components annually instead of quarterly at a facility by satisfying all the following provisions, except that compressor seals, pressure relief valves, polished rod stuffing boxes, and pump seals shall not be eligible for this reduction in inspection frequency:

    a. During 4 consecutive calendar quarters, successfully operate and maintain all components at the facility so that no more than 0.5 percent of the total components inspected, excluding polished rod stuffing boxes, have liquid leaks or major gas leaks that have not been immediately repaired.

b. A Notice of Violation from the District for a violation of Rule 74.10.C.2 was not received by the operator for the facility during the previous twelve months.

c. Submit a written request to the District for a reduction in inspection frequency. This request shall contain backup documentation including inspection reports that demonstrates that the above performance level in Rule 74.10.D.8.a has been achieved. Requests for a reduction in inspection frequency are not effective until written approval by the APCO is received by the operator.

12. Pursuant to Rule 74.10.D.9, an annual inspection frequency approved in Rule 74.10.D.8 shall revert to the inspection frequency specified in Rule 74.10.D.5 should the sum of liquid leaks and major gas leaks, not including leaks from polished rod stuffing boxes, exceed 0.5 percent of the total components inspected per inspection period or should the operator receive a Notice of Violation from the District for violation of Rule 74.10.C.2 for that facility.

13. Pursuant to Rule 74.10.E.1, each operator shall submit an Operator Management Plan to the APCO for approval. If the APCO fails to respond to the Plan in writing within 90 days after it has been received, then it shall be deemed approved. No provision in the Plan, approved or not, shall conflict with or take precedence over any provision of this rule. The Plan shall identify any component exempt from this rule or part of this rule, and describe the procedures which the operator intends to use to comply with the requirements of this rule. The Plan shall include:

a. Establishment of a data base of every leaking component that cannot be immediately repaired. The following parameters shall be included:

1) Identification number, name or code.

2) Component type, process unit and location.

3) Dates found leaking and repair description for each leak found.

This identification provision is for inspection, repair, replacement and recordkeeping purposes.

b. Identification of critical process units.

c. Identification of components for which exemption from Rule 74.10 is being claimed under Rule 74.10.G.1. Gaseous streams and liquid streams, exempted by

Rule 74.10, Subsections G.1.a, G.1.b, G.1.c, or G.1.e shall be verified by analysis of the ROC concentrations, and the results of such analyses shall be included.

d. Identification of liquid streams or components for which exemption is being claimed from the operator inspection requirements under Rule 74.10.G.3. The results of any testing used to qualify a stream for exemption shall be included.

e. Whether flanges or threaded fittings are exempt from all inspection requirements and subject to a zero leak threshold or whether flanges or threaded fittings are subject to annual inspection requirements and a one percent leak threshold as specified in Attachment 1 of Rule 74.10.

f. The inspection schedule to be followed.

g. Identification and description of any known hazard which may affect the safety of APCD personnel.

h. Identification of unmanned production facilities, if applicable.

14. Pursuant to Rule 74.10.E.2, the operator shall be required, upon written request by the APCO, to re-qualify, by analysis, the exemption(s) from the rule or part of the rule (Rule 74.10.G.1 and 74.10.G.3) if the exemption(s) may no longer be valid based on the changed composition of the process stream. The results of that analysis and any modification to the Plan shall be submitted to the District within 90 calendar days after receipt of the District request.

15. Pursuant to Rule 74.10.E.3, if the exempt status of a component is affected by a revision to Rule 74.10, then the Plan shall be modified accordingly by June 10, 1998.

16. Pursuant to Rule 74.10.E.4, existing operator management plans shall be updated no later than September 10, 1998, to include any provision that is needed to show compliance with Rule 74.10.

17. Pursuant to Rule 74.10.E.5, beginning September 10, 1998, each operator shall submit to the APCO, for approval in writing, an annual report to update the Operator Management Plan by no later than January 30 of each year. This report shall include any changes to exemptions, inspection schedule, or any other changes to the inspection and maintenance program. If no changes to the Plan have occurred over the past 12 months, then the operator shall indicate this in the annual report.

    If the APCO fails to respond to the Plan update in writing within 90 days after it has been received, then it shall be deemed approved. No provision in the Plan, approved or not, shall conflict with or take precedence over any provision of Rule 74.10.

18. Pursuant to Rule 74.10.F.1, the operator shall minimize all component leaks immediately if feasible but no later than 1 hour following detection during normal business hours. Component leaks detected during holidays, weekends and after business hours shall be immediately minimized if feasible but not later than the next normal business day.

19. Pursuant to Rule 74.10.F.2, any noncritical component found leaking shall be replaced or repaired to a leak free condition, within the time periods in Table 1 of Rule 74.10. For gaseous leaks, the repair period shall start at the time of leak measurement. For liquid leaks, the repair period shall start at the time of leak detection. If the Table 1 deadline for repairing any major gas leak or any liquid leak falls on a Saturday, Sunday or holiday, then the deadline shall be shifted to the next normal business day.

20. Pursuant to Rule 74.10.F.3, the operator shall re-inspect repaired or replaced components for leaks as soon as practicable using EPA Method 21, but not later than one calendar month after the date on which the component is repaired.

21. Pursuant to Rule 74.10.F.4, any component leak identified by District personnel shall be repaired and inspected as required by Rule 74.10.F.

22. Pursuant to Rule 74.10.F.5, any open-ended line found to be leaking shall be sealed with a blind flange, cap, plug, or a second closed valve at all times except during operations requiring process fluid flow through the open-ended line or valve. If a second closed valve is used, the process side valve shall be closed first, after the completion of any operations requiring flow through the open-ended valve.

23. Pursuant to Rule 74.10.F.6, for major gas leaks (>50,000 ppm) or major liquid leaks from any critical compressor seal, pump seal, pressure relief valve or valve that cannot be repaired within the repair periods set forth in Table 1 of Rule 74.10, the operator shall replace or retrofit the leaking component with Best Available Control Technology (BACT) equipment, as approved by the APCO in writing, within one year from the date of leak detection, or during the next critical process unit shutdown, whichever occurs first.

    For gas leaks less than or equal to 50,000 ppm or minor liquid leaks from critical components, or for leaks from critical components other than compressor seals, pump seals, pressure relief valves or valves, the owner or operator shall successfully repair or replace all leaking components within one year from leak detection or during the next critical process unit shutdown, whichever occurs first.

    The operator shall notify the District in writing within 3 months after detecting a major gas leak (> 50,000 ppm) or major liquid leak from a critical compressor seal, pump seal, pressure relief valve, or valve if such leak cannot be repaired within the repair periods set forth in Table 1 of Rule 74.10.

24. Pursuant to Rule 74.10.F.7, for a compressor seal, pump seal, pressure relief valve or valve that emits a total of 5 major leaks within a continuous 12 month period, the operator shall replace or retrofit the leaking component with BACT equipment, as approved by the APCO in writing, within one year from date of leak detection. The operator shall notify the District in writing within 3 months after a compressor, pump, pressure relief valve, or valve has had 5 major leaks in the previous 12 months.

25. Pursuant to Rule 74.10.G.1, the requirements of Rule 74.10 shall not apply to the following components that are verified in the Operator Management Plan:

    a. Components, not at natural gas processing plants, with gaseous streams with ROC concentrations of 10 percent, by weight or less.

    b. Components at natural gas processing plants with gaseous streams with ROC concentrations of one percent, by weight or less.

    c. Components, not at natural gas processing plants, in liquid service, with ROC concentrations of 10 percent, by weight or less.

    d. Underground components.

    e. Components exclusively handling fluids if the fluid weight evaporated is 10 percent or less at 150 degrees Celsius.

26. Pursuant to Rule 74.10.G.2, the operator inspection requirements of Rule 74.10.D shall not apply to the following components. All other requirements of this rule shall still apply.

    a. Pump seals, compressor seals, and pressure relief valves that are equipped with a closed-vent system to a vapor recovery system. The vapor disposal portion of the vapor recovery system shall consist of one of the following:

        1) A system which directs all vapors to a fuel gas system, a sales gas system, or a flare that combusts ROC.

        2) Any other system that processes all vapors and has a ROC vapor destruction or removal efficiency of at least 90 percent, by weight.

    b. One-half inch and smaller stainless steel tube fittings that have been determined to be leak-free.

c. Components in vacuum service.

d. Flanges or threaded connections that are designated in the Operator Management Plan as subject to the zero leak threshold specified in Attachment 1 of Rule 74.10.

27. Pursuant to Rule 74.10.G.3, the operator inspection requirements of Rule 74.10, Subsections D.1, D.2, D.4 and D.5 shall not apply to components that are inspected with or without instrumentation on a quarterly basis and are at oil and gas production facilities or pipeline transfer stations that handle liquids with the following properties and specified vapor recovery systems:

a. Liquid having an API gravity of 20 degrees or less after the point of primary separation;

b. Liquid having an API gravity between 20 and 30 degrees which are located either:

1) Downstream of a wellhead equipped with a casing vapor recovery system, provided that the vapor recovery system is operated at a pressure of less than 10 psig; or

2) After the point of primary separation of oil and gas, provided the separation vessel is equipped with a vapor recovery system and is operated at a pressure of less than 25 psig.

28. Pursuant to Rule 74.10.G.4, an owner or operator may petition the APCO for exemption from the replacement or retrofit requirements in Rules 74.10.F.6 and 74.10.F.7 by submitting a cost evaluation for retrofitting or replacing a compressor, pump, pressure relief valve, or valve. Each petition shall include:

a. A cost-effectiveness evaluation conducted in accordance with "BACT Cost-Effectiveness Procedures and Screening Levels for Costs," adopted by the Air Pollution Control Board on December 20, 1988. The cost analysis shall be based on the retrofit cost of the component if a retrofit is feasible. If the component cannot be retrofitted, then the following control option with the lower cost shall be used in the cost analysis:

1) Component replacement with the lowest feasible cost BACT option.

2) Enclosing the component seal and venting to a vapor recovery system.

b. Evidence of costs with written bids from vendors, published price lists, or other verifiable cost information. The potential emission reduction from the component retrofit/replacement shall be based on the ROC emissions over the previous 12 months. ROC emissions from a critical process unit shutdown shall be included if those emissions are associated with a critical leaking component. APCO-approved emission factors or source tests shall be used to quantify emissions.

29. Pursuant to Rule 74.10.H.1, any person subject to Rule 74.10 shall maintain an inspection log. The inspection log shall contain at least the following:

    a. Location, type, description, and name or code of each leaking component inspected that cannot be immediately repaired, and name of associated operating unit.

    b. For liquid leaks that cannot be immediately repaired: Date and time of leak detection and whether leak is major or minor.

    c. For gaseous leaks that cannot be immediately repaired: Date and time of leak detection, date and time of leak measurement, analyzer reading (ppmv) of the leak, and whether the leak is major or minor.

    d. Date that leak referenced in Rule 74.10.H.1.b or Rule 74.10.H.1.c is repaired to a leak-free condition, description of repair action, and date and emission level of re-check.

    e. Identification of leak as critical if the component is critical.

    f. Maintenance and calibration records of appropriate analyzer used in the EPA Method 21 measurements.

30. Pursuant to Rule 74.10.H.2, where a functional pressure relief has been detected, the operator shall record:

    a. Location, operating unit identification, and date of detection.

    b. Date of inspection of the pressure relief device after it was detected, and analyzer reading from EPA Method 21.

31. Pursuant to Rules 74.10.H.3 and 74.10.H.4, the inspection log shall be retained by the operator and shall be made available upon request to District personnel.

32. Pursuant to Rule 74.10.I.1, gaseous leaks from components shall be inspected or determined by EPA Method 21 by using an appropriate analyzer calibrated with methane. The calibration, maintenance, and operation of the appropriate analyzer shall follow the manufacturer's recommendations.

33. Pursuant to Rule 74.10.I.2, the ROC concentration, by weight, of process streams shall be measured by ASTM E168-88 (General Techniques of Infrared Qualitative Analysis), ASTM E169-87 (General Techniques of Ultraviolet Quantitative Analysis), or ASTM E260-85 (Gas Chromatography), or updated versions of these methods approved by EPA and published in the 40 CFR Part 60.

34. Pursuant to Rule 74.10.I.3, weight percentage of evaporated compounds of liquids shall be determined using ASTM Method D 86-82.

35. Pursuant to Rule 74.10.I.4, the API gravity of crude oil shall be determined using ASTM Method D287.

36. Pursuant to Rule 74.10.J, the failure of a person to meet any requirements of Rule 74.10 shall constitute a violation of Rule 74.10. Each leak exceeding the applicable maximum leak threshold in Attachment 1 of Rule 74.10 discovered by District personnel will be considered to be a violation.

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Ventura County Air Pollution Control District
Rule 74.11.1 Applicable Requirements
Rule 74.11.1, Large Water Heaters and Small Boilers

Rule 74.11.1, "Large Water Heaters and Small Boilers"
Adopted 09/11/12, Federally Enforceable

Applicability:

This attachment applies to all natural gas-fired water heaters, boilers, steam generators or process heaters (units) with a rated heat input capacity greater than or equal to 75,000 BTU/hr and less than 1,000,000 BTU/hr at this stationary source installed after January 1, 2013 and to the future installation of any such unit at this stationary source. Note that units rated less than 1,000,000 BTU/hr are exempt from District permit requirements pursuant to Rule 23.C.1.

Conditions:

1. Pursuant to Rule 74.11.1.B.2, no person shall sell, offer for sale, or install in Ventura County any new unit with a rated heat input capacity of greater than or equal to 75,000 BTU/hr and less than or equal to 400,000 BTU/hr that does not meet the following criteria:

   a. Oxides of nitrogen emissions shall not exceed 14 nanograms per joule of heat output (32.5 pounds per billion BTU), or 20 parts per million, and

   b. The unit is certified in accordance with Rule 74.11.1.C.

   The oxides of nitrogen emission standard required above (Condition No. 1.a) does not apply to units specifically designed to heat swimming pools, hot tubs, or spas. For such units, oxides of nitrogen emissions shall not exceed 40 nanograms per joule of heat output (93 pounds per billion BTU), or 55 parts per million.

2. Pursuant to Rule 74.11.1.B.4, no person shall sell, offer for sale, or install in Ventura County any new unit with a rated heat input capacity of greater than 400,000 BTU/hr and less than 1,000,000 BTU/hr that does not meet the following criteria:

   a. Oxides of nitrogen emissions shall not exceed 20 parts per million and carbon monoxide emissions shall not exceed 400 parts per million, and

   b. The unit is certified in accordance with Rule 74.11.1.C.

3. The permittee shall maintain a listing of manufacturer, brand name, model number, heat input rating, and installation date for each water heater, boiler, steam generator and

process heater, with a rated heat input capacity greater than or equal to 75,000 BTU/hr and less than 1,000,000 BTU/hr, at this stationary source. Permittee shall submit these identification records for all of these units to the District upon request.

4. On an annual basis, the permittee shall certify that all water heaters, boilers, steam generators and process heaters, with a rated heat input capacity greater than or equal to 75,000 BTU/hr and less than 1,000,000 BTU/hr, at this stationary source are complying with Rule 74.11.1. This annual certification shall include a formal survey identifying each unit and documentation of certification status (pursuant to Rule 74.11.1.C), as required.

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Ventura County Air Pollution Control District
Rule 74.22 Applicable Requirements
Rule 74.22, Natural Gas-Fired Fan-Type Central Furnaces

Rule 74.22, "Natural Gas-Fired Fan-Type Central Furnaces"
Adopted 11/09/93, Federally Enforceable

Applicability:

This attachment applies to all natural gas-fired, fan-type central furnaces at this stationary source installed after May 31, 1994 and to the future installation of any natural gas-fired, fan-type central furnaces at this stationary source. A fan-type central furnace is a self contained space heater providing for circulation of heated air at pressures other than atmospheric through ducts of more than 10 inches in length that has a rated heat input capacity of less than 175,000 BTU per hour and, for combination heating and cooling units, a rated cooling capacity of less than 65,000 BTU per hour. Natural gas-fired, fan-type central furnaces installed in manufactured housing (mobile homes) are exempt from Rule 74.22.

Conditions:

1. Pursuant to Rule 74.22.B, no person shall install, after May 31, 1994, any natural gas-fired fan-type central furnace:

    a. with NOx (oxides of nitrogen) emissions in excess of 40 nanograms per joule of heat output. (74.22.B.1)

    b. unless it is certified and identified in accordance with Section C of Rule 74.22. (74.22.B.2)

2. Permittee shall maintain a listing of manufacturer, brand name, model number, and heat input rating for each natural gas-fired fan-type central furnace at this stationary source. Permittee shall submit these identification records for all of these furnaces to the District upon request.

3. On an annual basis, permittee shall certify that all natural gas-fired fan-type central furnaces at this stationary source are complying with Rule 74.22. This annual certification shall include a formal survey identifying each natural gas-fired fan-type central furnace; whether it was installed before or after May 31, 1994; and for those furnaces installed after May 31, 1994, information indicating that the certification is contained on the furnace nameplate, or that the furnace is included on a District-provided list of certified furnaces.

Ventura County Air Pollution Control District
California Air Resources Board
Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities

California Code of Regulations, Title 17, Division 3, Chapter 1, Subchapter 10 Climate Change, Article 4, Subarticle 13:

Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities, Effective date October 1, 2017

District enforceable only. The Ventura County APCD (VCAPCD) signed a Memorandum of Understanding (MOU) with the California ARB on June 12, 2018 to implement and enforce this regulation. Prior to June 12, 2018, this regulation was implemented and enforced only by California Air Resources Board (CARB). The regulation is not federally-enforceable.

<u>Applicability:</u>

This regulation applies to owners or operators of equipment and components listed in Section 95668 located within California, including California waters, that are associated with facilities in the sectors listed below, regardless of emissions level:

(1) Onshore and offshore crude oil or natural gas production; and,
(2) Crude oil, condensate, and produced water separation and storage; and,
(3) Natural gas underground storage; and,
(4) Natural gas gathering and boosting stations; and,
(5) Natural gas processing plants; and,
(6) Natural gas transmission compressor stations.

This regulation does not apply to the OCS Offshore Oil Platforms that the VCAPCD regulates because they are not in state territorial waters.

VCAPCD enforces this regulation through its existing permit system. As required below, facilities are required to register equipment with the California ARB on an initial and annual basis.

<u>Conditions:</u>

1. The facility shall be operated in compliance with all applicable requirements of Sections 95665 to 95677, Title 17, Division 3, Chapter 1, Subchapter 10 Climate Change, Article 4, Subarticle 13 California Code of Regulations, "Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities". This includes, but is not limited to, the following requirements.

2. Separator and tank systems shall comply with Section 95668(a). Note that the GHG Regulation defines a separator as a tank or pressure vessel for separating oil, water, condensate, and natural gas. In VCAPCD terminology, a "Wash Tank" is a "Separator" in the GHG Regulation. VCAPCD LACT Tanks, COST Tanks, and Produced / Waste Water Tanks are "Tanks" in the GHG Regulation. Note that VCAPCD Rule 71.1, "Crude Oil Production and Separation" is far more stringent than the GHG Regulation in terms of requiring vapor recovery systems for Separator and Tank Systems. Flash testing is not required for new and existing tanks equipped with vapor recovery systems required by Rule 71.1.

3. Circulation tanks for well stimulation treatments shall comply with Section 95668(b).

4. Reciprocating natural gas compressors shall comply with Section 95668(c).

5. Centrifugal natural gas compressors shall comply with Section 95668(d).

6. Natural gas powered pneumatic devices and pumps shall comply with Section 95668(e).

7. Liquid unloading of natural gas wells shall comply with Section 95668(f).

8. Well casing vents shall comply with Section 95668(g).

9. Natural gas underground storage facilities shall comply with the monitoring requirements of Section 95668(h).

10. The facility shall comply with the leak detection and repair requirements of Section 95669. Critical components at critical process units shall comply with Section 95670.

11. Vapor collection systems and vapor control devices shall comply with Section 95671. These requirements do <u>not</u> apply to existing vapor collection systems and vapor control devices that are required by VCAPCD Rule 71.1, Section B for storage tanks and Rule 71.1, Section C for produced gas.

    The GHG Regulation defines "fuel gas system" and the VCAPCD considers it to be on-site combustion of natural gas in engines, boilers, heater treaters, steam generators, turbines, microturbines, glycol units, etc. Some oilfield facilities may sell gas to a party other than Southern California Gas (such as a nearby agricultural source). The VCAPCD considers these 3rd party gas sales to be a "sales gas system" in the GHG Regulation.

12. The facility shall comply with the record keeping requirements of Section 95672.

13. The facility shall comply with the reporting requirements of Section 95673.

14. The facility shall comply with the implementation requirements of Section 95674. The facility shall register equipment with the California Air Resources Board (ARB) on an initial basis as required by Section 95674(b)(2) and on an annual basis as required by Section 95674(b)(3).

The facility is not required to submit a permit application to the Ventura County APCD as a mechanism to comply with this regulation. This regulation, however, does not change the Ventura County APCD Rule 10 permitting requirements for new, modified, and replacement oil wells, gas wells, storage tanks, engines, loading racks, heaters, boilers, glycol units, flare, etc.

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10. GENERAL REQUIREMENTS FOR SHORT-TERM ACTIVITIES (ATTACHMENTS)

The general requirements for short-term activities are broadly applicable requirements that apply to temporary activities at the facility (e.g., abrasive blasting, architectural coatings, degassing operations, etc.). These are activities occurring infrequently and for a short duration. Requirements for short-term activities can normally be adequately addressed in the permit application with minimal or no reference to any specific emissions unit, provided that the scope of the requirement and the manner of its enforcement are clear.

As detailed in the Title V Permit Reissuance Application, general applicable requirements for short-term activities that apply to this facility were determined. The permit conditions associated with each requirement for a short-term activity are listed in an individual attachment. The attachment is identified with the label "Attachment (APCD Rule No.) ____" or "Attachment 40CFR61.M" in the lower left corner of each attachment.

Ventura County Air Pollution Control District
Rule 74.1 Applicable Requirements
Abrasive Blasting

Rule 74.1, "Abrasive Blasting"
Adopted 11/12/91, Federally Enforceable

Applicability:

This attachment applies to short term activities involving any abrasive blasting operation conducted at this facility. Abrasive blasting is the operation of cleaning or preparing a surface by forcibly propelling a stream of abrasive material against that surface. Abrasive materials subject to Rule 74.1 include, but are not limited to, sand, slag, steel shot, garnet or walnut shells.

Conditions:

1. Pursuant to Rule 74.1.B.1.a, all abrasive blasting operations shall be conducted within a permanent building, except for abrasive blasting operations conducted under one or more of the following conditions as detailed in Rule 74.1.B.1.b:

    a. Steel or iron shot/grit is used exclusively

    b. The item to be blasted exceeds eight feet in any dimension

    c. The surface being blasted is situated at its permanent location or no further away from its permanent location than is necessary to allow the surface to be blasted

2. Pursuant to Rule 74.1.B.1.c, any abrasive blasting that is allowed to be conducted outside of a permanent building, and is not exclusively using steel or iron shot/grit, must use one of the following:

    a. Wet abrasive blasting

    b. Hydroblasting

    c. Vacuum blasting

    d. Dry blasting with California ARB certified abrasives

3. Abrasive blasting for pavement marking shall comply with the requirements of Rule 74.1.B.2.

4. Abrasive blasting of stucco and concrete shall comply with the requirements of Rule 74.1.B.3.

5. Packages or containers for abrasives certified in accordance with Section 92530 of the California Code of Regulations used for permissible outdoor blasting shall comply with the labeling requirements of Rule 74.1.B.4.

6. Abrasive blasting operations shall comply with the visible emission standards of Rule 74.1.C.1 and the nuisance prohibition of Rule 74.1.C.2. The visible emission evaluation of abrasive blasting operations shall be conducted in accordance with Section 92400 of the California Code of Regulations.

7. Permittee shall monitor each abrasive blasting operation to ensure that compliance with Rule 74.1 is being maintained. For each abrasive blasting operation conducted at the facility, permittee shall maintain records of the following information:

   a. Date of operation

   b. Type of abrasive blasting media used

   c. Identity, size, and location of item blasted

   d. Whether operation was conducted inside or outside a permanent building

   e. California ARB certifications for abrasives used

   These records shall be maintained at the facility and submitted to the District upon request.

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Ventura County Air Pollution Control District
Rule 74.2 Applicable Requirements
Architectural Coatings

Rule 74.2, "Architectural Coatings"
Adopted 01/12/10, Federally Enforceable

Applicability:

This attachment applies to short term activities involving any person who supplies, sells, offers for sale, applies or solicits the application of any architectural coating at this stationary source. An architectural coating is a coating to be applied to stationary structures or their appurtenances at the site of installation, to portable buildings at the site of installation, to pavements, or to curbs. Coatings applied in shop applications or to nonstationary structures, such as airplanes, ships, boats, railcars and automobiles, are not considered to be architectural coatings for the purposes of this rule, nor are adhesives.

This attachment and Rule 74.2 do not apply to architectural coatings that are sold in a container with a volume of one liter (1.057 quart) or less and do not apply to any aerosol coating product.

Conditions:

1. Pursuant to Rule 74.2.B.1, the volatile organic compound (VOC) content of architectural coatings shall not exceed the following standards, as found in Table 2 of Rule 74.2.B.1, unless specifically exempted by Rule 74.2:

   a. The VOC content of flat coatings shall not exceed 50 grams per liter of coating.

   b. The VOC content of nonflat coatings shall not exceed 100 grams per liter of coating.

   c. The VOC content of nonflat-high gloss coatings shall not exceed 150 grams per liter of coating.

   Limits are expressed as VOC Regulatory (unless otherwise specified in Rule 74.2) thinned to the manufacturer's maximum recommendation, excluding colorant added to the tint bases. VOC Regulatory is defined in Rule 74.2.

2. Pursuant to Rule 74.2.B.1, the VOC content of specialty architectural coatings shall not exceed the VOC limits in the Table of Standards in Rule 74.2, unless specifically exempted by Rule 74.2.

   Specifically, the VOC content of industrial maintenance coatings shall not exceed 250 grams per liter of coating.

Limits are expressed as VOC Regulatory (unless otherwise specified in Rule 74.2) thinned to the manufacturer's maximum recommendation, excluding colorant added to the tint bases. VOC Regulatory is defined in Rule 74.2.

3. Pursuant to Rule 74.2.B.4, all architectural coating containers used to apply the contents therein to a surface directly from the container by pouring, siphoning, brushing, rolling, padding, ragging or other means, shall be closed when not in use. These architectural coating containers include, but are not limited to, drums, buckets, cans, pails, trays or other application containers. Containers of any VOC-containing materials used for thinning and cleanup shall also be closed when not in use.

4. Pursuant to Rule 74.2.B.5, no person who applies or solicits the application of any architectural coating shall apply or solicit the application of any coating that is thinned to exceed the applicable VOC limit specified in the Tables in Subsection B.1.

5. Permittee shall conduct periodic facility inspections and an annual compliance certification of architectural coating operations to ensure that compliance with Rule 74.2 is being maintained. Permittee shall specify the usage of compliant coatings and shall maintain VOC records of coatings used at the stationary source. The VOC coating records shall be submitted to the District upon request.

6. The VOC content of architectural coatings, along with other specified physical and chemical properties, shall be measured using the testing procedures in Rule 74.2.G.

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Ventura County Air Pollution Control District
Rule 74.4.D Applicable Requirements
Cutback Asphalt - Road Oils

Rule 74.4, "Cutback Asphalt"
Adopted 07/05/83, Federally-Enforceable

Applicability:

This attachment applies to short term activities involving the application of road oils for road, highway or street paving and maintenance. For the purpose of Rule 74.4, road oil shall be synonymous with slow cure asphalt.

Conditions:

1. Pursuant to Rule 74.4.D, road oils used for highway or street paving or maintenance applications shall contain no more than 0.5 percent of organic compounds which boil at less than 500^{o}F as determined by ASTM D402.

2. Permittee shall maintain a test report of oil being proposed for usage in order to ensure that compliance with Rule 74.4.D is being maintained. Permittee shall maintain records of oil analyses at the facility and submit these records to the District upon request.

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Ventura County Air Pollution Control District
Rule 74.16 Applicable Requirements
Oilfield Drilling Operations

Rule 74.16, "Oilfield Drilling Operations"
Adopted 01/08/91, Federally-Enforceable

Applicability:

This attachment applies to short term activities involving all oilfield drilling operations. Oilfield drilling operations are defined as activities powered by nonvehicular internal combustion engines for the purpose of drilling or redrilling oil wells, injection wells, or gas wells. For the purpose of Rule 74.16, drilling operations do not include any operations at any existing well where the derrick is a part of an oilwell production service unit, as defined in the California Vehicle Code. Rule 74.16 applies to drill rig engines over 50 HP including, but not limited to, engines supplying power to drawworks, rotary tables, mud pumps, mud mixers and auxiliary generators.

This attachment applies to an oil company, which Rule 74.16 defines as the person contracting the drilling rig and/or the person who applies for an Authority to Construct for the well. The APCD issues portable Permits to Operate to the owners of drilling rigs. If the drilling rig is registered with the California Air Resources Board Portable Equipment Registration Program (PERP), an APCD Permit to Operate is not required.

This permit does not authorize the operation of any non-vehicular engine of 50 BHP, or greater, for well drilling or workover operations. Prior to using such an engine, the engine owner shall obtain a Permit to Operate for the engine or shall use an engine that is registered with the California Air Resources Board PERP.

Conditions:

1. Pursuant to Rule 74.16.B.1, all drilling operations shall be powered by grid power, unless exempted by Rule 74.16.C.1. Grid power is defined as electricity conveyed by power lines connected physically and contractually to the Southern California Edison System, or any electricity generated by equipment permitted by the District and having permitted emissions commensurate with an emissions rate of not more than 1.0 pound of NO_x per megawatt-hour of electricity produced.

2. Pursuant to Rule 74.16.C.1, an oil company may petition the Air Pollution Control Officer for exemption from Rule 74.16.B.1 by submitting a cost evaluation for grid powered drilling. Best Available Control Technology cost guidelines shall be used to determine cost effectiveness. As detailed in APCD Rule 44, "Exemption Evaluation Fee", Rule 44.B.2 requires that any person requesting an exemption from Rule 74.16 that is based on a cost evaluation shall be assessed an evaluation fee of $450.00.

3. Pursuant to Rule 74.16.B.2.a, if a drilling operation is exempt from Rule 74.16.B.1, NOx emissions from drilling engines, or any exhaust stack of multiple engines permanently manifolded together, shall not exceed 515 ppmv corrected to 15% oxygen. As an alternate, pursuant to Rule 74.16.B.2.c, drilling engines certified by the manufacturer to emit 6.9 grams of NOx per brake horsepower-hour or less based on a California ARB approved heavy duty offroad engine testing procedure shall be deemed in compliance with Rule 74.16.B.2.a, and shall not be subject to the annual source test requirements in Rule 74.16.B.2.b.

   In order to comply with this condition, permittee shall ensure that the drilling rig utilized has a valid APCD Permit to Operate and that the drilling rig has demonstrated compliance with Rule 74.16.B.2.a in accordance with CARB Method 100 as detailed in Rule 74.16.E (Test Methods), or has demonstrated compliance with Rule 74.16.B.2.c. Alternatively, the permittee shall verify that the drilling rig is registered with the California Air Resources Board PERP.

4. In order to demonstrate compliance with Rule 74.16.B.2.a, the drilling rig company shall perform source testing on the drilling engine exhaust annually. Permittee shall obtain from the drilling rig company the most recent source test results for the exempt engines subject to Rule 74.16.B.2.a, or the engine manufacturer certification for engines subject to Rule 74.16.B.2.c. This information shall be made available on site and submitted to the District upon request.

   This condition does not apply to drilling rig engines registered with the California Air Resources Board PERP.

5. Upon District request, the NO_x emissions from the drilling engine exhaust shall be measured using CARB Method 100, in accordance with Rule 74.16.E (Test Methods).

6. In order to demonstrate compliance with Rule 74.16.C.1, permittee shall maintain documentation on the cost analysis as verification to the grid power exemption. This documentation shall be submitted to the District upon request.

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Ventura County Air Pollution Control District
Rule 74.26 Applicable Requirements
Crude Oil Storage Tank Degassing Operations

Rule 74.26, "Crude Oil Storage Tank Degassing Operations"
Adopted 11/08/94, Federally-Enforceable

<u>Applicability:</u>

This attachment applies to short term activities involving degassing of any aboveground crude oil or produced water storage tank that is equipped with a vapor recovery system and has a storage capacity greater than 2,000 barrels; or has a storage capacity of 2,000 barrels and stores a liquid having a modified Reid vapor pressure (mRVP) of 3.4 pounds per square inch (psi) absolute or greater. This attachment also applies to any external or internal floating roof crude oil tank that has a vapor space of 2,000 barrels or more when the tank's roof is resting on the tank's inner roof supports. Rule 74.26 does not apply to vessels rated and operated to contain normal working pressure of at least 15 psi gauge without vapor loss to the atmosphere.

Degassing is defined as the removal of organic vapors from a stationary storage tank for the purpose of cleaning, removing the tank, cleaning the tank's interior, or making repairs to the tank that would require the complete removal of product from the tank.

This permit does not authorize the operation of any air pollution control device for tank degassing operations. This includes, but is not limited to, a thermal or catalytic incinerator, a carbon adsorber, a condenser, or an internal combustion engine. Prior to using such a device, the owner of the air pollution control device shall obtain a Permit to Operate for the device.

<u>Conditions:</u>

1. Pursuant to Rule 74.26.B.1, no person shall conduct or allow the degassing of any storage tank subject to Rule 74.26, unless the emissions are controlled by one of the following options:

    a. Liquid displacement into a vapor recovery system, flare, or fuel gas system (Rule 74.26.B.1.a). Liquid displacement is defined as the removal of ROC vapors from within a storage tank drained of liquid product by introducing into the tank a liquid having an ROC modified Reid vapor pressure (mRVP) of less than 0.5 psi absolute until at least 90 percent of the tank's vapor volume has been displaced, with the mRVP determined using ASTM Method D 323-82 conducted at 68 degrees Fahrenheit (Rule 74.26.F.10). or

    b. An air pollution control device that has a vapor destruction and removal efficiency of at least 95 percent until the vapor concentration in (Rule 74.26.B.1.b):

1. Aboveground crude oil or produced water tanks equipped with a vapor recovery system, is less than 10 percent of the tank's initial vapor concentration determined immediately prior to the tank degassing, or less than 10,000 ppmv, measured as methane, or

2. Floating roof tanks, is less than 10,000 ppmv, measured as methane.

Fugitive emissions that do not qualify as a leak shall be allowed around tank openings such as a manhole during a tank degassing operation performed in compliance with Rule 74.26.

Pursuant to Rule 74.26.E.3, compliance with the above limits shall require that the tank vapor concentration remain at or below 10,000 ppmv for at least one hour as demonstrated by measuring the vapor concentration at least four times at 15-minute intervals. The monitoring instrument used to measure the vapor concentration shall meet the specifications of EPA Method 21.

2. Pursuant to Rule 74.26.B.2, any receiving vessel used during a tank cleaning operation shall either be bottom loaded or shall be loaded by submerged fill pipe. Any vapors emitted from such vessels during a tank degassing operation shall be controlled with an air pollution control device as required by Rule 74.26.B.1.b. As defined in Rule 74.26.F.14, a receiving vessel is a vessel used to receive liquids or sludge material removed from an ROC liquid storage tank during a tank degassing operation.

3. Pursuant to Rule 74.26.B.3, except during an emergency, the District Enforcement Section shall be notified verbally or in writing at least 48 hours prior to starting any tank degassing operation. Such notification shall include an identification of the tank(s) to be degassed and the air pollution control method employed. If a tank degassing operation was required due to an emergency, the District Enforcement Section shall be notified as soon as reasonably possible but no later than four hours after completion of the operation. An emergency is defined as an unplanned and unexpected event that, if not immediately attended to, presents a safety or public health hazard or an unreasonable financial burden.

4. In order to demonstrate compliance for air pollution control devices used to comply with Rule 74.26.B, operator shall record:

   a. The vapor concentration in parts per million (ppm) and gas flow rate in cubic feet per minute (cfm) entering and exiting the device (except for a flare) upon beginning use of the device and every thirty minutes thereafter. The instrument used to measure vapor concentration shall meet the specifications of EPA Method 21, and

b. The tank's vapor concentrations determined in accordance with Rule 74.26.E.3, and

c. If a refrigerated condenser is used, permittee shall record the condenser temperature in degrees Fahrenheit upon beginning use of the condenser and every thirty minutes thereafter. These records shall be maintained and shall be submitted to the District upon request.

5. Pursuant to Rule 74.26.D.3, any person claiming an exemption for a storage tank based on mRVP shall provide records that demonstrate that the liquid stored in the tank has a mRVP less than 3.4 psi absolute, as determined by ASTM Method D 323-82.

6. Pursuant to Rule 74.26.E.2, methods for determining vapor destruction or removal efficiency include vapor flow through the pipes, measured using EPA Method 2A; and the vapor concentration entering and exiting the device, measured using EPA Method 25A. This testing shall be performed upon District request.

7. Pursuant to Rule 74.26.E.3, the monitoring instrument used to measure the tank vapor concentration specified in Subsection B.1.b shall meet the specifications of EPA Method 21 and shall contain a probe inlet located one foot above the bottom of the tank or one foot above the surface of any sludge material on the bottom of the tank. For upright, cylindrical aboveground tanks, the probe inlet shall be (1) located at least 2 feet away from the inner surface of the tank wall and (2) if samples are withdrawn from a manhole, inserted in an opening of no more than one inch diameter on a flexible or inflexible material that is impermeable to reactive organic compound (ROC) vapors, secured over the manhole.

8. In order to comply with the above conditions, permittee shall insure that any tank degassing subcontractor utilized has a valid APCD Permit to Operate for portable tank degassing emission control equipment and that the control equipment complies with Rule 74.26, in accordance with Rule 74.26.E (Test Methods) when necessary.

9. Pursuant to Rule 74.26.C.2, the provisions of Section B of Rule 74.26 shall not apply to in-service tanks undergoing maintenance, including but not limited to repair of regulators, fittings, deck components, hatches, valves, flame arrestors, or compressors, or any leaks found pursuant to the operator inspection requirements in Rule 74.10, provided that (1) the operation will take no longer than 24 hours to complete and (2) the maintenance operation does not require the complete draining of product from the tank.

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Ventura County Air Pollution Control District
Applicable Requirements for Soil Aeration Operations
Rule 74.29, Soil Decontamination Operations

Rule 74.29, "Soil Decontamination Operations"
Adopted 04/08/08, Federally Enforceable

Applicability:

This attachment applies to short-term activities involving soils that contain gasoline, diesel fuel, or jet fuel. Rule 74.29 does not apply to soil that contains only crude oil or was contaminated by a leaking storage tank used in an agricultural operation engaged in the growing of crops or the raising of fowl or animals.

Specifically, this attachment applies to the aeration of soil that contains gasoline, diesel fuel, or jet fuel. Aeration is defined as the exposure of excavated soil, containing diesel fuel, gasoline, or jet fuel, to the atmosphere without the use of air pollution control equipment or vapor extraction, bioremediation, or bioventing system.

Remediation equipment, such as a vapor extraction system, bioremediation system, or bioventing system, for contaminated soil requires an APCD permit. Rule 74.29 requirements for such remediation equipment would be addressed in another permit attachment, if applicable. As detailed in APCD Rule 23.F.23, any soil aeration project exempt from the soil aeration limit in Rule 74.29 pursuant to Subsection C.1 or C.2 of Rule 74.29 is exempt from the requirement to obtain a permit for the soil aeration project. Also, pursuant to APCD Rule 23.F.24, any soil remediation project where collected vapors are not emitted to the atmosphere by any means is exempt from the requirement to obtain a permit.

Conditions:

1. Pursuant to Rule 74.29.B.1.a, no person shall cause or allow the aeration of soil that contains gasoline, diesel fuel, or jet fuel if such aeration emits reactive organic compounds (ROC) as measured by a certified vapor analyzer, in excess of 50 parts per million by volume (ppmv) above background, as hexane, except nonrepeatable momentary readings. In determining compliance, a portion of soil measuring three inches in depth and no less than six inches in diameter shall be removed from the soil surface and the probe inlet shall be placed near the center of the resulting hole, level with the soil surface surrounding the hole.

   For each soil decontamination operation where soil aeration occurs, the permittee shall determine compliance with Rule 74.29.B.1.a on a weekly basis as detailed above. A dated record of these measurements shall be maintained at the facility and submitted to the District upon request.

2. Pursuant to Rule 74.29.B.1.b, no person shall cause or allow the aeration of soil that contains gasoline, diesel fuel, or jet fuel if such aeration causes a nuisance, as defined in the California Health and Safety Code Section 41700 and APCD Rule 51, "Nuisance." In addition, offsite aeration is prohibited.

3. Pursuant to Rule 74.29.B.2, no person shall excavate an underground storage tank and/or transfer piping currently or previously used to store an applicable compound, or excavate or grade soil containing an applicable compound, unless ROC emissions are monitored with a certified organic vapor analyzer at least once every 15 minutes during the excavation period commencing at the beginning of excavation or grading. Soil with emission measurements in excess of 50 parts per million by volume (ppmv), as hexane, a shall be considered contaminated.

   During excavation, all inactive exposed contaminated soil surfaces shall be treated with a vapor suppressant or covered with continuous heavy duty plastic sheeting (4 mil or greater) or other covering to minimize emissions of ROC to the atmosphere. Covering shall be in good condition, overlapped at the seams, and securely anchored to minimize headspace where vapors may accumulate.

4. Pursuant to Rule 74.29.B.5, the owner or operator of any applicable underground storage tank shall notify the District Compliance Division at least 24 hours prior to the beginning the excavation of the said storage tank and/or transfer piping.

5. Pursuant to Rule 74.29.B.6, contaminated soil in active storage piles shall be kept visibly moist by water spray, treated with a vapor suppressant, or covered with continuous heavy duty plastic sheeting (4 mil or greater) or other covering to minimize emissions of ROC to the atmosphere. Covering shall be in good condition, overlapped at the seams, and securely anchored to minimize headspace where vapors may accumulate. For any active storage pile, the surface area not covered by plastic sheeting or other covering shall not exceed 6,000 square feet. An "active" storage pile is defined as a worksite to which soil is currently being added or from which soil is being currently being removed. Activity must occur within one hour to be current.

6. Pursuant to Rule 74.29.B.7, contaminated soil in inactive storage piles shall be with covered with continuous heavy duty plastic sheeting (4 mil or greater) or other covering to minimize emissions to the atmosphere. The covering shall be in good condition, overlapped at the seams, and securely anchored to minimize headspace where vapors may accumulate.

7. Pursuant to Rule 74.29.B.8, if not removed within 30 days of excavation, on-site treatment to remove contamination from contaminated soil at an excavation or grading site shall be initiated. The treatment of contaminated soil shall be subject to all applicable District Rules and Regulations. This includes, but is not limited to,

compliance with Rule 10, "Permits Required," and Rule 51, "Nuisance."

8. Pursuant to Rule 74.29.B.9, trucks used to transport contaminated soil must meet the following requirements:

   a. The truck and trailer shall be tarped prior to leaving the site. Contaminated material shall not be visible beyond the tarp and shall not extend above the sides or rear of the truck or trailer; and

   b. The exterior of the truck, trailer and tires shall be cleaned prior to leaving the site.

9. Pursuant to Rule 74.29.C.2, the soil aeration requirements of Rule 74.29.B.1.a shall not apply to:

   a. Soil excavation activities necessary for the removal of in-situ soil such as in the removal of an underground storage tank, pipe or piping system, provided the exposed soil is covered as specified in Condition No. 6 while inactive; or

   b. Soil moving, loading, or transport activities performed for the sole purpose of complying with local, state, or federal laws, provided the soil is handled in accordance with such laws; or

   c. Soil excavation or handling occurring as a result of an emergency as declared by an authorized health officer, agricultural commissioner, fire protection officer, or other authorized agency officer. Whenever possible, the District Compliance Division shall be notified prior to commencing such excavation; or

   d. Any soil aeration project involving less than 1 cubic yard of contaminated soil; or

   e. Situations where the soil contamination which resulted from a spill or release of less than five (5) gallons of diesel fuel, jet fuel, or gasoline; or

   f. Contaminated soil used as daily cover at permitted Class III Solid Waste Disposal Sites if such soils do not have a gasoline concentration exceeding 100 parts per million by weight (ppmw) or a diesel fuel concentration exceeding 1,000 ppmw, as determined by the method specified in Rule 74.29.F.1. Daily cover is defined as soil that is applied on a daily basis or less frequently as a covering over landfill waste.

      The permittee shall maintain records of the gasoline concentration and diesel fuel concentration of any contaminated soil used as daily cover that need to qualify for this exemption.

10. Pursuant to Rule 74.29.F.1, the percent by weight of contaminant in soil samples shall be determined by EPA Method 8015B. Samples shall be introduced using Method 5035 (Purge and Trap) and shall be taken in accordance with the Los Angeles Regional Water Quality Control Board's guidelines for contaminated soil sampling. Standards shall be the same as the contaminant believed to be in the soil. If the soil is contaminated with methanol 85 (M85) the standard used shall be M85.

11. Pursuant to Rule 74.29.F.3, the ROC concentration measurements required in Subsections B.1 and B.2 of the rule (Condition Nos. 1 – 3 above) shall be made using an organic vapor analyzer certified according to the requirements of EPA Method 21.

12. Pursuant to Rule 74.29.D, for any soil aeration project subject to Rule 74.29, the permittee shall record each date that the soil was disturbed and the quantity of soil disturbed on each date. These records shall be maintained at the facility and submitted to the District upon request.

13. For any soil decontamination project subject to Rule 74.29, other than a soil aeration project, the following information shall be made available to the District upon request:

    a. All dates that soil was disturbed and the quantity of soil disturbed on each date.

    b. Reasons for excavation or grading.

    c. Cause of VOC soil contamination and history of the site.

    d. Description of tanks or piping associated with the soil contamination.

    e. Description of mitigation measures employed for dust, odors and ROC emissions.

    f. Details of treatment and/or disposal of ROC contaminated soil, including the ultimate receptor.

    g. Description of monitoring equipment and techniques.

    h. All ROC emission measurements shall be recorded on a continuous permanent strip-chart or in a format approved by the Air Pollution Control Officer (APCO).

    i. A map showing the facility layout, property line, and surrounding area up to 2500 feet away, and including any schools, residential areas or other sensitive receptors such as hospitals or locations where children or elderly people live or work.

14. The permittee shall monitor each soil aeration operation or underground gasoline storage tank excavation operation to ensure that compliance with Rule 74.29.B.1 and/or

74.29.B.2 is being maintained. This monitoring requirement shall include ensuring that proper operation requirements are being met and shall include the recordkeeping required above.

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11. GENERAL PERMIT CONDITIONS

This section contains general Part 70 permit conditions and general APCD permit to operate conditions. The general Part 70 permit conditions are associated with general federal requirements that apply to all Title V facilities. These conditions are based on APCD Rules 8, 30, 32, and 33, and 40 CFR Part 70.

The general permit to operate conditions are associated with general District requirements that apply to all operating Title V facilities. These conditions are based on APCD Rules 19, 20, 22, and 27.

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Ventura County Air Pollution Control District
General Part 70 Permit Conditions

1. The permittee shall comply with all federally-enforceable conditions of the Part 70 permit. Any permit noncompliance constitutes a violation of the federal Clean Air Act and is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or for denial of an application for reissuance of the permit. (40 CFR 70.6(a)(6)(i), APCD Rule 33.3.B.1)

2. The permittee shall continue to comply with all the applicable requirements with which the company has certified that it is already in compliance. The permittee shall comply in a timely manner with applicable requirements that become effective during the permit term of this permit.

3. The permittee shall promptly report deviations from Part 70 permit requirements, including those attributable to upset conditions as defined in the Part 70 permit, the probable cause of the deviations, and any corrective actions or preventive measures taken. Promptly is defined as no later than four (4) hours after its detection by such owner or operator, or his agents or employees. (40 CFR 70.6(a)(3)(iii)(B), APCD Rule 33.3.A.3, APCD Rule 32.B.1)

4. The need to halt or reduce activity is not a defense. It shall not be a defense for a permittee in an enforcement action that it would be necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this Part 70 permit. (40 CFR 70.6(a)(6)(ii), APCD Rule 33.3.B.2)

5. All applicable records, monitoring data, and support information shall be maintained for a period of at least 5 years from the date of the monitoring sample, measurement, report, or application. Support information includes all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, and copies of all reports required by the Part 70 permit. All applicable reports shall be submitted to the District every 6 months and shall be certified by a responsible official. Such reports shall identify any deviations from Part 70 permit conditions. (40 CFR 70.6(a)(3)(ii)(B), 40 CFR 70.6(a)(3)(iii)(A), APCD Rule 33.3.A.3)

6. The permittee shall furnish to the District, within a reasonable time, any information that the District may request in writing to determine whether cause exists for modifying, revoking and reissuing, or terminating the Part 70 permit or to determine compliance with the Part 70 permit. Upon request, the permittee shall also furnish to the District copies of records required to be kept by the Part 70 permit or, for information claimed to be confidential, the permittee may furnish such records directly to the Administrator of the EPA along with a claim of confidentiality. (40 CFR 70.6(a)(6)(v), APCD Rule 33.3.B.5)

7. Upon presentation of credentials and other documents as may be required by law, the permittee shall allow the District or an authorized representative to perform the following:

   a. Enter upon the permittee's premises where a Part 70 source is located or emissions-related activity is conducted, or where records must be kept under the conditions of the Part 70 permit;

   b. Have access to and copy, at reasonable times, any records that must be kept under the conditions of the Part 70 permit;

   c. Inspect at reasonable times any facilities, equipment (including monitoring and air pollution control equipment), practices, or operations regulated or required under the Part 70 permit; and

   d. As authorized by the federal Clean Air Act, sample or monitor at reasonable times substances or parameters for the purpose of assuring compliance with the Part 70 permit or applicable requirements.

   (40 CFR 70.6(c)(2), APCD Rule 8, APCD Rule 33.3.B.7)

8. The Part 70 permit may be modified, revoked, reopened, reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or of a notification of planned changes or anticipated noncompliance does not stay any permit condition. (40 CFR 70.6(a)(6)(iii), APCD Rule 33.3.B.3)

9. A Part 70 permit shall be reopened under the following conditions:

   a. Additional applicable requirements under the federal Clean Air Act become applicable to the facility with a remaining Part 70 permit term of 3 or more years. Such a reopening shall be completed not later than 18 months after promulgation of the applicable requirement. No such reopening is required if the effective date of the requirement is later than the date on which the Part 70 permit is due to expire, unless the original Part 70 permit or any of its terms and conditions has been extended pursuant to APCD Rule 33.6.D;

   b. Additional requirements (including excess emissions requirements) become applicable to an affected source under the acid rain program. Upon approval by the Administrator of the EPA, excess emissions offset plans shall be deemed to be incorporated into the Part 70 permit;

c. The District or EPA determines that the Part 70 permit contains a material mistake or that inaccurate statements were made in establishing the emissions standards or other terms or conditions of the Part 70 permit; or

d. The Administrator of the EPA or the District determines that the Part 70 permit must be revised or revoked to assure compliance with the applicable requirements.

(40 CFR 70.7(f), APCD Rule 33.8.A)

10. All fees required by District Regulation III, Fees, shall be paid on a timely basis as requested by the District. Notwithstanding the term of the Part 70 permit, if the permittee fails to pay the annual renewal fees required pursuant to APCD Rule 42.H within the time period specified in APCD Rule 30, the Part 70 permit will be void. (40 CFR 70.6(a)(7), APCD Rule 30, APCD Rule 33.3.B.6)

11. The Part 70 permit does not convey any property rights of any sort, or any exclusive privilege. (40 CFR 70.6(a)(6)(iv), APCD Rule 33.3.B.4)

12. The provisions of this Part 70 permit shall be severable, and in the event of any challenge to any portion of the permit, or if any portion is held invalid, the remaining permit conditions shall remain valid and in force. (40 CFR 70.6(a)(5), APCD Rule 33.3.B.8)

13. An application for reissuance of this Part 70 Permit shall be submitted no more than 18 months prior to the expiration date and no less than 6 months prior to the expiration date as stated on this permit. The application shall be subject to the same procedural requirements, including those for public participation and EPA review, that apply to initial Part 70 permit issuance. (40 CFR 70.5(a)(1)(iii), 40 CFR 70.7(c)(1)(i), APCD Rule 33.6.B)

14. Any Part 70 application and any document, including reports, schedule of compliance progress reports, and compliance certification, required by this Part 70 permit shall be certified by a responsible official. The certification shall state that, based on information and belief formed after a reasonable inquiry, the statements and information in the document are true, accurate, and complete (40 CFR 70.5(d), APCD Rule 33.9.C)

15. Permittee must submit certification of compliance with all applicable requirements and all Part 70 permit conditions. A compliance certification shall be submitted with any Part 70 permit application and annually, on the anniversary date of the Part 70 permit, or on a more frequent schedule if required by an applicable requirement or permit condition.

    This compliance certification shall identify each applicable requirement or condition of the Part 70 permit, the compliance status of the stationary source, whether the compliance was continuous or intermittent since the last certification, and the method(s) used to determine compliance. In addition, the certification shall indicate the stationary source's compliance status with any applicable enhanced monitoring and compliance certification requirement of the federal Clean Air Act. A copy of each compliance certification shall be submitted to EPA Region IX. (40 CFR 70.5(c)(9), 40 CFR 70.6(c)(5), APCD Rule 33.3.A.9, APCD Rule 33.9.B)

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Ventura County Air Pollution Control District
General Permit to Operate Conditions

1. Within 30 days after receipt of a permit to operate, the permittee may petition the Hearing Board, in writing, to review any new or modified condition on the permit. (APCD Rule 22)

2. This permit to operate, or a copy, shall be posted reasonably close to the subject equipment and shall be readily accessible to inspection personnel from the District. Posting a copy of the "Permitted Equipment and Applicable Requirements Table" contained in Section No. 2 will fulfill this requirement if the entire permit to operate is readily available at another location at the stationary source. (APCD Rule 19)

3. This permit to operate is not transferable from one location to another unless the equipment is specifically listed as being portable. (APCD Rule 20)

4. If, within a reasonable amount of time, any permittee refuses to furnish information requested by the District, the District may suspend this permit to operate. The permittee will be informed, in writing, of the permit suspension and the reasons for the suspension. (APCD Rule 27)

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Ventura County Air Pollution Control District
Permit Shield - New Source Performance Standards
Part 70 Permit No. 00012

40 CFR Part 60, Subpart J, "Standards of Performance for Petroleum Refineries"

40 CFR Part 60, Subpart UU, "Standards of Performance for Asphalt Processing and Asphalt Roofing Manufacture"

40 CFR Part 60, Subpart GGG, "Standards of Performance for Equipment Leaks of VOC in Petroleum Refineries"

40 CFR Part 60, Subpart QQQ, "Standards of Performance for VOC Emissions From Petroleum Refinery Wastewater Systems"

Permit Shield:

The New Source Performance Standards listed above have been reviewed and it has been determined that they are not applicable to this stationary source. Subpart J, Subpart GGG, and Subpart QQQ apply to affected facilities located at petroleum refineries. Subpart UU applies to affected facilities at asphalt processing plants, petroleum refineries, and asphalt roofing plants. This stationary source is not a petroleum refinery, asphalt roofing plant, or asphalt processing plant as defined in these New Source Performance Standards, and therefore these standards do not apply to this stationary source.

This stationary source is primarily a crude oil production facility. Steam and petroleum diluent are injected into heavy crude oil wells. The wells then produce a mixture of heavy crude oil, natural gas, diluent, and water. The mixture is initially separated by gravity, aided by heat. In order to recover the diluent, final separation is done in an atmospheric distillation tower.

The heavy crude oil is then sold as various grades of asphalt, and the diluent is recycled back into the oil wells. To balance the process on a seasonal basis, diluent is sold or purchased as necessary.

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Ventura County Air Pollution Control District
Permit Shield - New Source Performance Standards
Part 70 Permit No. 00012

40 CFR Part 60, Subpart Dc, "Standards of Performance for Small Industrial - Commercial - Institutional Steam Generating Units"

Permit Shield:

The New Source Performance Standard listed above has been reviewed and it has been determined that it is not applicable to this stationary source. The following discussion details the determination of this permit shield for specific emission units at the stationary source. All of the units below burn natural gas as the primary fuel and burn fuel oil only during natural gas curtailment.

Six (6) 20.0 MMBTU/Hr Steam Generators (Unit Nos. 0, 1, 2, 3, 4, 5)
Five of these six steam generators were originally constructed prior to June 9, 1989. Authority to Construct No. 0010-100, issued on March 25, 1991, allowed for modifications to each of these steam generators to meet the emission limitations of Rule 74.15, "Boilers, Steam Generators, and Process Heaters". Pursuant to 40 CFR Part 60.14.e.5, this change did not fit the definition of a modification subject to New Source Performance Standards since this was "the addition or use of any system or device whose primary function is the reduction of air pollutants." The 20 MMBTU/hr Steam Generator No. 0 was installed after July 9, 1989; however, the unit operates on natural gas or a mixture of natural gas and produced gas. There are no applicable requirements in the Subpart for units operated on natural gas. This includes recordkeeping requirements.

One (1) 20.0 MMBTU/Hr Erie City Boiler
This boiler was originally constructed prior to June 9, 1989. Authority to Construct No. 0012-110, issued on August 13, 1990, allowed for modifications to this boiler to meet the emission limitations of Rule 74.15, "Boilers, Steam Generators, and Process Heaters". Pursuant to 40 CFR Part 60.14.e.5, this change did not fit the definition of a modification subject to New Source Performance Standards since this was "the addition or use of any system or device whose primary function is the reduction of air pollutants."

One (1) 20.0 MMBTU/Hr Natco Crude Oil Heater
This crude oil heater was originally constructed after June 9, 1989. Authority to Construct No. 0012-110, issued on August 13, 1990, allowed for the installation of this unit as a replacement for two existing units as a strategy to meet the emission limitations of Rule 74.15, "Boilers, Steam Generators, and Process Heaters". The Natco Crude Oil Heater does not fit the definition of a steam generating unit as detailed in 40 CFR Part 60.41c. This unit does not heat water or any other heat transfer medium. Nor is it a process heater that heats a material to initiate or

promote a chemical reaction. It is, rather, a process heater that heats a mixture of heavy crude oil and diluent to promote their physical separation.

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Ventura County Air Pollution Control District
Standards of Performance (NSPS) for
Crude Oil and Natural Gas Production, Transmission and Distribution

40 CFR Part 60, Subpart OOOO, "Standards of Performance (NSPS) for Crude Oil and Natural Gas Production, Transmission and Distribution for which Construction, Modification or Reconstruction Commenced After August 23, 2011, and on or before September 18, 2015"

Applicability:

This NSPS was replaced by 40 CFR Part 60, Subpart OOOOa that now applies to affected oil and gas facilities after September 18, 2015.

This NSPS applies to all well completions, pneumatic controllers, equipment leaks from natural gas processing plants, reciprocating compressors, centrifugal compressors and storage vessels which are constructed, modified or reconstructed after August 23, 2011, and on or before September 18, 2015, as discussed in more detail below. Well completions subject to the NSPS are limited to the flowback period following hydraulic fracturing operations at an applicable gas well. These applicable completions include those conducted at newly drilled and fractured gas wells, as well as completions conducted following refracturing operations that may occur at various times over the life of the gas well. When a gas well is refractured, the applicability of this NSPS does not by itself trigger applicability beyond the well head to other ancillary components that may be at the well site such as existing storage vessels, compressors, pneumatic controllers, process vessels, separators, dehydrators or any other components or apparatus. Note that the NSPS does not apply to gas wells located on offshore oil platforms in Ventura County. This document summarizes the requirements of the NSPS and is not intended to supersede or conflict with the requirements of the NSPS.

Note that the issuance of this NSPS now includes, incorporates, and / or revises the requirements of 40 CFR Part 60 Subpart KKK, "Standards of Performance for Equipment Leaks of VOC From Onshore Natural Gas Processing Plants", and 40 CFR Part 60 Subpart LLL, "Standards of Performance for Onshore Natural Gas Processing: SO2 Emissions". These NSPS now each have sunset dates of August 23, 2011 and their requirements are now contained in 40 CFR Part 60, Subpart OOOO, "Standards of Performance (NSPS) for Crude Oil and Natural Gas Production, Transmission and Distribution".

Conditions:

1. Gas wells undergoing hydraulic fracturing subject to this NSPS shall comply with Section 60.5375. A gas well or natural gas well is defined as an onshore well drilled principally for production of natural gas. The NSPS requires the use of reduced emissions completions (REC) also known as green completions.

The drilling of all new oil wells and all new gas wells requires a Ventura County APCD Authority to Construct. In addition, an Authority to Construct shall be obtained prior to refracturing an existing gas well.

2. Centrifugal compressors subject to this NSPS shall comply with Section 60.5380. A centrifugal compressor is defined as any machine for raising the pressure of a natural gas by drawing in low pressure natural gas and discharging significantly higher pressure natural gas by means of mechanical rotating vanes or impellers. Screw, sliding vane, and liquid ring compressors are not centrifugal compressors as defined in this NSPS. The NSPS requires the operators of affected centrifugal compressors to reduce VOC emissions from each centrifugal compressor wet seal fluid degassing system by 95.0 percent or greater. Compressors located past the point of custody transfer in the gas transmission and storage segments are not covered by this NSPS. A compressor located at a well site, or an adjacent well site and servicing more than one well site, is not covered by this NSPS.

   The Ventura County APCD does not require permits for natural gas compressors, but does require permits for an internal combustion engine (in lieu of an electric motor) powering a natural gas compressor (Rule 23.F.18). Therefore, this condition authorizes the installation of the equipment necessary to comply with these centrifugal compressor requirements provided that the permittee comply with all the requirements of Section 60.5380, including the required notification, recordkeeping and reporting requirements.

3. Reciprocating compressors subject to this NSPS shall comply with Section 60.5385. A reciprocating compressor is defined as a piece of equipment that increases the pressure of a process gas by positive displacement, employing linear movement of a drive shaft. The NSPS requires the operators of affected reciprocating compressors to replace the rod packing every 26,000 hours or 36 months from the date of initial startup of the reciprocating compressor affected facility. Compressors located past the point of custody transfer in the gas transmission and storage segments are not covered by this NSPS. A compressor located at a well site, or an adjacent well site and servicing more than one well site, is not covered by this NSPS.

   The Ventura County APCD does not require permits for natural gas compressors, but does require permits for an internal combustion engine (in lieu of an electric motor) powering a natural gas compressor (Rule 23.F.18). Therefore, this condition authorizes the work necessary to comply with these reciprocating compressor requirements provided that the permittee comply with all the requirements of Section 60.5385, including the required notification, recordkeeping and reporting requirements.

4. Pneumatic controllers subject to this NSPS shall comply with Section 60.5390. A pneumatic controller is defined as an automated instrument used for maintaining a

process condition such as liquid level, pressure, delta-pressure and temperature. The requirements apply to natural gas-driven pneumatic controllers located (a) in the oil production segment between the wellhead and the point of custody transfer to an oil pipeline; or (b) in the natural gas production segment between the wellhead and the point at which the gas enters the transmission and storage segment. This NSPS requires each pneumatic controller affected facility at a natural gas processing plant to have a natural gas bleed rate of zero standard cubic feet per hour. Each pneumatic controller affected facility between the wellhead and a natural gas processing plant, or between the wellhead and the point of custody transfer to an oil pipeline, must have a natural gas bleed rate of less than or equal to 6 standard cubic feet per hour. Note that a natural gas processing plant is defined as any processing site engaged in the extraction of natural gas liquids from field gas, fractionation of mixed natural gas liquids to natural gas products, or both. A Joule-Thompson valve, a dew point suppression valve, or an isolated or stand-alone Joule-Thompson skid is not a natural gas processing plant.

The Ventura County APCD does not require permits for the installation and operation of pneumatic controllers and other components such as valves and flanges. Therefore, this condition authorizes the work necessary to comply with these pneumatic controller requirements provided that the permittee comply with all the requirements of Section 60.5390, including the required notification, recordkeeping and reporting requirements.

5. Storage vessels subject to this NSPS shall comply with Section 60.5395. A storage vessel is defined as a unit that is constructed primarily of nonearthen materials (such as wood, concrete, steel, fiberglass, or plastic) which provides structural support and is designed to contain an accumulation of liquids or other materials. Note that pressure vessels designed to operate in excess of 204.9 kilopascals (29.7 psi) and without emissions to the atmosphere are not considered to be storage vessels. Also, process vessels such as surge control vessels, bottoms receivers, and knockout vessels are not considered to be process vessels.

The NSPS requires that individual storage vessels with VOC emissions equal to or greater than 6 tons per year achieve at least 95.0 percent reduction in VOC emissions. These requirements do not apply to storage vessels subject to and controlled in accordance with the requirements for storage vessels in 40 CFR Part 60, Subpart Kb, or 40 CFR Part 63, Subparts G, CC, HH, or WW.

The Ventura County APCD does require permits for the installation and operation of storage vessels such as crude oil storage tanks, wash tanks, and produced water storage tanks. In addition, these tanks must comply with the vapor recovery requirements of Rule 71.1, “Crude Oil Production and Separation”. If a tank that complies with Rule 71.1 has VOC emissions of 6 tons per year or more, the permittee shall apply for, and obtain, an APCD Authority to Construct for the equipment necessary to comply with Section 60.5395 of the NSPS.

6. All process units, except compressors, located at an onshore natural gas processing plant subject to this NSPS shall comply with Section 60.5400. A process unit means components assembled for the extraction of natural gas liquids from field gas, the fractionation of the liquids into natural gas products or other operations associated with the processing of natural gas products.

The NSPS requires a leak detection and repair program for components such as pressure relief devices, pumps and valves that reflects the procedures and leak thresholds established in 40 CFR Part 60, Subpart VVa, the NSPS for Equipment Leaks of VOC in the Synthetic Organic Chemicals Manufacturing Industry (that is, this NSPS OOOO references out to NSPS VVa). For certain components, a leak is defined as 500 ppm or greater and a first attempt at a repair must be made no later than 5 calendar days after a leak is detected.

The Ventura County APCD does not require permits for the installation and operation of components such as pressure relief devices, pumps, valves and flanges. Therefore, this condition authorizes any work necessary to comply with these leak detection and repair requirements provided that the permittee comply with all the requirements of Section 60.5400, including the required notification, recordkeeping and reporting requirements. Any onshore natural gas processing plant at this facility subject to this NSPS will be specifically addressed elsewhere in this permit, as applicable.

7. Sweetening units at onshore natural gas processing plants subject to this NSPS shall comply with Section 60.5405. A sweetening unit is defined as a process device that removes hydrogen sulfide and / or carbon dioxide from the sour natural gas stream. To qualify as a sweetening unit, there must be sulfur recovery technology with a liquid sulfur accumulation rate. These requirements do not apply to sweetening units located on offshore oil platforms in Ventura County. The requirements also do not apply to devices that remove hydrogen sulfide or carbon dioxide that use replaceable media or units that use membrane separation technology.

The NSPS requires that the sweetening unit achieve a minimum SO_2 reduction efficiency that varies from approximately 74.0% to 99.9% depending on the hydrogen sulfide content of the acid gas and the sulfur feed rate.

The Ventura County APCD does require an Authority to Construct for the installation of a sweetening unit at both onshore natural gas plants and offshore natural gas plants. Any sweetening unit at this facility subject to this NSPS will be specifically addressed elsewhere in this permit, as applicable.

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Ventura County Air Pollution Control District
Standards of Performance (NSPS) for
Crude Oil and Natural Gas Facilities

40 CFR Part 60, Subpart OOOOa, "Standards of Performance for Crude Oil and Natural Gas Facilities for which Construction, Modification or Reconstruction Commenced After September 18, 2015"

Applicability:

This NSPS establishes emission standards and compliance schedules for the control of the pollutant greenhouse gases (GHG). The greenhouse gas standard in this NSPS is in the form of a limitation on emissions of methane from affected facilities in the crude oil and natural gas source category that commence construction, modification, or reconstruction after September 18, 2015. This NSPS also establishes emission standards and compliance schedules for the control of volatile organic compounds (VOC) and sulfur dioxide (SO_2) emissions from affected facilities in the crude oil and natural gas source category that commence construction, modification or reconstruction after September 18, 2015. The effective date of the NSPS is August 2, 2016.

This NSPS applies to all onshore well completions, centrifugal compressors, reciprocating compressors, pneumatic controllers, storage vessels, process units for the extraction or fractionation of natural gas liquids from field gas, sweetening units, pneumatic pumps, and fugitive emissions from well sites and compressor stations which are constructed, modified or reconstructed after September 18, 2015, as discussed in more detail below. Note that this NSPS does not apply to offshore oil platforms in Ventura County.

Well completions subject to the NSPS are limited to the flowback period following hydraulic fracturing operations at an applicable oil or gas well. These applicable well completions include those conducted at newly drilled and fractured wells, as well as completions conducted following refracturing operations that may occur at various times over the life of the well.

Note that the issuance of this NSPS now includes, incorporates, and / or revises the requirements of 40 CFR Part 60, Subpart OOOO, "Standards of Performance (NSPS) for Crude Oil and Natural Gas Production, Transmission and Distribution". 40 CFR Part 60, Subpart OOOO now has an effective date of August 23, 2011 to September 18, 2015 and its requirements are now contained in 40 CFR Part 60, Subpart OOOOa. This document summarizes the requirements of the NSPS and is not intended to supersede or conflict with the requirements of the NSPS.

Conditions:

1. Wells undergoing hydraulic fracturing or hydraulic refracturing subject to this NSPS shall comply with Section 60.5375a. A well is defined as an onshore well drilled for the purpose of producing oil or natural gas, or a well into which fluids are injected. During

the flowback period following hydraulic fracturing or refracturing, the NSPS requires the recovery of flowback liquids and the control of flowback gas. Note that the NSPS has specific requirements for wildcat wells and delineation wells, non-wildcat low pressure gas wells or non-delineation low pressure gas wells, and wells with less than 300 scf of gas per stock tank barrel of oil produced.

The drilling of all new oil wells and all new gas wells requires a Ventura County APCD Authority to Construct. In addition, an Authority to Construct shall be obtained prior to refracturing an existing oil or gas well.

2. Centrifugal compressors subject to this NSPS shall comply with Section 60.5380a. A centrifugal compressor is defined as any machine for raising the pressure of a natural gas by drawing in low pressure natural gas and discharging significantly higher pressure natural gas by means of mechanical rotating vanes or impellers. Screw, sliding vane, and liquid ring compressors are not centrifugal compressors as defined in this NSPS. The NSPS requires the operators of affected centrifugal compressors to reduce methane and VOC emissions from each centrifugal compressor wet seal fluid degassing system by 95.0 percent or greater. Compressors located at or past the point of custody transfer are not covered by this NSPS. A centrifugal compressor located at a well site, or an adjacent well site and servicing more than one well site, is not an affected facility under this NSPS.

   The Ventura County APCD does not require permits for natural gas compressors, but does require permits for an internal combustion engine (in lieu of an electric motor) powering a natural gas compressor (Rule 23.F.18). Therefore, this condition authorizes the installation of the equipment necessary to comply with these centrifugal compressor requirements provided that the permittee comply with all the requirements of Section 60.5380a, including the required notification, recordkeeping and reporting requirements.

3. Reciprocating compressors subject to this NSPS shall comply with Section 60.5385a. A reciprocating compressor is defined as a piece of equipment that increases the pressure of a process gas by positive displacement, employing linear movement of a drive shaft. The NSPS requires the operators of affected reciprocating compressors to replace the rod packing every 26,000 hours or 36 months from the date of initial startup, or last rod packing replacement, of the reciprocating compressor affected facility. As an alternative to rod packing replacement, the NSPS requires that operators collect the methane and VOC emissions from the rod packing using a rod packing emissions collection system that operates under negative pressure and route the rod packing emissions to a process through a closed vent system. Compressors located at or past the point of custody transfer are not covered by this NSPS. A compressor located at a well site, or an adjacent well site and servicing more than one well site, is not an affected facility under this NSPS.

The Ventura County APCD does not require permits for natural gas compressors, but does require permits for an internal combustion engine (in lieu of an electric motor) powering a natural gas compressor (Rule 23.F.18). Therefore, this condition authorizes the work necessary to comply with these reciprocating compressor requirements provided that the permittee comply with all the requirements of Section 60.5385a, including the required notification, recordkeeping and reporting requirements.

4. Pneumatic controllers subject to this NSPS shall comply with Section 60.5390a. A pneumatic controller is defined as an automated instrument used for maintaining a process condition such as liquid level, pressure, delta-pressure and temperature. This NSPS requires each pneumatic controller affected facility at a natural gas processing plant to have a natural gas bleed rate of zero standard cubic feet per hour. Each pneumatic controller affected facility, at a location other than at a natural gas processing plant, must have a natural gas bleed rate of less than or equal to 6 standard cubic feet per hour. Note that a natural gas processing plant is defined as any processing site engaged in the extraction of natural gas liquids from field gas, fractionation of mixed natural gas liquids to natural gas products, or both. A Joule-Thompson valve, a dew point suppression valve, or an isolated or stand-alone Joule-Thompson skid is not a natural gas processing plant.

   These requirements do not apply if it is determined that the use of a pneumatic controller affected facility with a bleed rate greater than the applicable standard is required based on functional needs, including but not limited to response time, safety and positive actuation. However, an applicable pneumatic controller must be tagged with the month and year of installation, reconstruction or modification, and identification information that allows traceability to the records for that pneumatic controller.

   The Ventura County APCD does not require permits for the installation and operation of pneumatic controllers and other components such as valves and flanges (Rule 23.J.9). Therefore, this condition authorizes the work necessary to comply with these pneumatic controller requirements provided that the permittee comply with all the requirements of Section 60.5390a, including the required notification, recordkeeping and reporting requirements.

5. Pneumatic pumps subject to this NSPS shall comply with Section 60.5393a. For natural gas processing plants, each pneumatic pump affected facility is a single natural gas-driven diaphragm pump. For well sites, each pneumatic pump affected facility is a single natural gas-driven diaphragm pump. A single natural gas-driven diaphragm pump that is in operation less than 90 days per calendar year is not an affected facility under this subpart provided the owner/operator keeps records of the days of operation each calendar year and submits such records to the EPA Administrator (or delegated enforcement authority) upon request.

This NSPS requires each pneumatic pump affected facility at a natural gas processing plant to have a natural gas bleed rate of zero standard cubic feet per hour. A pneumatic pump affected facility located at a well site must reduce natural gas emissions by 95.0 percent, except as provided in paragraphs (b)(3) and (4) of this section for a well site at a greenfield site, and except as provided in paragraphs (b)(3), (4) and (5) of this section for a well site not located at a greenfield site. Greenfield site is defined as a site, other than a natural gas processing plant, which is entirely new construction. Natural gas processing plants are not considered to be greenfield sites, even if they are entirely new construction.

The Ventura County APCD does not require permits for the installation and operation of pneumatic pumps and other components such as valves and flanges (Rule 23.J.9). Therefore, this condition authorizes the work necessary to comply with these pneumatic pump requirements provided that the permittee comply with all the requirements of Section 60.5393a, including the required notification, recordkeeping and reporting requirements.

6. Storage vessels subject to this NSPS shall comply with Section 60.5395a. A storage vessel is defined as a tank or other vessel that contains an accumulation of crude oil, condensate, intermediate hydrocarbon liquids, or produced water, and that is constructed primarily of non-earthen materials (such as wood, concrete, steel, fiberglass, or plastic) which provide structural support. A well completion vessel that receives recovered liquids from a well after startup of production following flowback for a period which exceeds 60 days is considered a storage vessel under this NSPS. Note that pressure vessels designed to operate in excess of 204.9 kilopascals (29.7 psi) and without emissions to the atmosphere are not considered to be storage vessels. Also, process vessels such as surge control vessels, bottoms receivers, and knockout vessels are not considered to be storage vessels.

   The NSPS requires that individual storage vessels with VOC emissions equal to or greater than 4 tons per year achieve at least 95.0 percent reduction in VOC emissions. These requirements do not apply to storage vessels subject to and controlled in accordance with the requirements for storage vessels in 40 CFR Part 60, Subpart Kb, and 40 CFR Part 63, Subparts G, CC, HH, or WW.

   The Ventura County APCD does require permits for the installation and operation of storage vessels such as crude oil storage tanks, wash tanks, and produced water storage tanks. Pressure vessels without routine emissions to the atmosphere are not required to be listed on the permit. In addition, these tanks must comply with the vapor recovery requirements of Rule 71.1, "Crude Oil Production and Separation", which in most cases is more stringent than this NSPS.

7. Fugitive emissions from well sites and compressor stations, except compressors located at a well site or compressors located at an onshore natural gas processing plant, subject to

this NSPS shall comply with Section 60.5397a.

The NSPS requires a leak detection and repair program for fugitive emissions components such as valves, connectors, pressure relief devices, open-ended lines, flanges, certain covers and closed vent systems, thief hatches or other openings on a controlled storage vessel (not subject to Section 60.5395a), compressors, instruments, and meters. An emissions monitoring plan is required and emission monitoring surveys are required at least semiannually for well sites and a least quarterly for compressor stations. "Difficult-to-monitor" components must be monitored at least once per calendar year and "unsafe-to-monitor" components must be monitored on a schedule, as included in the monitoring plan.

Fugitive emissions are defined as: a) any visible emission from a fugitive emissions component observed using optical gas imaging, or b) an instrument reading 500 ppm or greater using EPA Method 21.

Each identified source of fugitive emissions shall be repaired or replaced as soon as practicable, but no later than 30 calendar days after the detection of the fugitive emissions, except as provided for specified repairs and replacements in the NSPS.

The Ventura County APCD does not require permits for the installation and operation of components subject to the fugitive emissions requirements of this NSPS. Therefore, this condition authorizes any work necessary to comply with these leak detection and repair requirements provided that the permittee comply with all the requirements of Section 60.5397a, including the monitoring, repair, replacement, recordkeeping and reporting requirements.

8. All process units, except compressors, located at an onshore natural gas processing plant subject to this NSPS shall comply with Section 60.5400a. A process unit means components assembled for the extraction of natural gas liquids from field gas, the fractionation of the liquids into natural gas products or other operations associated with the processing of natural gas products.

   The NSPS requires a leak detection and repair program for components such as pressure relief devices, pumps and valves that reflects the procedures and leak thresholds established in 40 CFR Part 60, Subpart VVa, the NSPS for Equipment Leaks of VOC in the Synthetic Organic Chemicals Manufacturing Industry (that is, this NSPS OOOO references out to NSPS VVa). For specified components, a leak is defined as 500 ppm or greater as measured by EPA Method 21, and a first attempt at a repair must be made no later than 5 calendar days after a leak is detected. The leak must be repaired as soon as practicable, but no later than 15 days after detection.

9. Sweetening units at onshore natural gas processing plants subject to this NSPS shall

comply with Section 60.5405a. A sweetening unit is defined as a process device that removes hydrogen sulfide and / or carbon dioxide from the sour natural gas stream. To qualify as a sweetening unit, there must be sulfur recovery technology with a liquid sulfur accumulation rate. These requirements do not apply to sweetening units located on offshore oil platforms in Ventura County. The requirements also do not apply to devices that remove hydrogen sulfide or carbon dioxide that use replaceable media or units that use membrane separation technology.

The NSPS requires that the sweetening unit achieve a minimum SO2 reduction efficiency that varies from 74.0% to 99.9% depending on the hydrogen sulfide content of the acid gas and the sulfur feed rate.

The Ventura County APCD does require an Authority to Construct for the installation of a sweetening unit at both onshore natural gas plants and offshore natural gas plants. Any sweetening unit at this facility subject to this NSPS will be specifically addressed elsewhere in this permit, as applicable.

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12. MISCELLANEOUS FEDERAL PROGRAM CONDITIONS

This section contains miscellaneous federal program conditions that are not emission unit-specific or short-term. These federal requirements are broadly applicable requirements that apply and are enforced in the same manner for all subject emissions units or short-term activities. Permit conditions associated with these miscellaneous federal program requirements are listed in individual attachments. The attachment is identified with the label "Attachment 40CFR(Part No.) __" in the lower left corner of each attachment.

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Ventura County Air Pollution Control District
40 CFR Part 68 Applicable Requirements
Accidental Release Prevention and Risk Management Plans

40 CFR Part 68, "List of Regulated Substances and Thresholds for Accidental Release Prevention"
Federally-Enforceable

Applicability:

This attachment applies to regulated substances that are contained in a process at this facility and that exceed the threshold quantity, as presented in 40 CFR Part 68.130. This regulation addresses the requirements of section 112(r) of the federal Clean Air Act as amended. Specifically, this attachment applies to a facility that has stated that a federal Risk Management Plan pursuant to section 112(r) is currently not required, but where flexibility is desired to preclude a permit reopening should 40 CFR Part 68 become an applicable requirement.

Conditions:

1. Should the stationary source, as defined in 40 CFR Part 68.3, become subject to Part 68, then the owner or operator shall submit a risk management plan (RMP) by the date specified in Part 68.10 and shall certify compliance with the requirements of Part 68 as part of the annual compliance certification as required by 40 CFR Part 70.

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Ventura County Air Pollution Control District
40 CFR Part 82 Applicable Requirements
Protection of Stratospheric Ozone

40 CFR Part 82, "Protection of Stratospheric Ozone"
40 CFR Part 82, Subpart B, "Servicing of Motor Vehicle Air Conditioners"
40 CFR Part 82, Subpart F, "Recycling and Emissions Reduction"
Federally Enforceable (last revised 11/18/16)

Applicability:

This attachment applies to activities conducted at this facility that involve producing, importing, exporting, or consuming of the specified controlled substances described under 40 CFR Part 82.4. Specifically, this attachment includes the requirements of 40 CFR Part 82, Subpart B, "Servicing of Motor Vehicle Air Conditioners," and 40 CFR Part 82, Subpart F, "Recycling and Emissions Reduction."

As stated in 40 CFR Part 82.30, 40 CFR Part 82, Subpart B applies to any person performing service on a motor vehicle for consideration when this service involves the refrigerant in the motor vehicle air conditioner.

As stated in 40 CFR Part 82.150, 40 CFR Part 82, Subpart F applies to any person maintaining, servicing, or repairing appliances containing class I, class II, or non-exempt substitute refrigerants. This subpart also applies to persons disposing of such appliances (including small appliances and motor vehicle air conditioners), refrigerant reclaimers, technician certifying programs, appliance owners and operators, manufacturers of appliances, manufacturers of recovery and/or recycling equipment, approved recovery and/or recycling equipment testing organizations, and persons buying, selling, or offering to sell class I, class II, or non-exempt substitute refrigerants.

As defined in 40 CFR82.152, *appliance* means any device which contains and uses a class I or class II substance or substitute as a refrigerant and which is used for household or commercial purposes, including any air conditioner, motor vehicle air conditioner, refrigerator, chiller, or freezer. For a system with multiple circuits, each independent circuit is considered a separate appliance. *Refrigerant* means, for purposes of this subpart, any substance, including blends and mixtures, consisting in part or whole of a class I or class II ozone-depleting substance or substitute that is used for heat transfer purposes and provides a cooling effect.

Conditions:

1. If the permittee performs a service on motor (fleet) vehicles when this service involves ozone-depleting substance refrigerant (or regulated substitute substance) in the motor vehicle air conditioner (MVAC), the permittee is subject to all the applicable

requirements as specified in 40 CFR Part 82, Subpart B, "Servicing of Motor Vehicle Air Conditioners."

The term "motor vehicle" as used in Subpart B does not include a vehicle in which final assembly of the vehicle has not been completed. The term "MVAC" as used in Subpart B does not include the air-tight sealed refrigeration system used as refrigerated cargo, or system used on passenger buses using HCFC-22 refrigerant.

2. If the permittee performs maintenance on, or services, repairs, or disposes of appliances, the permittee is subject to all of the applicable requirements as specified in 40 CFR Part 82, Subpart F, "Recycling and Emissions Reduction."

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13. PART 70 PERMIT APPLICATION PACKAGE

The Part 70 permit application, which was submitted by this facility, is included in this section for reference only and is not a part of the Part 70 permit.

During the processing of the permit application, additional information was submitted by the facility in response to District requests. This additional information is included with the application. If the applicant was asked to replace a page or a portion of the application, the original submittal is stamped "REPLACED" and the replacement page or section is placed in front of the original. The applicant and District correspondence for the Part 70 permit application is located in the District permit file for this stationary source.

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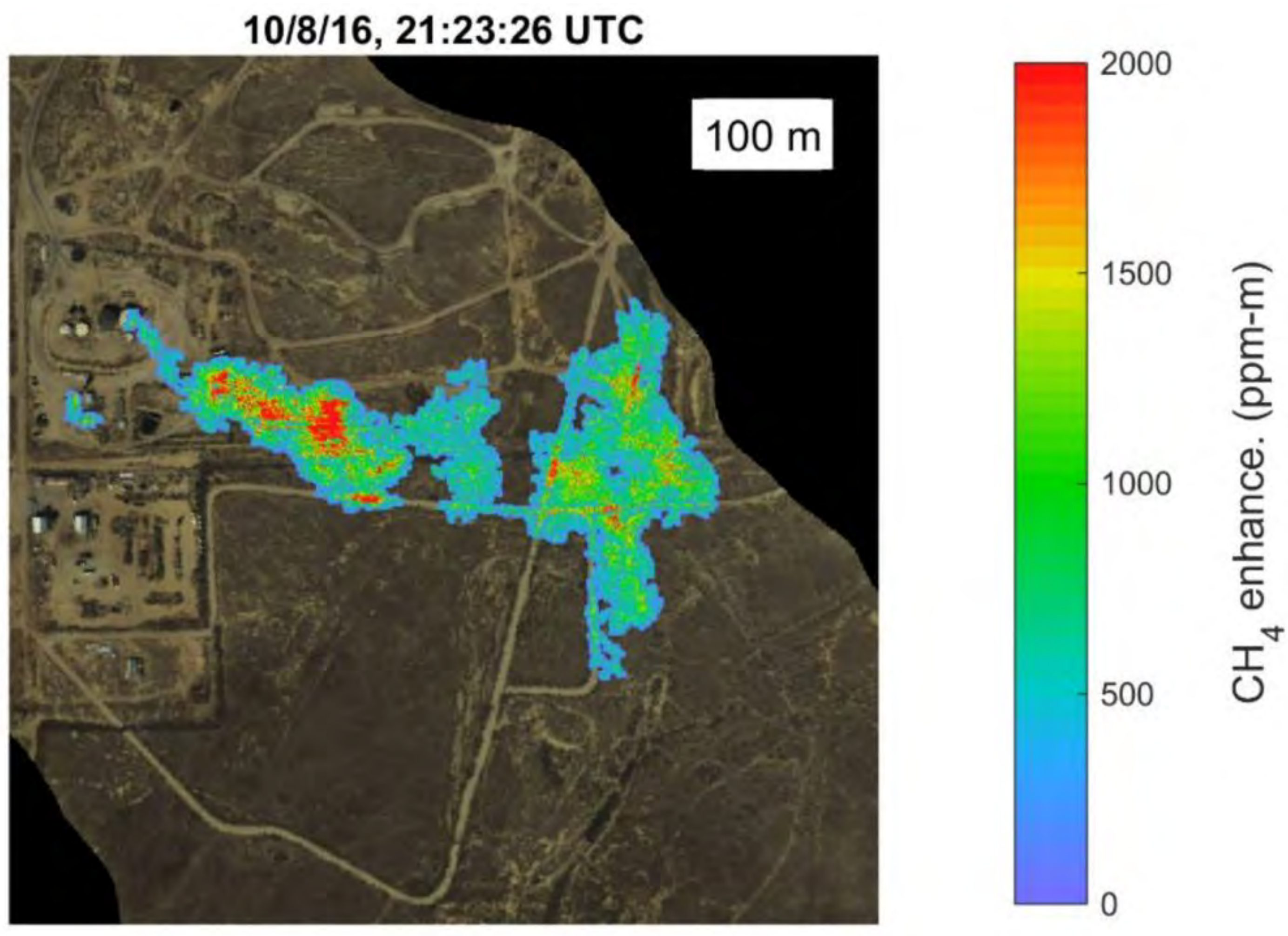
EXHIBIT 7

Climate Changed

NASA Flew Gas Detectors Above California, Found 'Super Emitters'

By Lynn Doan
November 6, 2019, 1:33 PM PST
Updated on November 7, 2019, 2:01 AM PST

- A handful of sites account for most of California's methane
- Researchers published their survey findings in a Nature report



A methane plume captured at an oil field in California. *Source: California Air Resources Board*

Over the course of three years, NASA flew a plane carrying gas-imaging equipment above California and made a discovery that surprised even the state's own environmental agencies: A handful of operations are responsible for the vast majority of methane emissions.

In a report published in Nature on Wednesday, scientists estimated that 10% of the places releasing methane -- including landfills, natural gas facilities and dairy farms -- are responsible for more than half of the state's total emissions. And a fraction of the 272,000 sources surveyed -- just 0.2% -- account for as much as 46%.

The report doesn't identify these "super emitters," but notes that landfills give off more methane than any other source in the state. NASA's equipment found that a subset of these landfills were the largest emitters in California and exhibited "persistent anomalous activity."

The study marks the first time anyone has ever carried out a systematic survey across California of methane, a greenhouse gas that's 25 times more potent than carbon dioxide in trapping heat and contributing to global warming. The release of methane has been a continual challenge for California, which has some of the most aggressive goals in the nation for curbing emissions and slowing the impacts of climate change.

NASA's aircraft made dozens of flights across 10,000 square miles from 2016 through 2018. Landfills accounted for 41% of the source emissions it identified, manure management 26% and oil and gas operations 26%.

Researchers cautioned that the survey wasn't foolproof. It was, after all, their first attempt at estimating emissions from individual sources on such a large scale over multiple years. Some of the emissions detected were intermittent, some were too small to measure and others were affected by winds.

The results, however, are already effecting change. The survey revealed four incidents of leaking natural gas distribution lines and one leaking liquefied natural gas storage tank, which operators confirmed and repaired.

– With assistance by Eric Roston

In this article

CL1
WTI Crude
58.48 USD/bbl. ▼ -0.04 -0.07%

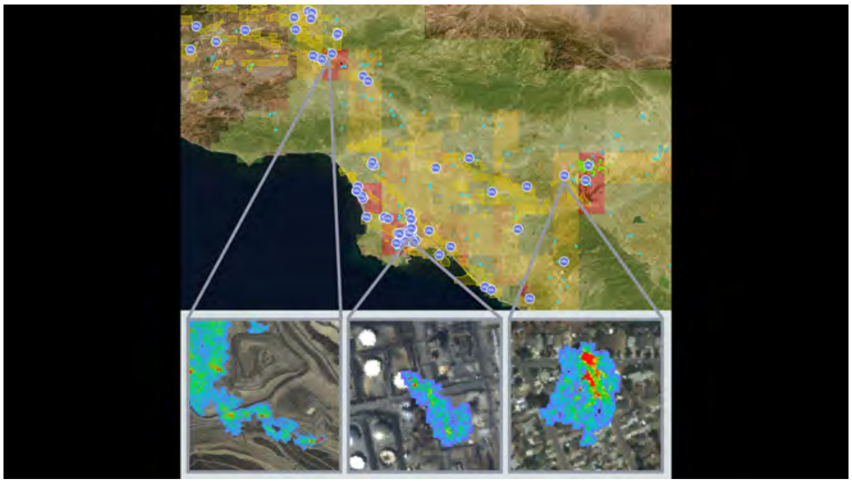
NG1
Generic 1st 'NG' Future
2.01 USD/MMBtu ▼ -0.07 -3.27%

EXHIBIT 8

NEWS | November 6, 2019

A Third of California Methane Traced to a Few Super-Emitters

By Esprit Smith,
NASA's Earth Science News Team



Views from NASA's Methane Source Finder, a tool that provides methane data for the state of California. The data are derived from airborne remote-sensing, surface-monitoring networks and satellites and are presented on an interactive map alongside infrastructure information. Credit: NASA/JPL-Caltech
› Larger view

NASA scientists are helping California create a detailed, statewide inventory of methane point sources — highly concentrated methane releases from single sources — using a specialized airborne sensor. The new data, published this week in the journal Nature, can be used to target actions to reduce emissions of this potent greenhouse gas.

Like carbon dioxide, methane traps heat in the atmosphere, but it does so more efficiently and for a shorter period of time. Scientists estimate that most methane emissions in California are driven by industrial facilities, such as oil and gas fields, large dairies and landfills. To help reduce methane's impact on climate, the state has made cutting human-caused emissions a priority. But in order to cut these hard-to-detect emissions, they have to be measured and the sources identified.

NASA, through partnerships with the California Air Resources Board (CARB) and the California Energy Commission, set out to do just that. Over a two-year period, a research team at NASA's Jet Propulsion Laboratory in Pasadena, California, flew a plane equipped with the Airborne Visible InfraRed

Imaging Spectrometer - Next Generation (AVIRIS-NG)instrument over nearly 300,000 facilities and infrastructure components in those sectors. The instrument can detect plumes of methane in great detail. Each pixel covers an area of about 10 feet (3 meters) across, which allows scientists to see even small plumes that often go undetected.

The team identified more than 550 individual point sources emitting plumes of highly concentrated methane. Ten percent of these sources, considered super-emitters, contributed the majority of the emissions detected. The team estimates that statewide, super-emitters are responsible for about a third of California's total methane budget.

Emissions data like this can help facility operators identify and correct problems — and in turn, bring California closer to its emissions goals. For example, of the 270 surveyed landfills, only 30 were observed to emit large plumes of methane. However, those 30 were responsible for 40 percent of the total point-source emissions detected during the survey. This type of data could help these facilities to identify possible leaks or malfunctions in their gas-capture systems.

"These findings illustrate the importance of monitoring point sources across multiple sectors [of the economy] and broad regions, both for improved understanding of methane budgets and to support emission mitigation efforts," said the lead scientist on the study, Riley Duren, who conducted the work for NASA's Jet Propulsion Laboratory.

Initial results have been shared with facility operators in California to make them aware of the need to improve their methane-leak detection processes and to institute better controls on methane emissions. Results will also be used to help state and local agencies and businesses prioritize investments in methane-emission mitigation.

Although the survey provides a detailed map of methane emissions for the areas observed in the state, researchers caution that this was the first attempt to estimate emissions for individual methane sources from a large population distributed across such an extensive area over multiple years.

Additionally, this survey was designed to detect highly concentrated releases of methane from a single component or piece of industrial equipment, such as an oil well. The survey excluded non-point sources, such as small natural gas leaks from millions of homes, because even though they may have a collective impact on atmospheric methane levels, their individual emissions are below the detection levels of this method.

The survey builds on a decade of cooperation between NASA, CARB and the California Energy Commission to support the state's ambitious climate change mitigation program, specifically on the study of air pollution impacts from the oil and gas sector.

"This new remote-sensing technology addresses the continuing need for detailed, high-quality data about methane," said California Air Resources Board Chair Mary D. Nichols. "It will help us and the Energy Commission develop the best strategies for capturing this highly potent greenhouse gas."

The final report of the California Methane Survey will be available in the fall.

The map and data from this survey can be viewed here:

http://methane.jpl.nasa.gov/

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EXHIBIT 9

8 Anthropogenic and Natural Radiative Forcing

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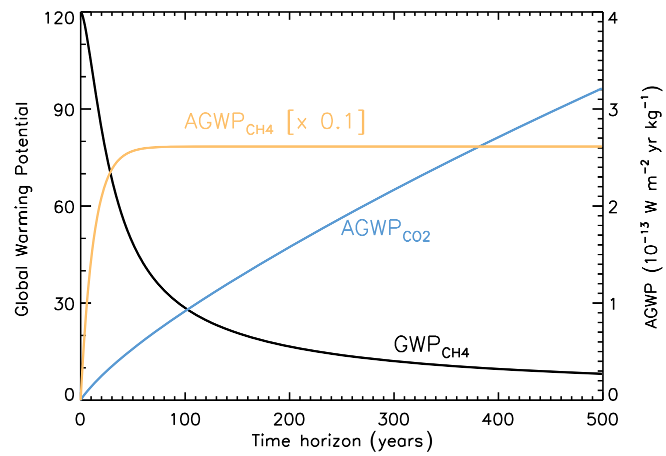


Figure 8.29 | Development of AGWP-CO_2, AGWP-CH_4 and GWP-CH_4 with time horizon. The yellow and blue curves show how the AGWPs changes with increasing time horizon. Because of the integrative nature the AGWP for CH_4 (yellow curve) reaches a constant level after about five decades. The AGWP for CO_2 continues to increase for centuries. Thus the ratio which is the GWP (black curve) falls with increasing time horizon.

on the relative weight assigned to effects at different times. Other important choices include the background atmosphere on which the GWP calculations are superimposed, and the way indirect effects and feedbacks are included (see Section 8.7.1.4).

For some gases the variation in GWP with time horizon mainly reflects properties of the reference gas, not the gas for which the GWP is calculated. The GWP for NTCFs decreases with increasing time horizon, as GWP is defined with the integrated RF of CO_2 in the denominator. As shown in Figure 8.29, after about five decades the development in the GWP for CH_4 is almost entirely determined by CO_2. However, for long-lived gases (e.g., SF_6) the development in GWP is controlled by both the increasing integrals of RF from the long-lived gas and CO_2.

8.7.1.3 The Global Temperature change Potential Concept

Compared to the GWP, the Global Temperature change Potential (GTP; Shine et al., 2005a) goes one step further down the cause–effect chain (Figure 8.27) and is defined as the *change in global mean surface temperature at a chosen point in time* in response to an emission pulse—relative to that of CO_2. Whereas GWP is integrated in time (Figure 8.28a), GTP is an end-point metric that is based on temperature change for a selected year, *t*, (see Figure 8.28b with formula). Like for the GWP, the impact from CO_2 is normally used as reference, hence, for a component *i*, $GTP(t)_i = AGTP(t)_i \,/\, AGTP(t)_{CO2} = \Delta T((t)_i \,/\Delta T(t)_{CO2}$, where AGTP is the absolute GTP giving temperature change per unit emission (see Supplementary Material Section 8.SM.11 for equations and parameter values). Shine et al. (2005a) presented the GTP for both pulse and sustained emission changes based on an energy balance model as well as analytical equations. A modification was later introduced (Shine et al., 2007) in which the time horizon is determined by the proximity to a target year as calculated by using scenarios and climate models (see Section 8.7.1.5).

Like GWP, the GTP values can be used for weighting the emissions to obtain 'CO_2 equivalents' (see Section 8.7.1.1). This gives the temperature effects of emissions relative to that of CO_2 for the chosen time horizon. As for GWP, the choice of time horizon has a strong effect on the metric values and the calculated contributions to warming.

In addition, the AGTP can be used to calculate the global mean temperature change due to any given emission scenario (assuming linearity) using a convolution of the emission scenarios and $AGTP_i$:

$$\bar{A}\bar{A}(\bar{A})\ \bar{A}\ \sum_{\bar{A}}\int_{\bar{A}}^{\bar{A}} \bar{A}_{\bar{A}}(\bar{A})\bar{A}\quad A\ _{\bar{A}}(\bar{A}\bar{A}\ \bar{A})\bar{A} \qquad (8.1)$$

where *i* is component, *t* is time, and *s* is time of emission (Berntsen and Fuglestvedt, 2008; Peters et al., 2011b; Shindell et al., 2011).

By accounting for the climate sensitivity and the exchange of heat between the atmosphere and the ocean, the GTP includes physical processes that the GWP does not. The GTP accounts for the slow response of the (deep) ocean, thereby prolonging the response to emissions beyond what is controlled by the decay time of the atmospheric concentration. Thus the GTP includes both the atmospheric adjustment time scale of the component considered and the response time scale of the climate system.

The GWP and GTP are fundamentally different by construction and different numerical values can be expected. In particular, the GWPs for NTCFs, over the same time frames, are higher than GTPs due to the integrative nature of the metric. The GTP values can be significantly affected by assumptions about the climate sensitivity and heat uptake by the ocean. Thus, the relative uncertainty ranges are wider for the GTP compared to GWP (see Section 8.7.1.4). The additional uncertainty is a typical trade-off when moving along the cause–effect chain to an effect of greater societal relevance (Figure 8.27). The formulation of the ocean response in the GTP has a substantial effect on the values; thus its characterization also represents a trade-off between simplicity and accuracy. As for GWP, the GTP is also influenced by the background atmosphere, and the way indirect effects and feedbacks are included (see Section 8.7.1.4).

8.7.1.4 Uncertainties and Limitations related to Global Warming Potential and Global Temperature change Potential

The uncertainty in the numerator of GWP; that is, the $AGWP_i$ (see formula in Figure 8.28a) is determined by uncertainties in lifetimes (or perturbation lifetimes) and radiative efficiency. Inclusion of indirect effects increases uncertainties (see below). For the reference gas CO_2, the uncertainty is dominated by uncertainties in the *impulse response function* (IRF) that describes the development in atmospheric concentration that follows from an emission pulse (Joos et al., 2013); see Box 6.2 and Supplementary Material Section 8.SM.12. The IRF is sensitive to model representation of the carbon cycle, pulse size and background CO_2 concentrations and climate.

Based on a multi-model study, Joos et al. (2013) estimate uncertainty ranges for the time-integrated IRF for CO_2 to be ±15% and ±25% (5 to 95% uncertainty range) for 20- and 100-year time horizons, respectively. Assuming quadratic error propagation, and ±10% uncertainty in radiative efficiency, the uncertainty ranges in AGWP for CO_2 were estimated to be ±18% and ±26% for 20 and 100 years. These uncertainties affect all metrics that use CO_2 as reference. Reisinger et al. (2010) and Joos et al. (2013) show that these uncertainties increase with time horizon.

The same factors contribute to uncertainties in the GTP, with an additional contribution from the parameters describing the ocean heat uptake and climate sensitivity. In the first presentation of the GTP, Shine et al. (2005a) used one time constant for the climate response in their analytical expression. Improved approaches were used by Boucher and Reddy (2008), Collins et al. (2010) and Berntsen and Fuglestvedt (2008) that include more explicit representations of the deep ocean that increased the long-term response to a pulse forcing. Over the range of climate sensitivities from AR4, GTP_{50} for BC was found to vary by a factor of 2, the CH_4 GTP_{50} varied by about 50%, while for N_2O essentially no dependence was found (Fuglestvedt et al., 2010). AGTPs for CO_2 were also calculated in the multi-model study by Joos et al. (2013). They found uncertainty ranges in AGTP that are much larger than for AGWP; ±45% and ±90% for 20 and 100 years (5 to 95% uncertainty range). These uncertainty ranges also reflect the signal-to-noise ratio, and not only uncertainty in the physical mechanisms.

There are studies combining uncertainties in various input parameters. Reisinger et al. (2011) estimated the uncertainty in the GWP for CH_4 and found an uncertainty of –30 to +40% for the GWP_{100} and –50 to +75% for GTP_{100} of CH_4 (for 5 to 95% of the range). Boucher (2012) performed a Monte Carlo analysis with uncertainties in perturbation lifetime and radiative efficiency, and for GWP_{100} for CH_4 (assuming a constant background atmosphere) he found ±20%, and –40 to +65 for GTP_{100} (for 5 to 95% uncertainty range).

Here we estimate uncertainties in GWP values based on the uncertainties given for radiative efficiencies (Section 8.3.1), perturbation lifetimes, indirect effects and in the AGWP for the reference gas CO_2 (see Supplementary Material Section 8.SM.12). For CH_4 GWP we estimate an uncertainty of ±30% and ±40% for 20- and 100-year time horizons, respectively (for 5 to 95% uncertainty range). The uncertainty is dominated by AGWP for CO_2 and indirect effects. For gases with lifetimes of a century or more the uncertainties are of the order of ±20% and ±30% for 20- and 100-year horizons. The uncertainty in GWPs for gases with lifetimes of a few decades is estimated to be of the order of ±25% and ±35% for 20 and 100 years. For shorter-lived gases, the uncertainties in GWPs will be larger (see Supplementary Material Section 8.SM.12 for a discussion of contributions to the total uncertainty.) For GTP, few uncertainty estimates are available in the literature. Based on the results from Joos et al. (2013), Reisinger et al. (2010) and Boucher (2012) we assess the uncertainty to be of the order of ±75% for the CH_4 GTP_{100}.

The metric values are also strongly dependent on which processes are included in the definition of a metric. Ideally all indirect effects (Sections 8.2 and 8.3) should be taken into account in the calculation of metrics. The indirect effects of CH_4 on its own lifetime, tropospheric ozone and stratospheric water have been traditionally included in its GWP. Boucher et al. (2009) have quantified an indirect effect on CO_2 when fossil fuel CH_4 is oxidized in the atmosphere. Shindell et al. (2009) estimated the impact of reactive species emissions on both gaseous and aerosol forcing species and found that ozone precursors, including CH_4, had an additional substantial climate effect because they increased or decreased the rate of oxidation of SO_2 to sulphate aerosol. Studies with different sulphur cycle formulations have found lower sensitivity (Collins et al., 2010; Fry et al., 2012). Collins et al. (2010) postulated an additional component to their GWPs and GTPs for ozone precursors due to the decreased productivity of plants under higher levels of surface ozone. This was estimated to have the same magnitude as the ozone and CH_4 effects. This effect, however, has so far only been examined with one model. In a complex and interconnected system, feedbacks can become increasingly complex, and uncertainty of the magnitude and even direction of feedback increases the further one departs from the primary perturbation, resulting in a trade-off between completeness and robustness, and hence utility for decision-making.

Gillett and Matthews (2010) included climate–carbon feedbacks in calculations of GWP for CH_4 and N_2O and found that this increased the values by about 20% for 100 years. For GTP of CH_4 they found an increase of ~80%. They used numerical models for their studies and suggest that climate–carbon feedbacks should be considered and parameterized when used in simple models to derive metrics. Collins et al. (2013) parameterize the climate-carbon feedback based on Friedlingstein et al. (2006) and Arora et al. (2013) and find that this more than doubles the GTP_{100} for CH_4. Enhancement of the GTP for CH_4 due to carbon–climate feedbacks may also explain the higher GTP values found by Reisinger et al. (2010).

The inclusion of indirect effects and feedbacks in metric values has been inconsistent in the IPCC reports. In SAR and TAR, a carbon model without a coupling to a climate model was used for calculation of IRF for CO_2 (Joos et al., 1996), while in AR4 climate-carbon feedbacks were included for the CO_2 IRF (Plattner et al., 2008). For the time horizons 20 and 100 years, the $AGWP_{CO2}$ calculated with the Bern3D-LPJ model is, depending on the pulse size, 4 to 5% and 13 to 15% lower, respectively, when carbon cycle–climate feedbacks are not included (Joos et al., 2013). While the AGWP for the reference gas CO_2 included climate–carbon feedbacks, this is not the case for the non-CO_2 gas in the numerator of GWP, as recognized by Gillett and Matthews (2010), Joos et al. (2013), Collins et al. (2013) and Sarofim (2012). This means that the GWPs presented in AR4 may underestimate the relative impacts of non-CO_2 gases. The different inclusions of feedbacks partially represent the current state of knowledge, but also reflect inconsistent and ambiguous definitions. In calculations of AGWP for CO_2 in AR5 we use the IRF for CO_2 from Joos et al. (2013) which includes climate–carbon feedbacks. Metric values in AR5 are presented both with and without including climate–carbon feedbacks for non-CO_2 gases. This feedback is based on the carbon-cycle response in a similar set of models (Arora et al., 2013) as used for the reference gas (Collins et al., 2013).

The effect of including this feedback for the non-reference gas increases with time horizon due to the long-lived nature of the initiated CO_2 perturbation (Table 8.7). The relative importance also increases with decreasing lifetime of the component, and is larger for GTP than GWP due to the integrative nature of GWP. We calculate an increase in the CH_4 GWP_{100} of 20%. For GTP_{100}, however, the changes are much larger; of the order of 160%. For the shorter time horizons (e.g., 20 years) the effect of including this feedback is small (<5%) for both GWP

Table 8.7 | GWP and GTP with and without inclusion of climate–carbon feedbacks (cc fb) in response to emissions of the indicated non-CO_2 gases (climate-carbon feedbacks in response to the reference gas CO_2 are always included).

	Lifetime (years)		GWP_{20}	GWP_{100}	GTP_{20}	GTP_{100}
CH_4[b]	12.4[a]	No cc fb	84	28	67	4
		With cc fb	86	34	70	11
HFC-134a	13.4	No cc fb	3710	1300	3050	201
		With cc fb	3790	1550	3170	530
CFC-11	45.0	No cc fb	6900	4660	6890	2340
		With cc fb	7020	5350	7080	3490
N_2O	121.0[a]	No cc fb	264	265	277	234
		With cc fb	268	298	284	297
CF_4	50,000.0	No cc fb	4880	6630	5270	8040
		With cc fb	4950	7350	5400	9560

Notes:

Uncertainties related to the climate–carbon feedback are large, comparable in magnitude to the strength of the feedback for a single gas.

[a] Perturbation lifetime is used in the calculation of metrics.

[b] These values do not include CO_2 from methane oxidation. Values for fossil methane are higher by 1 and 2 for the 20 and 100 year metrics, respectively (Table 8.A.1).

and GTP. For the more long-lived gases the GWP_{100} values increase by 10 to 12%, while for GTP_{100} the increase is 20 to 30%. Table 8.A.1 gives metric values including the climate–carbon feedback for CO_2 only, while Supplementary Material Table 8.SM.16 gives values for all halocarbons that include the climate–carbon feedback. Though uncertainties in the carbon cycle are substantial, it is *likely* that including the climate–carbon feedback for non-CO_2 gases as well as for CO_2 provides a better estimate of the metric value than including it only for CO_2.

Emission metrics can be estimated based on a constant or variable background climate and this influences both the adjustment times and the concentration–forcing–temperature relationships. Thus, all metric values will need updating due to changing atmospheric conditions as well as improved input data. In AR5 we define the metric values with respect to a constant present-day condition of concentrations and climate. However, under non-constant background, Joos et al. (2013) found decreasing CO_2 $AGWP_{100}$ for increasing background levels (up to 23% for RCP8.5). This means that GWP for all non-CO_2 gases (except CH_4 and N_2O) would increase by roughly the same magnitude. Reisinger et al. (2011) found a reduction in AGWP for CO_2 of 36% for RCP8.5 from 2000 to 2100 and that the CH_4 radiative efficiency and AGWP also decrease with increasing CH_4 concentration. Accounting for both effects, the GWP_{100} for CH_4 would increase by 10 to 20% under low and mid-range RCPs by 2100, but would decrease by up to 10% by mid-century under the highest RCP. While these studies have focused on the background levels of GHGs, the same issues apply for temperature. Olivié et al. (2012) find different temperature IRFs depending on the background climate (and experimental set up).

User related choices (see Box 8.4) such as the time horizon can greatly affect the numerical values obtained for CO_2 equivalents. For a change in time horizon from 20 to 100 years, the GWP for CH_4 decreases by a factor of approximately 3 and its GTP by more than a factor of 10. Short-lived species are most sensitive to this choice. Some approaches have removed the time horizon from the metrics (e.g., Boucher, 2012), but discounting is usually introduced which means that a discount rate r (for the weighting function e^{-rt}) must be chosen instead. The choice of discount rate is also value based (see WGIII, Chapter 3).

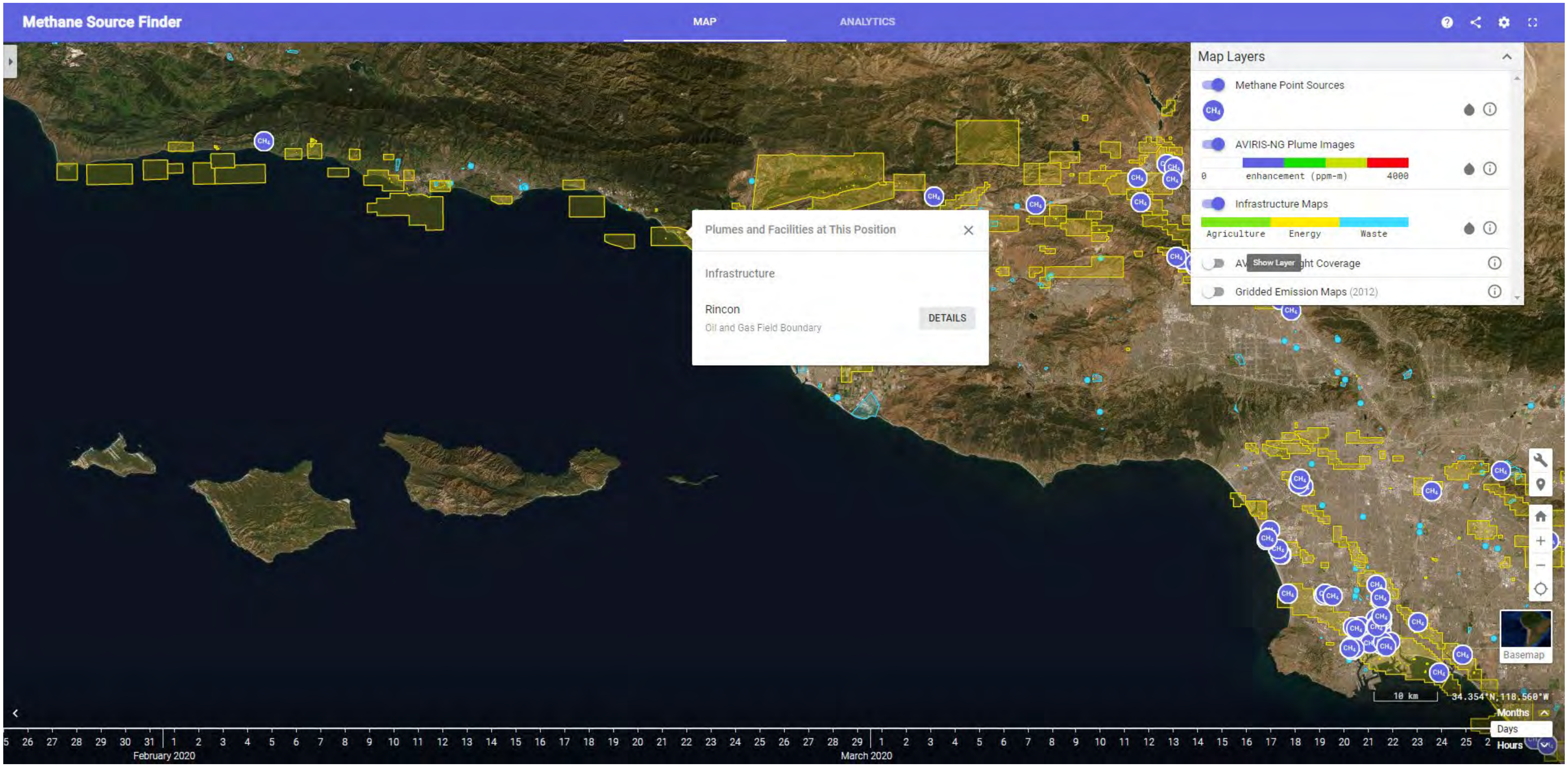
For NTCFs the metric values also depend on the location and timing of emission and whether regional or global metrics are used for these gases is also a choice for the users. Metrics are usually calculated for pulses, but some studies also give metric values that assume constant emissions over the full time horizon (e.g., Shine et al., 2005a; Jacobson, 2010). It is important to be aware of the idealized assumption about constant future emissions (or change in emissions) of the compound being considered if metrics for sustained emissions are used.

8.7.1.5 New Metric Concepts

New metric concepts have been developed both to modify physical metrics to address shortcomings as well as to replace them with metrics that account for economic dimensions of problems to which metrics are applied. Modifications to physical metrics have been proposed to better represent CO_2 emissions from bioenergy, regional patterns of response, and for peak temperature limits.

Emissions of CO_2 from the combustion of biomass for energy in national emission inventories are currently assumed to have no net RF, based on the assumption that these emissions are compensated by biomass regrowth (IPCC, 1996). However, there is a time lag between combustion and regrowth, and while the CO_2 is resident in the atmosphere it leads to an additional RF. Modifications of the GWP and GTP for bioenergy (GWP_{bio}, GTP_{bio}) have been developed (Cherubini et al., 2011; Cherubini et al., 2012). The GWP_{bio} give values generally between zero (current default for bioenergy) and one (current for fossil fuel emissions) (Cherubini et al., 2011), and negative values are possible for GTP_{bio} due to the fast time scale of atmospheric–ocean CO_2 exchange relative to the growth cycle of biomass (Cherubini et al., 2012). GWP_{bio} and GTP_{bio} have been used in only a few applications, and more research is needed to assess their robustness and applicability. Metrics for biogeophysical effects, such as albedo changes, have been proposed (Betts, 2000; Rotenberg and Yakir, 2010) , but as for NTCFs regional variations

EXHIBIT 10


Methane Source Finder
MAP
ANALYTICS
Map Layers
Methane Point Sources
AVIRIS-NG Plume Images
0
enhancement (ppm-m)
4000
Infrastructure Maps
Agriculture
Energy
Waste
Show Layer
Gridded Emission Maps (2012)
Plumes and Facilities at This Position
Infrastructure
Rincon
Oil and Gas Field Boundary
DETAILS
Basemap
10 km
34.354°N,118.560°W
Months
Days
Hours
February 2020
March 2020

Methane Source Finder MAP ANALYTICS

BACK TO MAP

Rincon

1B2 Oil and Natural Gas · undefined, CA

Facility Overview

Site	Rincon	Facility Type	1B2 Oil and Natural Gas
Operator	(no operator name)	Location	34.34317°N, -119.40835°W
Facility Address	(no address), (no city), CA	Number of Flyovers	5
Vista ID	FLD000362		

VIEW IN GOOGLE MAPS

Vista Facility Metadata

Source	CEC DOGGR	State	CA
VistaDate	7/12/2019	VistaIPCC	1B2 Oil and Natural Gas
VistaName	Rincon	VistaSType	Oil and Gas Field Boundary
Vista_ID	FLD000362		

Flyovers of: **Rincon**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source ▾

LIST THUMBNAILS CHART

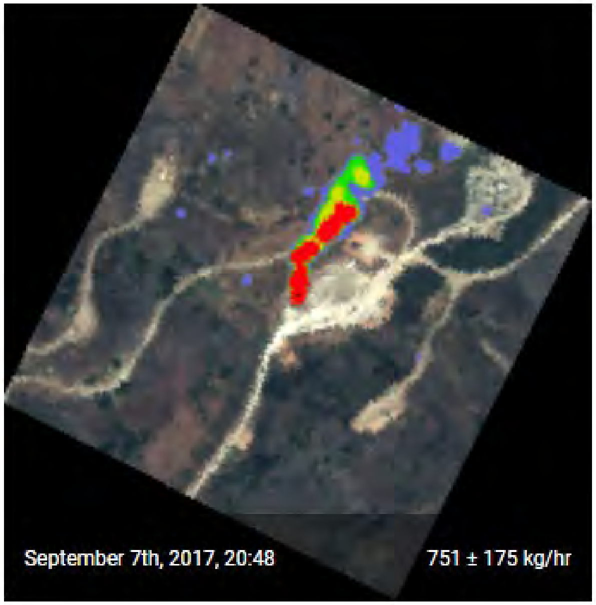
Plume Detected	Source ID	Flyover Date	Candidate ID	Emissions (kg/hr)
Yes	S00678	9/7/2017 20:48	ang20170907t204826-B	751 ± 175
Yes	S00678	9/7/2017 21:00	ang20170907t210002-A	1587 ± 454
Yes	S00678	9/7/2017 21:06	ang20170907t210629-A	1713 ± 529
No		10/1/2018 19:07	-	-
No		10/1/2018 19:15	-	-

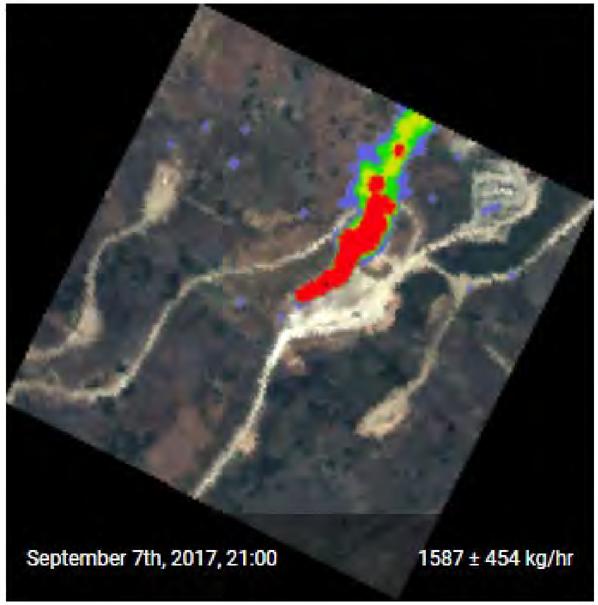
Flyovers of: **Rincon**

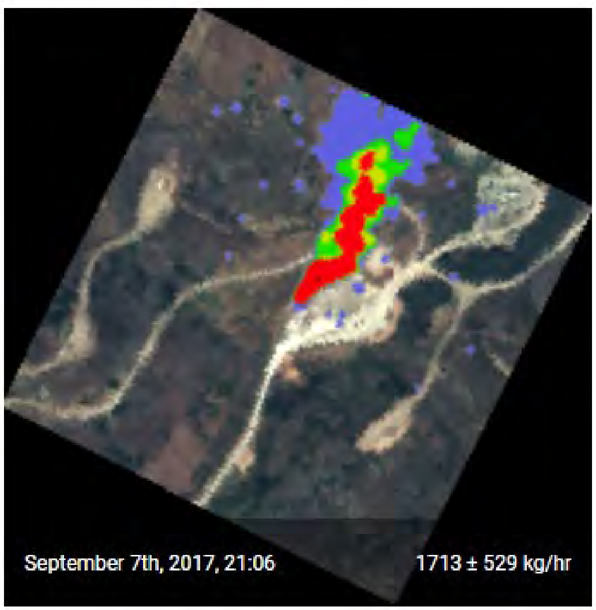
Uncertainty Warning:*Flyovers may not include the entire facility.*

Plume Source ▾

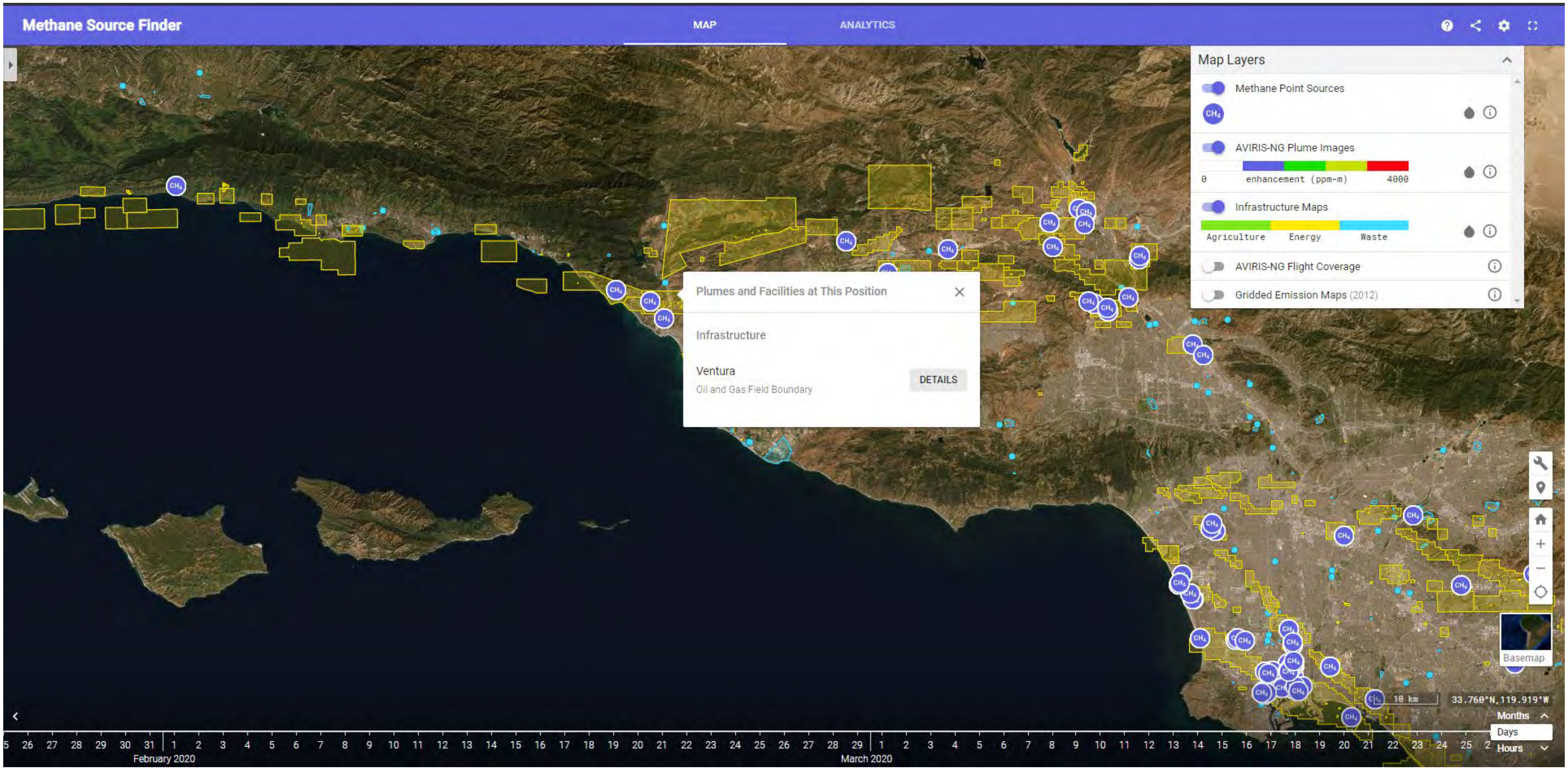
LIST | THUMBNAILS | CHART







Flyovers of: Rincon
Uncertainty Warning Flyovers may not include the entire facility
Plume Source
LIST
THUMBNAILS
CHART
Emissions (kg/hr)
1800
1600
1400
1200
1000
800
600
400
200
0
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Source: S00678
Flyover with no plume detected



Methane Source Finder
MAP
ANALYTICS
Map Layers
Methane Point Sources
AVIRIS-NG Plume Images
0 enhancement (ppm-m) 4000
Infrastructure Maps
Agriculture Energy Waste
AVIRIS-NG Flight Coverage
Gridded Emission Maps (2012)
Plumes and Facilities at This Position
Infrastructure
Ventura
Oil and Gas Field Boundary
DETAILS
Basemap
10 km
33.760°N,119.919°W
Months
Days
Hours
February 2020
March 2020

Methane Source Finder

MAP ANALYTICS

BACK TO MAP

Ventura

1B2 Oil and Natural Gas · undefined, CA

Facility Overview

Site	Ventura
Operator	(no operator name)
Facility Address	(no address), (no city), CA
Vista ID	FLD000486
Facility Type	1B2 Oil and Natural Gas
Location	34.3207°N, -119.26691°W
Number of Flyovers	6

VIEW IN GOOGLE MAPS

Vista Facility Metadata

Source	CEC DOGGR
VistaDate	7/12/2019
VistaName	Ventura
Vista_ID	FLD000486
State	CA
VistaIPCC	1B2 Oil and Natural Gas
VistaSType	Oil and Gas Field Boundary

Flyovers of: **Ventura**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source

LIST THUMBNAILS CHART

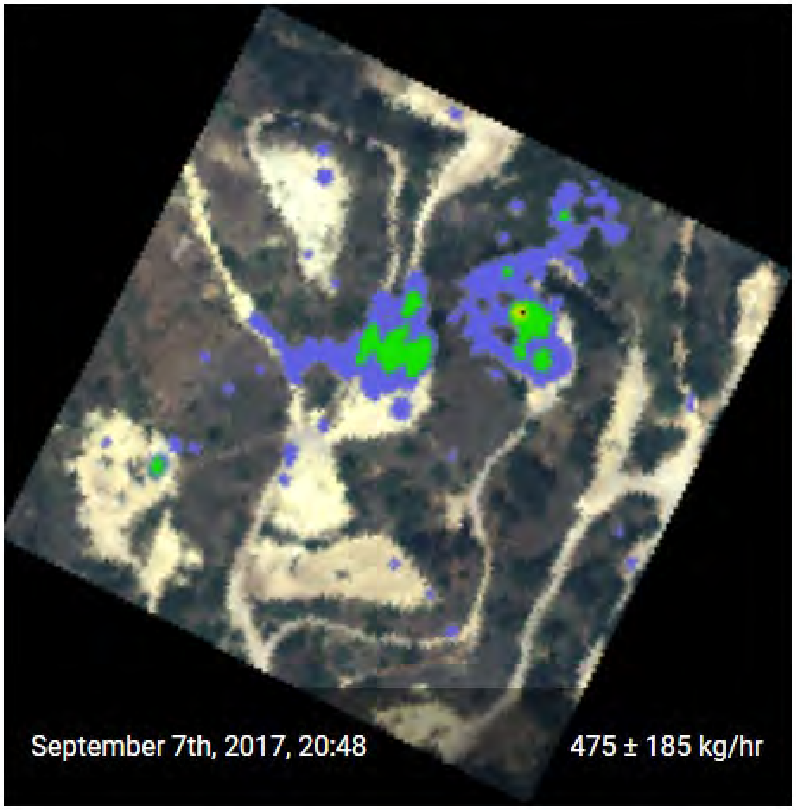
Plume Detected	Source ID	Flyover Date	Candidate ID	Emissions (kg/hr)
Yes	S00677	9/7/2017 20:48	ang20170907t204826-A	475 ± 185
No		9/7/2017 21:00	-	-
No		9/7/2017 21:06	-	-
No		10/16/2017 21:02	-	-
No		10/1/2018 19:07	-	-
No		10/1/2018 19:15	-	-

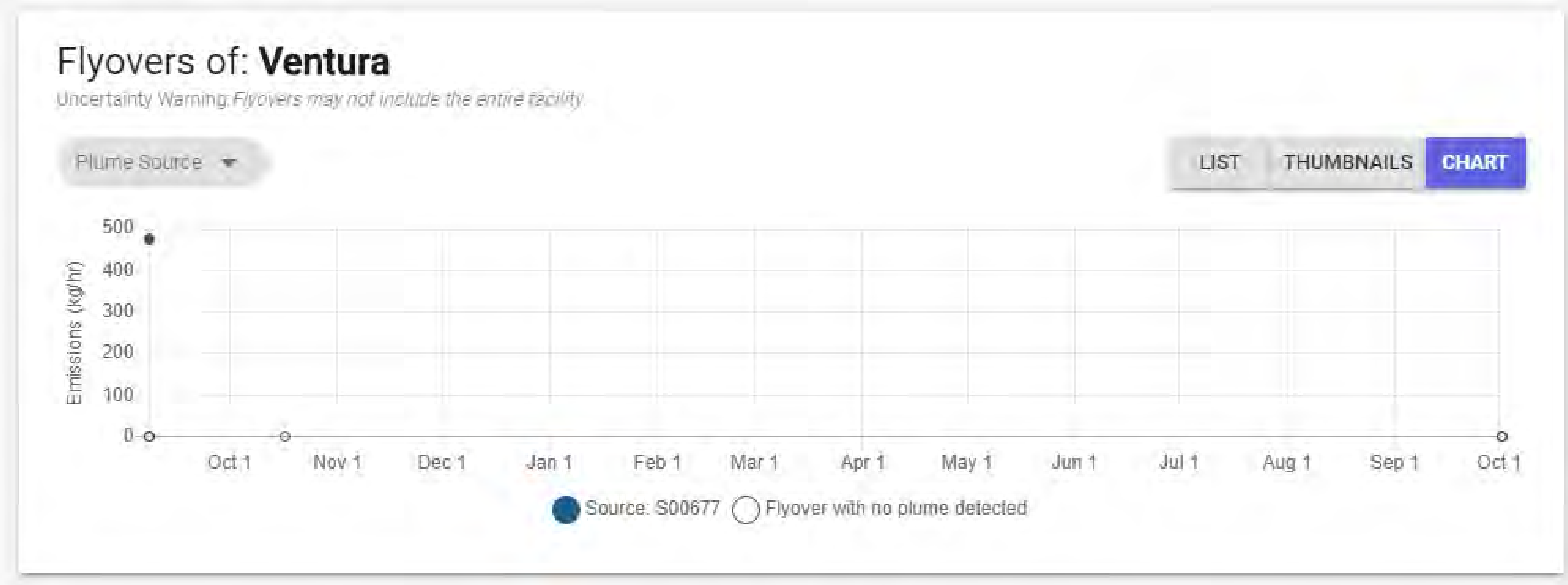
Flyovers of: **Ventura**

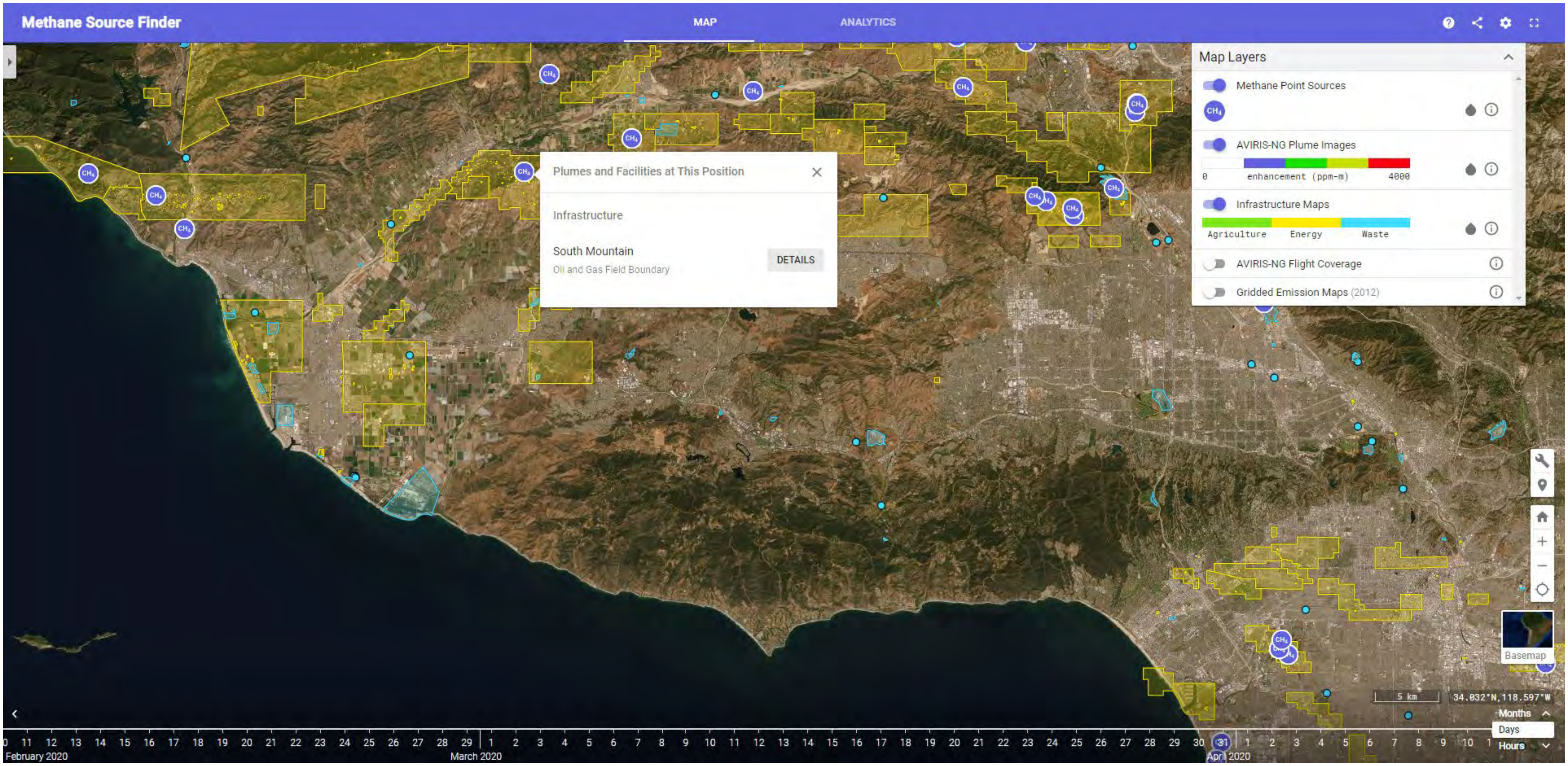
Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source ▾

LIST | THUMBNAILS | CHART




Flyovers of: Ventura
Uncertainty Warning: Flyovers may not include the entire facility
Plume Source
LIST
THUMBNAILS
CHART
Emissions (kg/hr)
500
400
300
200
100
0
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Source: S00677
Flyover with no plume detected


Methane Source Finder
MAP
ANALYTICS
Plumes and Facilities at This Position
Infrastructure
South Mountain
Oil and Gas Field Boundary
DETAILS
Map Layers
Methane Point Sources
AVIRIS-NG Plume Images
0
enhancement (ppm-m)
4000
Infrastructure Maps
Agriculture
Energy
Waste
AVIRIS-NG Flight Coverage
Gridded Emission Maps (2012)
Basemap
5 km
34.032°N,118.597°W
Months
Days
Hours
February 2020
March 2020
April 2020

Methane Source Finder MAP ANALYTICS

BACK TO MAP

South Mountain

1B2 Oil and Natural Gas · undefined, CA

Facility Overview

Site	South Mountain	Facility Type	1B2 Oil and Natural Gas
Operator	(no operator name)	Location	34.33237°N, -119.02436°W
Facility Address	(no address), (no city), CA	Number of Flyovers	1
Vista ID	FLD000428		

VIEW IN GOOGLE MAPS

Vista Facility Metadata

Source	CEC DOGGR	State	CA
VistaDate	7/12/2019	VistaIPCC	1B2 Oil and Natural Gas
VistaName	South Mountain	VistaSType	Oil and Gas Field Boundary
Vista_ID	FLD000428		

Flyovers of: **South Mountain**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source

LIST THUMBNAILS CHART

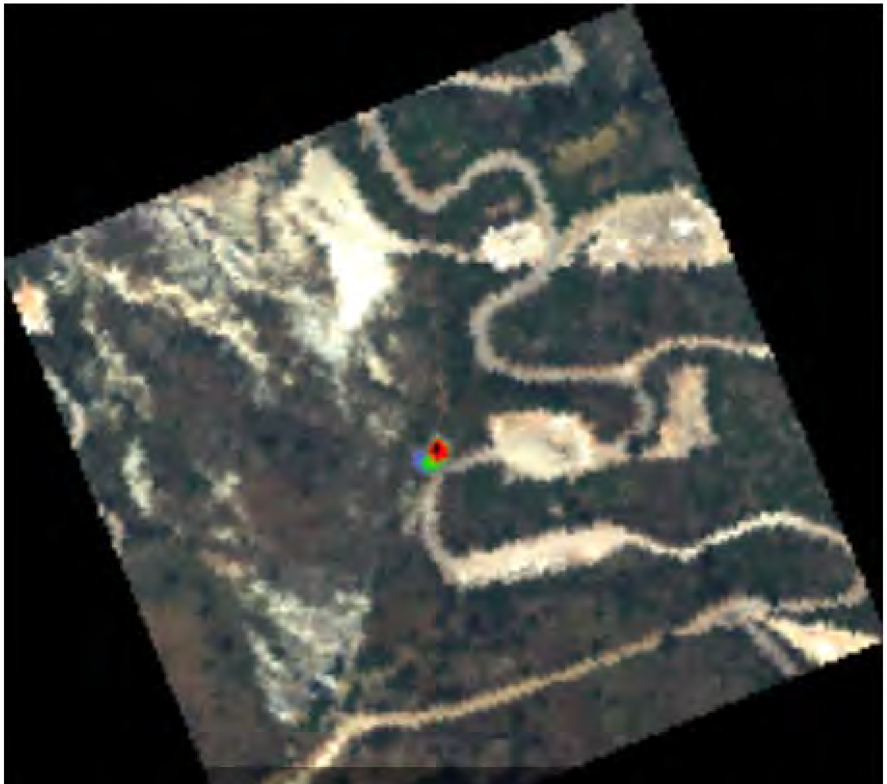
Plume Detected	Source ID	Flyover Date	Candidate ID	Emissions (kg/hr)
Yes	S00923	9/7/2017 20:24	ang20170907t202408-A	404 ± 50

Flyovers of: **South Mountain**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source ▾

LIST | THUMBNAILS | CHART



September 7th, 2017, 20:24

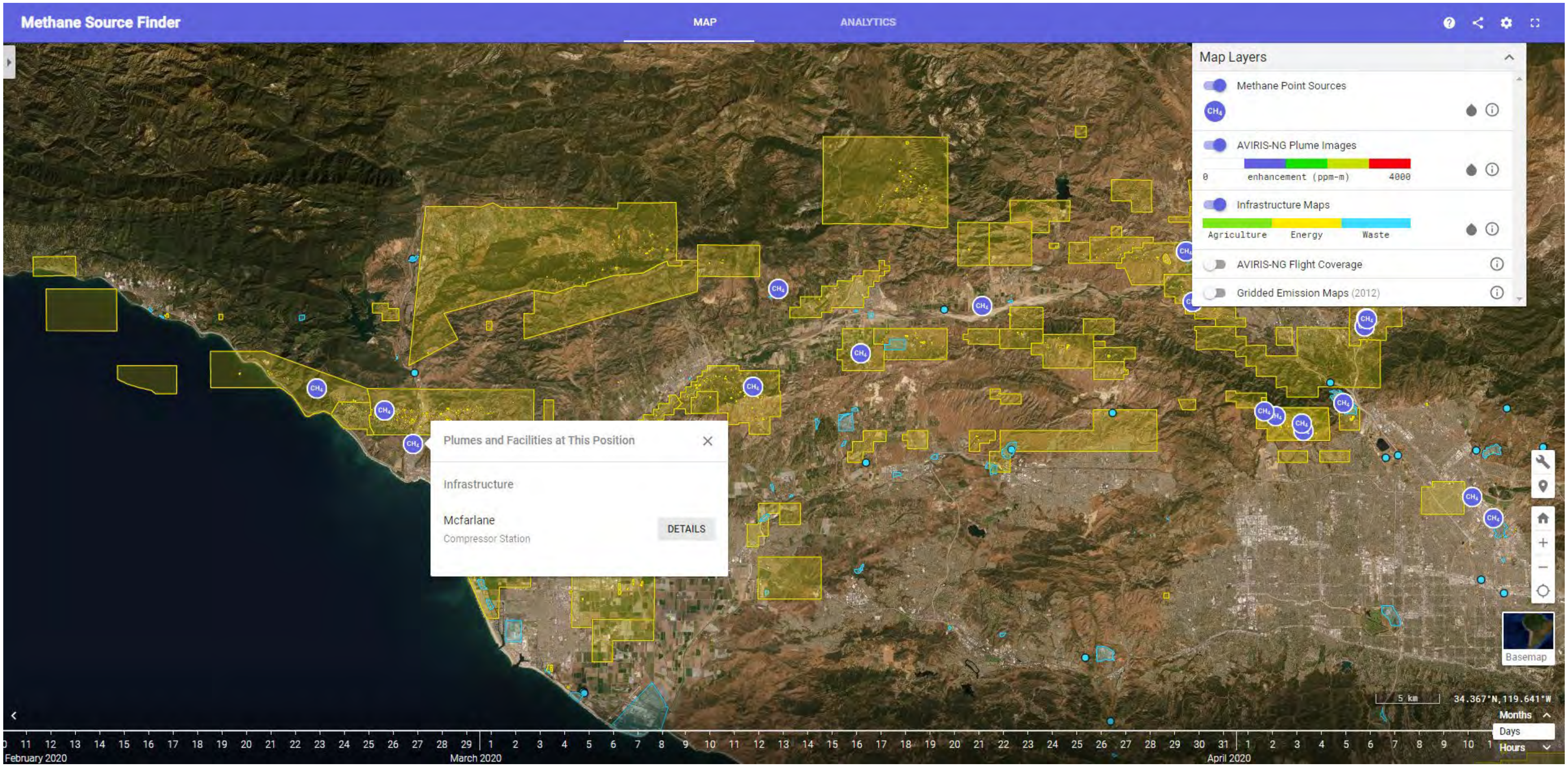
404 ± 50 kg/hr

Flyovers of: **South Mountain**

Uncertainty Warning: *Flyovers may not include the entire facility*

Plume Source

LIST THUMBNAILS CHART



Methane Source Finder
MAP
ANALYTICS
Map Layers
Methane Point Sources
AVIRIS-NG Plume Images
0
enhancement (ppm-m)
4000
Infrastructure Maps
Agriculture
Energy
Waste
AVIRIS-NG Flight Coverage
Gridded Emission Maps (2012)
Plumes and Facilities at This Position
Infrastructure
Mcfarlane
Compressor Station
DETAILS
Basemap
5 km
34.367°N,119.641°W
Months
Days
Hours
February 2020
March 2020
April 2020

Methane Source Finder MAP ANALYTICS

BACK TO MAP

Mcfarlane

1B2 Oil and Natural Gas · Ventura, CA

Facility Overview

Site	Mcfarlane	Facility Type	1B2 Oil and Natural Gas
Operator	SoCal Gas	Location	34.2984062945°N, -119.299887748°W
Facility Address	(no address), Ventura, CA	Number of Flyovers	2
Vista ID	COM000288		

VIEW IN GOOGLE MAPS

Vista Facility Metadata

City	Ventura	Source	CEC
State	CA	VistaDate	2019/07/12
VistaIPCC	1B2 Oil and Natural Gas	VistaName	Mcfarlane
VistaSType	Compressor Station	Vista_ID	COM000288

Flyovers of: **Mcfarlane**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source

LIST THUMBNAILS CHART

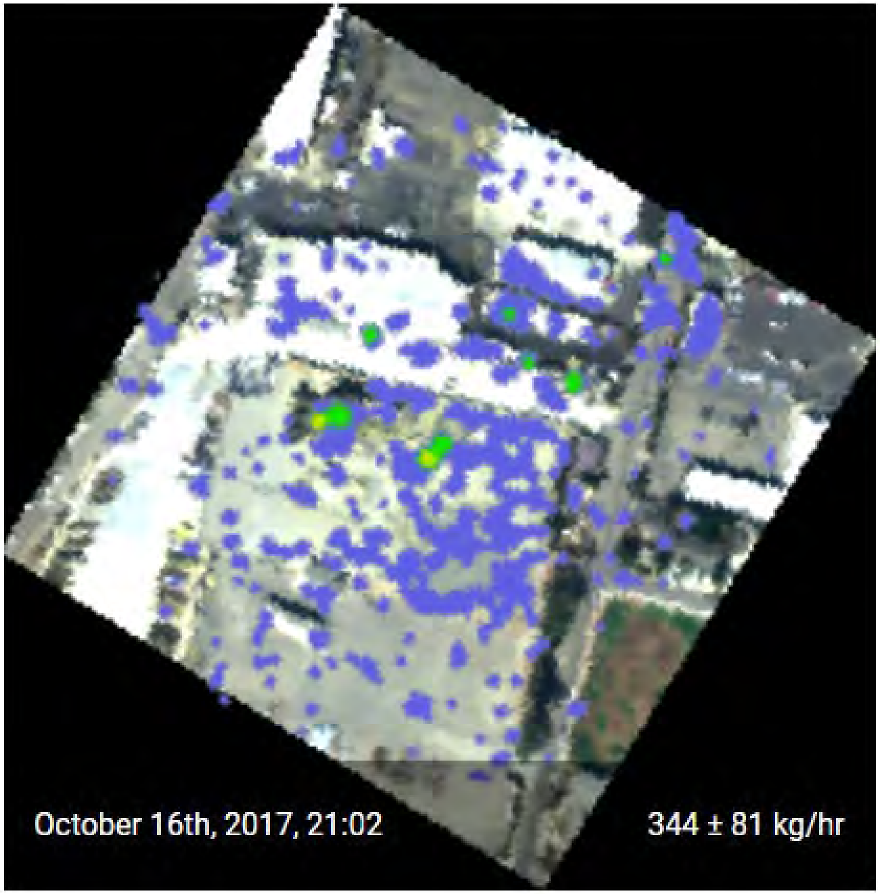
Plume Detected	Source ID	Flyover Date	Candidate ID	Emissions (kg/hr)
No		9/7/2017 21:06	-	-
Yes	S00930	10/16/2017 21:02	ang20171016t210259-A	344 ± 81

Flyovers of: **Mcfarlane**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source

LIST | **THUMBNAILS** | CHART

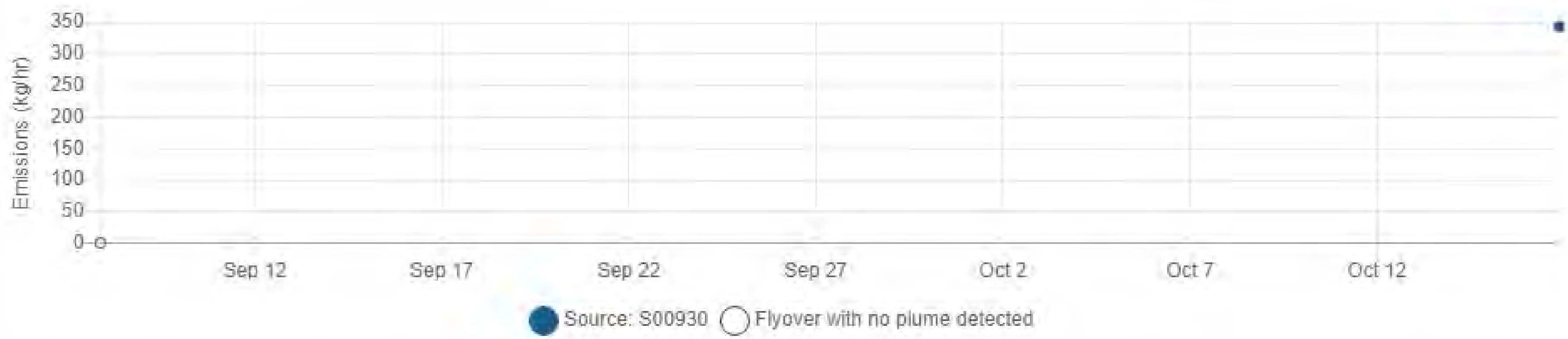


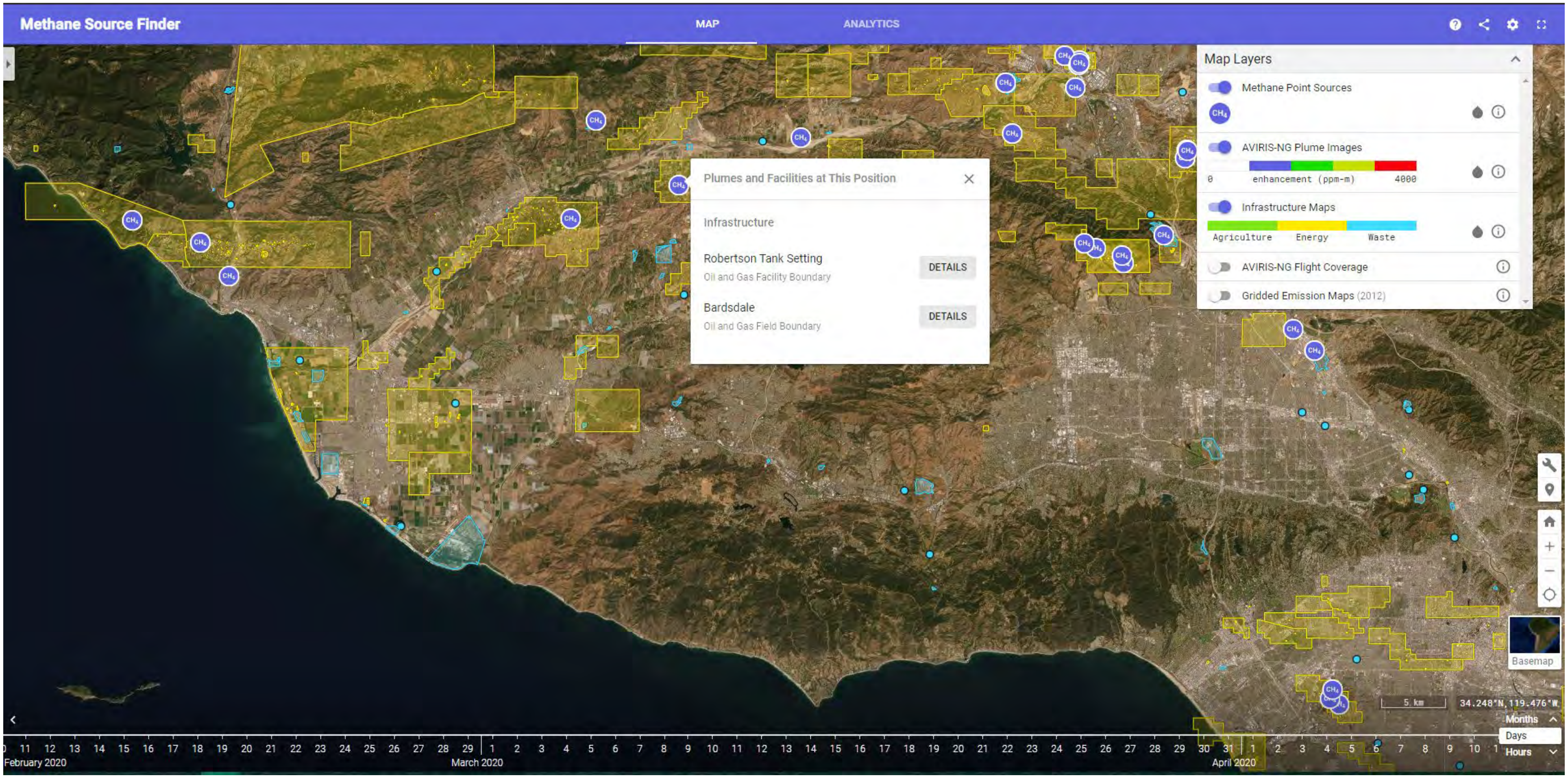
Flyovers of: **Mcfarlane**

Uncertainty Warning *Flyovers may not include the entire facility*

Plume Source

LIST THUMBNAILS CHART





Methane Source Finder
MAP
ANALYTICS
Map Layers
Methane Point Sources
AVIRIS-NG Plume Images
0
enhancement (ppm-m)
4000
Infrastructure Maps
Agriculture
Energy
Waste
AVIRIS-NG Flight Coverage
Gridded Emission Maps (2012)
Plumes and Facilities at This Position
Infrastructure
Robertson Tank Setting
Oil and Gas Facility Boundary
DETAILS
Bardsdale
Oil and Gas Field Boundary
DETAILS
Basemap
5 km
34.248°N, 119.476°W
Months
Days
Hours
February 2020
March 2020
April 2020

Methane Source Finder MAP ANALYTICS

BACK TO MAP

Bardsdale

1B2 Oil and Natural Gas · undefined, CA

Facility Overview

Site	Bardsdale	Facility Type	1B2 Oil and Natural Gas
Operator	(no operator name)	Location	34.3632°N, -118.92241°W
Facility Address	(no address), (no city), CA	Number of Flyovers	4
Vista ID	FLD000020		

VIEW IN GOOGLE MAPS

Vista Facility Metadata

Source	CEC DOGGR	State	CA
VistaDate	7/12/2019	VistaIPCC	1B2 Oil and Natural Gas
VistaName	Bardsdale	VistaSType	Oil and Gas Field Boundary
Vista_ID	FLD000020		

Flyovers of: **Bardsdale**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source ▾

LIST | THUMBNAILS | CHART

Plume Detected	Source ID	Flyover Date	Candidate ID	Emissions (kg/hr)
No		9/30/2016 21:12	-	-
No		9/30/2016 21:30	-	-
No		9/30/2016 22:39	-	-
Yes	S00924	9/7/2017 20:24	ang20170907t202408-B	115 ± 17

Flyovers of: **Bardsdale**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source ▾

LIST THUMBNAILS CHART

Flyovers of: **Bardsdale**

Uncertainty Warning: *Flyovers may not include the entire facility.*

Plume Source

LIST THUMBNAILS CHART

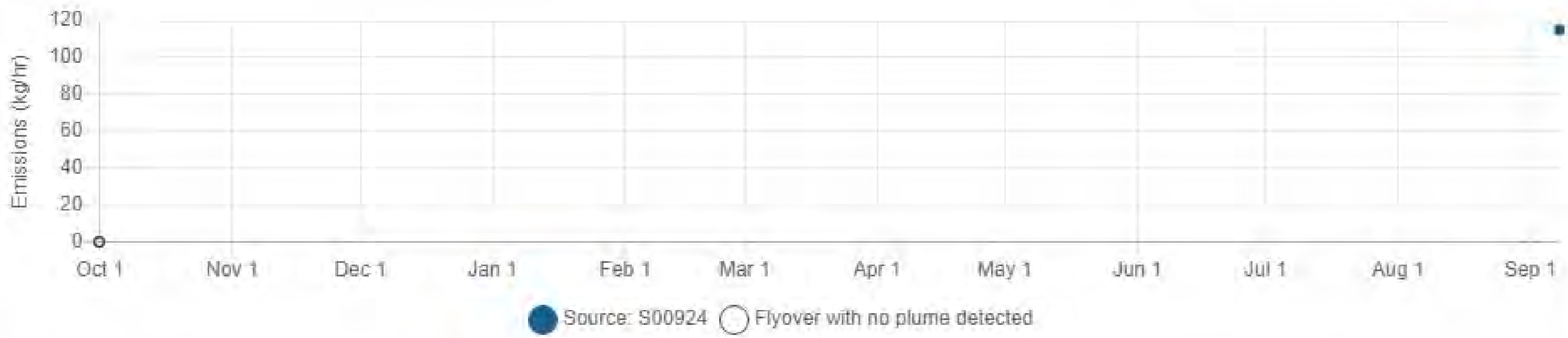


EXHIBIT 11

carbon

Carbon Energy Corporation

Corporate Overview

2019

IMPORTANT DISCLOSURES

Forward-Looking Statements

The slides contain certain forward-looking statements within the meaning of Section 27A of the Securities Act of 1933, as amended (the "Securities Act"), and Section 21E of the Securities Exchange Act of 1934, as amended (the "Exchange Act"). Except for historical information, statements made in the slide presentation, including those relating to the Company's strategies, estimated and anticipated production, expenditures, infrastructure, estimated costs, number of wells to be drilled, estimated reserves, reserve potential, recoverable reserves, and financial position are forward-looking statements as defined by the Securities and Exchange Commission. These statements are based on assumptions and estimates that management believes are reasonable based on currently available information; however, management's assumptions and the Company's future performance are subject to a wide range of business risks and uncertainties and there is no assurance that these goals and projections can or will be met. Any number of factors could cause actual results to differ materially from those in the forward-looking statements, including, but not limited to, the volatility of oil and gas prices, the costs and results of drilling and operations, the timing of production, mechanical and other inherent risks associated with oil and gas production, weather, the availability of drilling equipment, changes in interest rates, litigation, uncertainties about reserve estimates, and environmental risk. We caution you not place undue reliance on these forward-looking statements, which speak only as of the date reflected in the slide presentation, and we undertake no obligation to publicly update or revise any forward-looking statements. Further information on risks and uncertainties is available in the Company's filings with the Securities and Exchange Commission, which are incorporated by reference.

Actual quantities of oil and gas that may be ultimately recovered from Carbon's interests will differ substantially from our estimates. Factors affecting ultimate recovery include the scope of Carbon's drilling program, which will be directly affected by the availability of capital, drilling and production costs, commodity prices, availability of drilling services and equipment, drilling results, lease expirations, transportation constraints, regulatory approvals, field spacing rules, recovery of gas in place, length of horizontal laterals, actual drilling results, and geological and mechanical factors affecting recovery rates and other factors. Estimates of reserves potential may change significantly as development of our reserves plays provides additional data. Investors are urged to consider closely the disclosure in our filings with the SEC available upon request to: Corporate Secretary, Carbon Energy Corporation, 1700 Broadway, Suite 1170, Denver, Colorado 80290; tel: (720) 407-7030. You can also obtain our public filings from the SEC's website, http://www.sec.gov.

Non-GAAP Measures

The slide presentation contains certain references to EBITDA and Adjusted EBITDA value, which are non-GAAP financial measures, as defined under Regulation G of the rules and regulations of the SEC.

EBITDA and Adjusted EBITDA

"EBITDA" and "Adjusted EBITDA" are non-GAAP financial measures. We define EBITDA as net income or loss before interest expense, taxes, depreciation, depletion and amortization. We define Adjusted EBITDA as EBITDA prior to accretion of asset retirement obligations, ceiling test write downs of oil and gas properties, non-cash stock-based compensation expense and the gain or loss on sold investments or properties. EBITDA and Adjusted EBITDA is consolidated including non-controlling interests and as used and defined by us, may not be comparable to similarly titled measures employed by other companies and are not measures of performance calculated in accordance with GAAP. EBITDA and Adjusted EBITDA should not be considered in isolation or as a substitute for operating income, net income or loss, cash flows provided by or used in operating, investing and financing activities, or other income or cash flow statement data prepared in accordance with GAAP. EBITDA and Adjusted EBITDA provide no information regarding a company's capital structure, borrowings, interest costs, capital expenditures, and working capital movement or tax position. EBITDA and Adjusted EBITDA do not represent funds available for discretionary use because those funds are required for debt service, capital expenditures, working capital, income taxes, franchise taxes, exploration and development expenses, and other commitments and obligations. However, our management believes EBITDA and Adjusted EBITDA are useful to an investor in evaluating our operating performance because these measures are widely used by investors in the oil and natural gas industry to measure a company's operating performance without regard to items excluded from the calculation of such term, which can vary substantially from company to company depending upon accounting methods and book value of assets, capital structure and the method by which assets were acquired, among other factors; and help investors to more meaningfully evaluate and compare the results of our operations from period to period by removing the effect of our capital structure from our operating structure; and are used by our management for various purposes, including as a measure of operating performance, in presentations to our board of directors, as a basis for strategic planning and forecasting and by our lenders pursuant to a covenant under our credit facility.

There are significant limitations to using EBITDA and Adjusted EBITDA as a measure of performance, including the inability to analyze the effect of certain recurring and non-recurring items that materially affect our net income or loss, the lack of comparability of results of operations of different companies and the different methods of calculating EBITDA and Adjusted EBITDA reported by different companies.

carbon

Carbon Strategy

- Emphasize Health, Safety and Environmental best practices and compliance
- Acquire and develop oil and gas producing assets
  - Appalachian Basin
  - Ventura Basin
- Build value from acquired assets through
  - Lease operating expense reductions
  - Gathering and compression optimization
  - Return to production projects
  - Recompletions
  - Operational synergies
- Utilize science and technology to develop assets with highest rate of return on capital invested
- Develop assets through drilling as commodity prices warrant
- Maintain favorable debt metrics and financial flexibility
- Management team has long-term successful track record of creating value for its shareholders and partners
- Strong technical team with acquisition, production and drilling expertise

Carbon Growth Strategy
Acquire and Develop

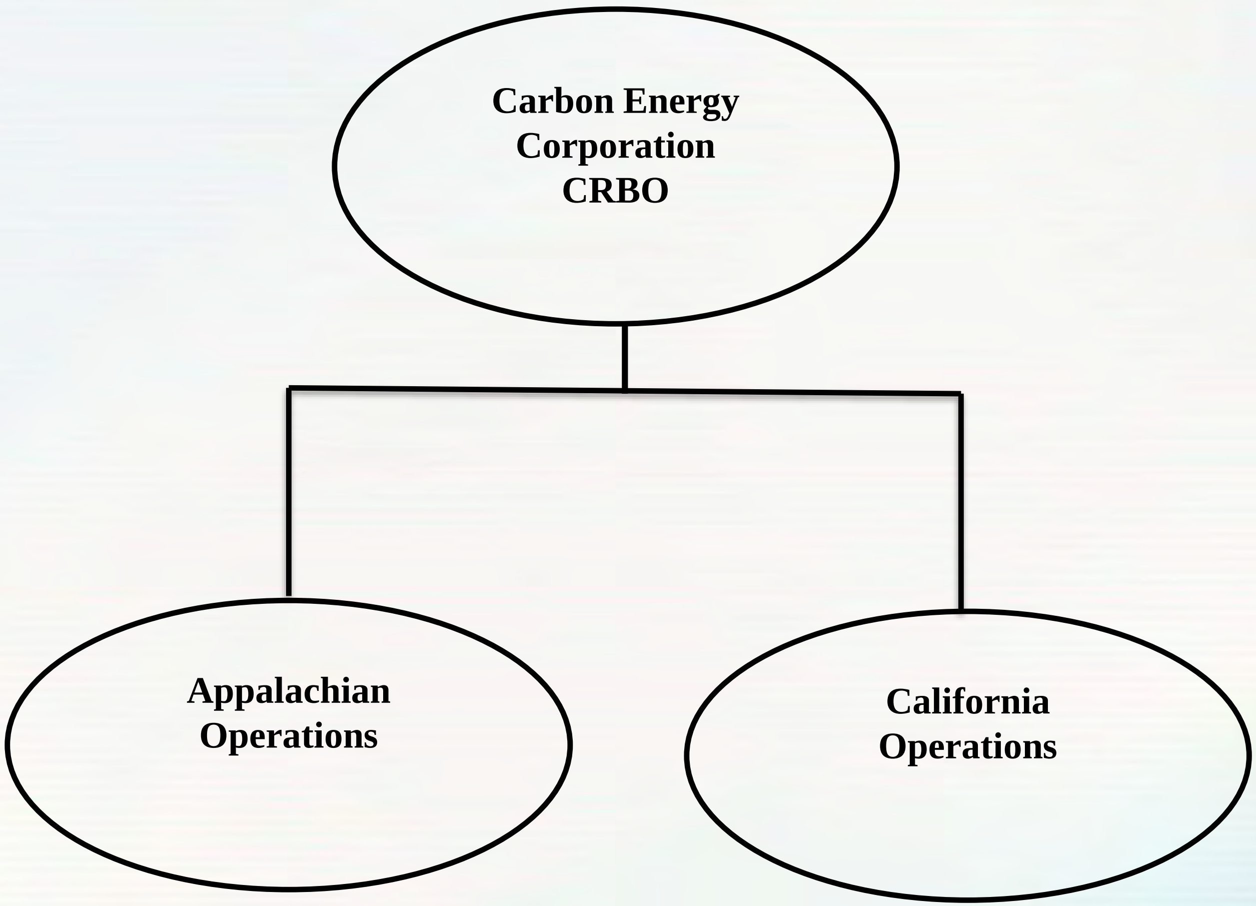
Appalachian Basin

- **Legacy producers are divesting southern Appalachia production and midstream assets.**
- **This creates opportunity to acquire and develop producing and midstream assets and consolidate a southern Appalachian position.**
- **Extensive field development opportunities exist within the company's existing properties.**

Ventura Basin, California

- **Legacy producers are divesting Ventura Basin production and midstream assets.**
- **This creates an opportunity to acquire and develop a portfolio of light oil, low operating cost producing properties.**
- **Extensive field development opportunities exist within the company's existing properties.**

carbon

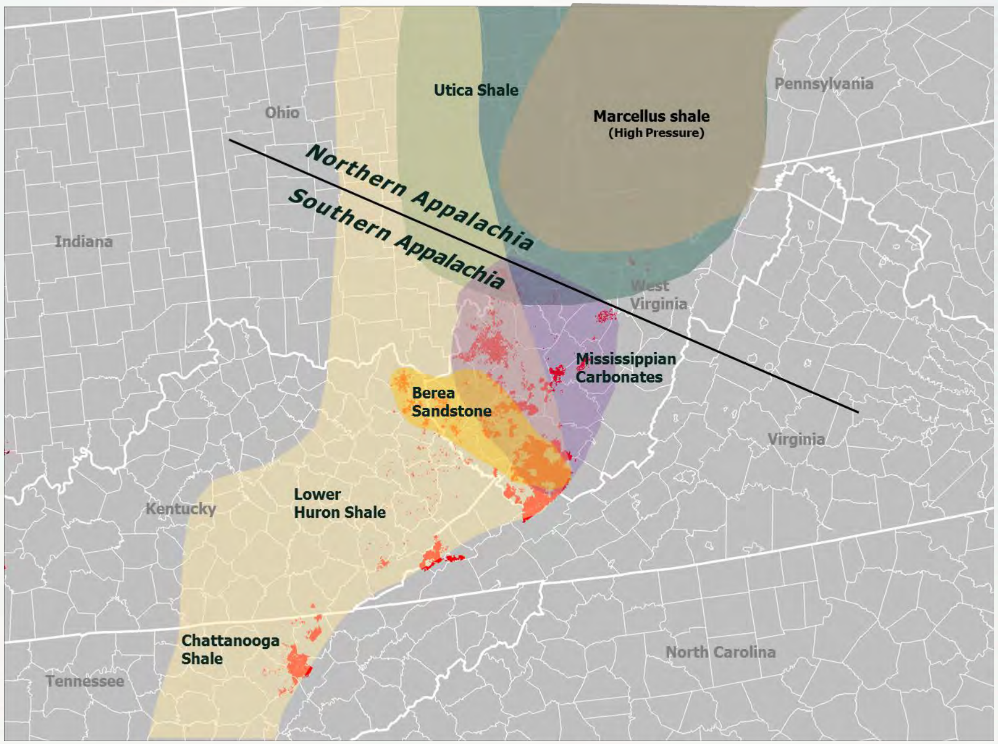

Carbon Energy Corporation CRBO
Appalachian Operations
California Operations

Southern Appalachian Basin Investment Strategy

Northern and Southern Appalachia are both historical producing regions.

Both have same geologic history and similar producing formations.

- ***Marcellus and Utica Shales in North***
  - ✓ **Very high land, drilling and completion costs**
  - ✓ **Low gas price netback**
  - ✓ **Highly competitive**
- ***Huron/Chattanooga Shale in the South***
  - ✓ **Reasonable costs**
  - ✓ **Attractive gas price netback**
  - ✓ **Lack of competition**



Exploration and production companies are divesting legacy production in Southern Appalachia to focus on the Marcellus and Utica Shales in the north.

This creates opportunity for Carbon to acquire and develop producing assets in the south, build on existing operations, and to consolidate Southern Appalachian position.

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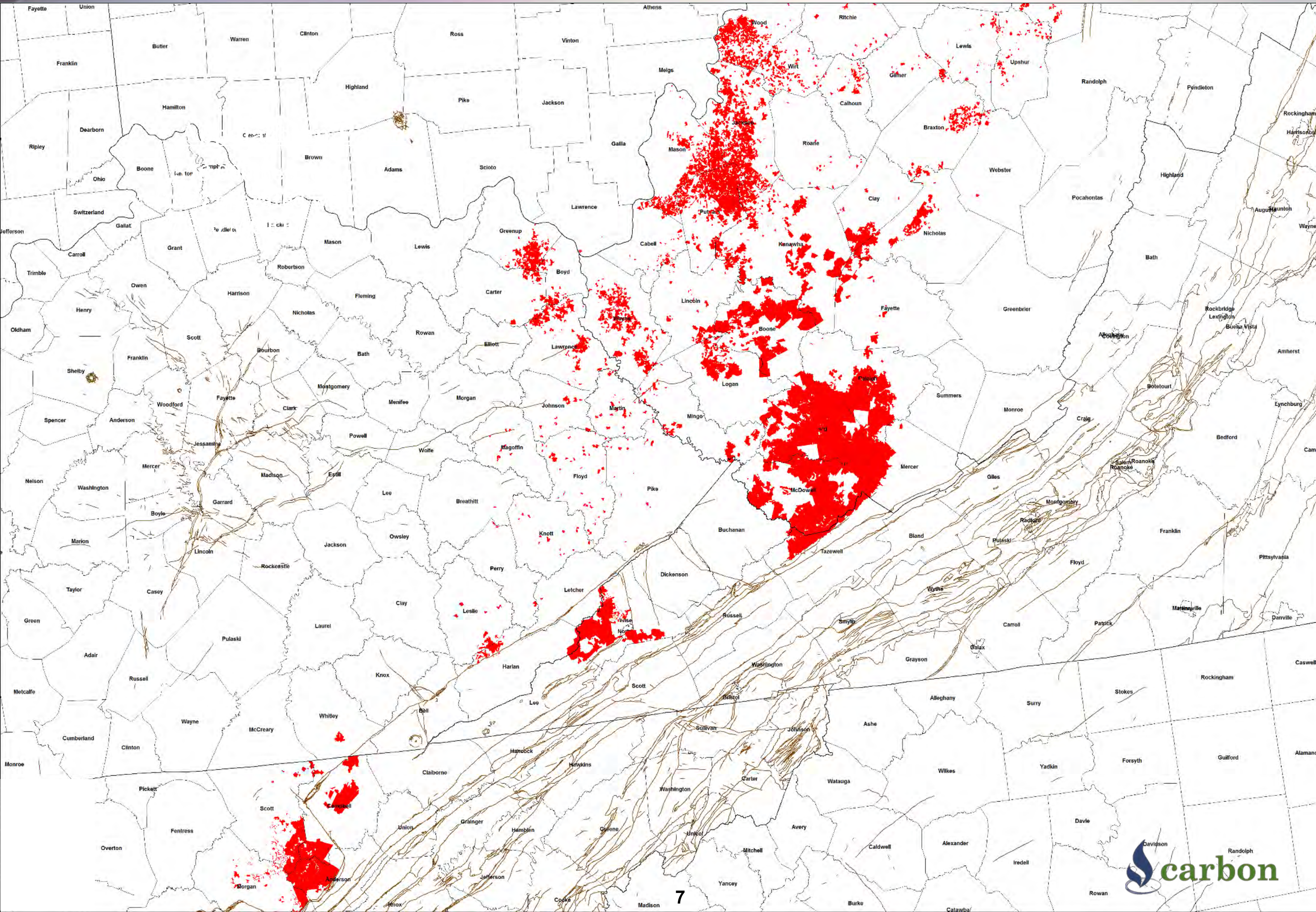
Carbon Appalachian Basin Assets



Carbon Appalachian Basin Operations

- Approximately 60,000 mcfe net daily production, 90% operated
- Proved reserves of 442 bcfe
- Interest in approximately 8,200 wells
- Ownership of 4,700 miles of midstream gathering pipelines and associated compression facilities
- Multiple direct connect end use customers and transportation pipeline interconnects
- Operation of natural gas storage facilities enhances midstream operations
- Approximately 1,650,000 net acres of oil, gas and/or coalbed methane rights
  - 73% Held by Production
  - 80% of remainder expires later than 5 years
- Extensive Inventory of Field Development Projects
  - Berea Sandstone Oil
  - Lower Huron Shale
  - Chattanooga Shale
- Low lease operating expenses
- High BTU natural gas in close proximity to market, average netback price Nymex $(0.25)/mmbtu

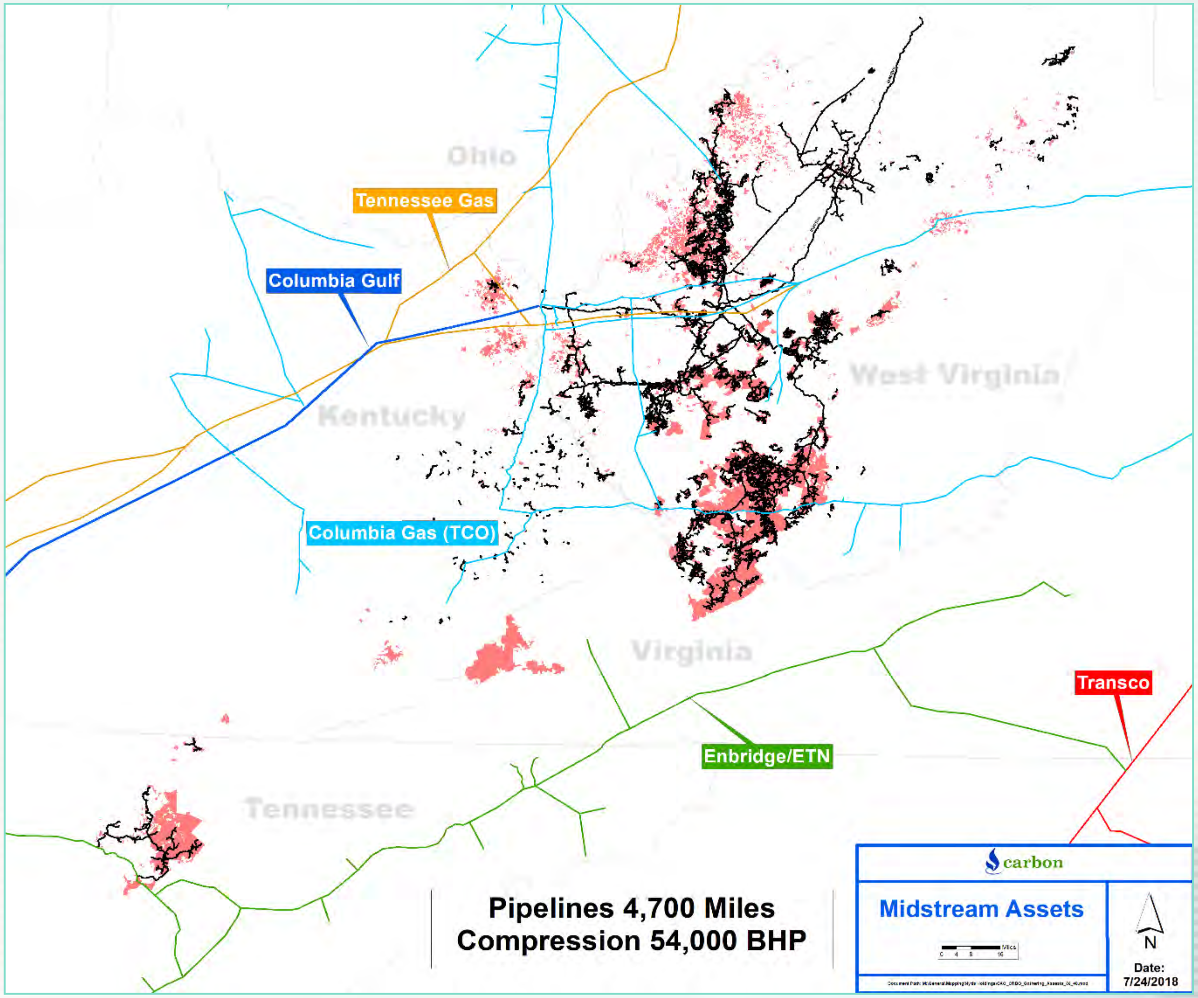
carbon

Southern Appalachia | *Midstream Business Segment*

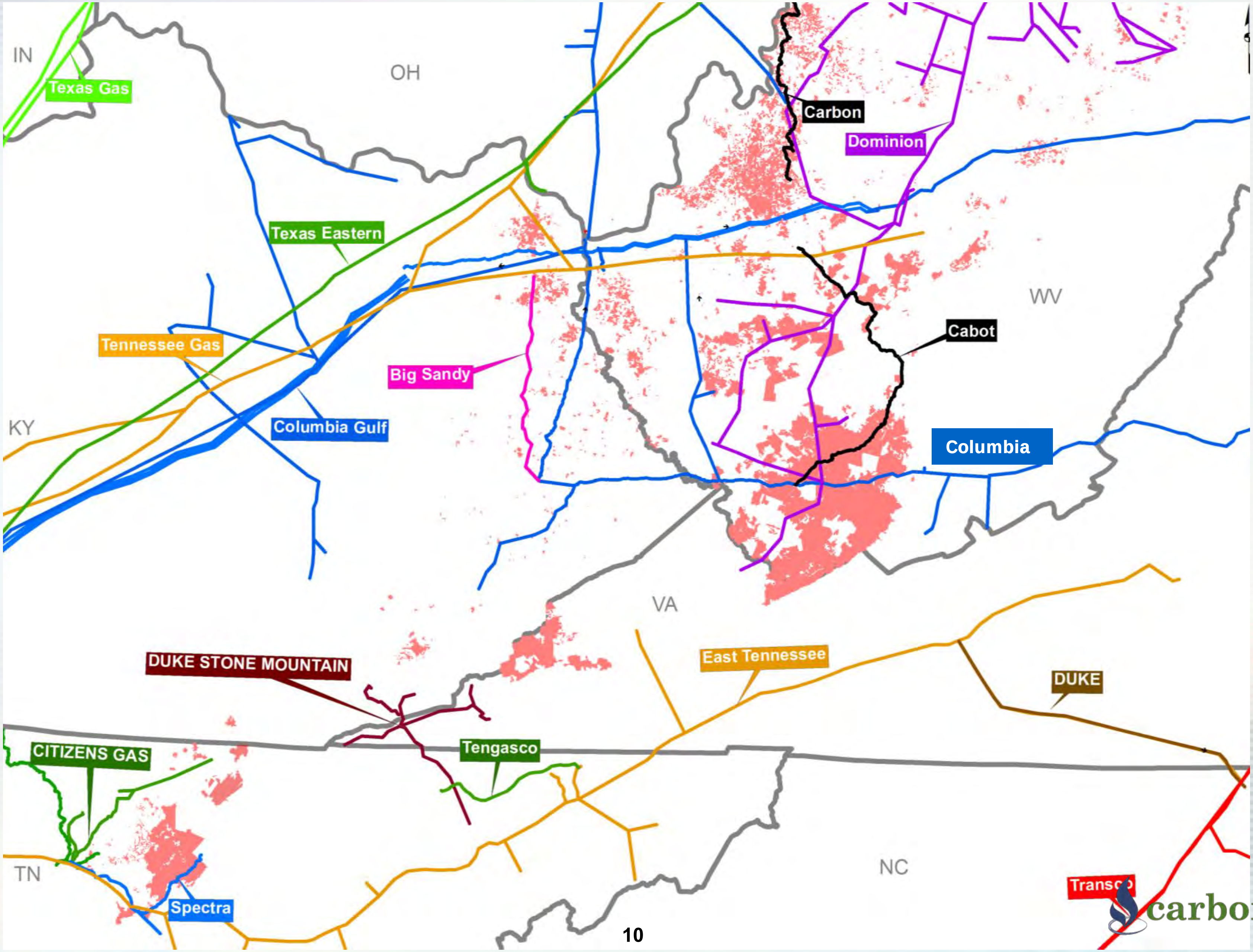
Overview

- System transports over 90 MMcf/d
- Direct on system industrial end use customers
- Carbon owned gas storage facilities provide direct end user sales flexibility and gas marketing opportunities
- Extensive gathering and compression system basin wide
  - Gas Gathering: 4,700 miles of pipe
  - Compression: 54,000 BHP
- Access to 3rd party pipelines (TCO, ETN, DTI) provide gas marketing and index arbitrage opportunities
- Firm transport agreements on main line transportation pipelines

Asset Locator Map



Transportation Pipeline Access



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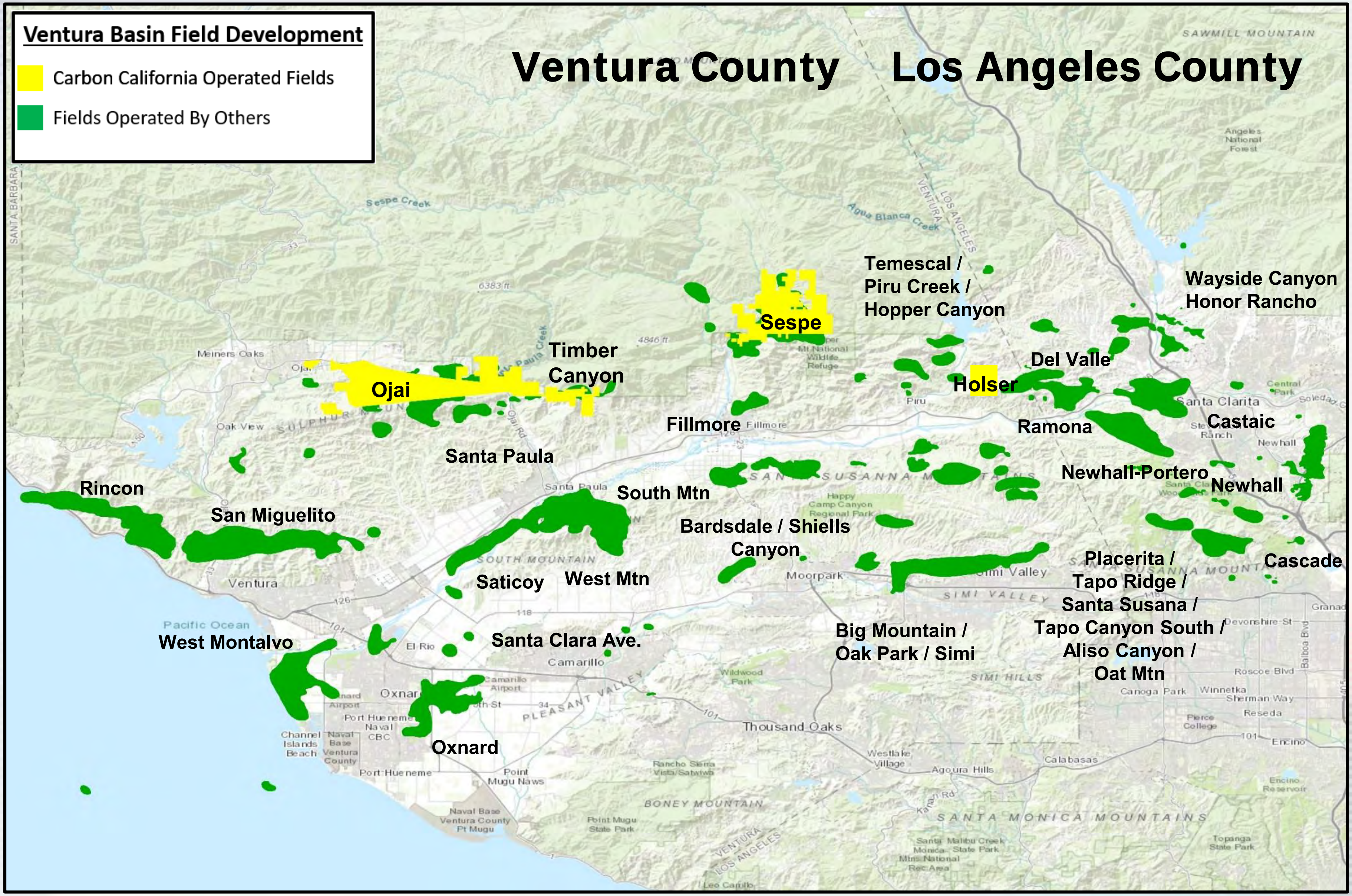
California Oil and Gas Basins

Ventura Basin



Ventura Basin Investment Strategy

- Carbon has identified the Ventura Basin of California as an area which presents an excellent opportunity to acquire and develop a portfolio of light oil, low operating cost producing properties
- Carbon has acquired Ojai Field, Timber Canyon Field, Holser Field and Sespe Field assets, and is currently implementing production optimization programs and field development
- Carbon will grow the asset base through low-risk exploitation and development of the properties

- **California Acquisition Criteria**

- Shallow decline, long life reserves
- Low capital maintenance requirements
- Multipay "conventional" producing formations
- No thermal / steam flood operations
- Light crude oil
- Low water cut
- Shallow depth (2,000′ to 6,500′)
- Permitted water management systems
- Favorable land and regulatory environment

Carbon Ventura Basin California

- 1,400 barrels of oil and liquids per day and 1,860 mcf of gas per day net production, 100% operated
- Proved reserves of 23.1 million barrels of oil equivalent (84% oil and NGL)
- Interest in approximately 570 wells
- Approximately 17,000 net acres of oil, gas rights
  - 100% Held by Production
  - 7,700 mineral fee acres
- Multiple producing horizons
- Low lease operating expenses
- Brent oil price
- Inventory of Return to Production, Behind Pipe Recompletion and Proved Undeveloped drilling projects
- Operating cost improvements through facility consolidation

carbon


carbon
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EXHIBIT 12

BEFORE THE HEARING BOARD
OF THE
VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
STATE OF CALIFORNIA

In the matter of the application of: Carbon California Operating Company 270 Quail Ct, Suite B Santa Paula, CA 93060 For a variance from: Rule 29.C, Conditions on Permits – Violation of Condition 3 APCD Permit to Operate No. 00939	Hearing Board Case No. 878 ORDER GRANTING INTERIM VARIANCE Granted: August 26, 2019 Effective to: November 22, 2019

On August 12, 2019, PETITIONER CARBON CALIFORNIA OPERATING COMPANY (Carbon), filed with this Hearing Board petitions for Interim and Regular Variances pursuant to California Health and Safety Code Section 42350(a). The petitioner requested that the Hearing Board grant an interim variance from District Rule 29.C, Conditions on Permits – Violation of Permit to Operate (PO) No. 00939, Condition 3.

Petitioner is requesting authorization to continue operating the permitted 18.0 million British Thermal Units per hour (MMBTU/hr) Waste Gas Flare with excess emissions. A regular variance hearing will be held on or before November 22, 2019. Notice of the application and hearing is not required for interim variances.

On August 26, 2019, a hearing on the petition for variance was held. The Ventura County Air Pollution Control District (District) was represented by Mr. Keith Macias, Compliance Manager, and Ms. Michelle Wood, Supervising Air Quality Specialist. The Petitioner was represented by Mr. Scott Price, President, Carbon, Mr. Luke Faith, Area Manager, Carbon, Ms. Jane Farkas, Director of Land & Regulatory Affairs, Carbon, and Mr. Rob Alfaro, Vice President, Sespe Consulting. All persons, including the public, were given the opportunity to give testimony or make comment.

The Hearing Board heard testimony on the "good cause" issue set forth in Section 42351(b) of the California Health and Safety Code. Section 42351(b) states in part: "An interim variance may be granted for good causes stated in the order granting such a variance."

The Hearing Board declared the hearing closed after receiving testimony and took the matter under submission for decision. The Hearing Board made the following findings of fact.

EQUIPMENT AND LOCATION

1. Petitioner is in the business of producing and separating crude oil and natural gas. Carbon's Clark and West Leases, Timber Canyon is located in a remote area north of the City of Santa Paula, Ventura County, California.

2. The subject equipment consists of a 18.0 MMBTU/hr Waste Gas Flare, authorized by District Permit to Operate number 00939.

BACKGROUND

Natural gas is a byproduct of crude oil production. Gas may be collected from oil wells and storage tanks, compressed and sent to sales via a pipeline. When it is not possible to sell the natural gas, due to sales pipeline problems or electrical failure, the produced gas must be flared, or the entire facility must be shut down.

The emission source authorized by District PO number 00939 is one 18.0 MMBTU/hr Waste Gas Flare. The flare is used to manage produced gas attendant to oil-gas production operations. As opposed to "stacking" gas, which can impact the environment and present a safety hazard and is prohibited by District Rules. The flare provides an effective way to temporarily manage gas from operations attendant to oil-gas production, maintenance activities, and ancillary operating and processing when it cannot be sent via pipeline.

Carbon and California Resources Petroleum Corporation (CRC) are parties to a Gas Treating and Purchase Agreement dated September 19, 2002, where Carbon sends the natural gas produced to CRC for processing and sales to the Southern California Gas Company (SoCal Gas).

On June 26, 2019, CRC notified Carbon that, due to a SoCal Gas project that includes the relocation and repair to the main pipeline that CRC delivers gas to, SoCal Gas has significantly reduced the amount of gas that CRC can deliver into the existing pipeline. Due to this "force majeure" event, CRC indicated that it temporarily would not accept gas from Carbon into the CRC pipeline system as of June 27, 2019. This limitation on Carbon's gas deliveries will continue until SoCal Gas has completed the relocation and repairs of the main pipeline or until CRC develops an alternative pipeline option. There are no current alternative sales gas lines available to Carbon. The event was unexpected and completely out of Carbon's control.

On June 27, 2019, CRC shut-in Carbon and stopped receiving natural gas from Carbon's pipelines. Since June 27, 2019, Carbon has flared its gas consistent with Carbon's allowed fuel consumption limit for the flare under District PO number 00939.

On July 2, 2019, Carbon informed the District that they believed the unexpected SoCal Gas event will eventually cause an exceedance of the permitted fuel consumption limit for the flare.

On August 12, 2019, Carbon filed an interim variance petition with the Clerk of the Board, as well as a regular variance petition. Carbon is seeking a variance because CRC's gas processing system, which is the only market for produced gas from Carbon's existing fields, is currently constrained. Carbon currently has no other feasible option than to flare the gas until the pipelines to CRC are available for processing. Carbon currently has no other alternative means to dispose of the produced gas. Additionally, there are no mitigation measures available.

Carbon intends to come into compliance by feeding natural gas back into the line to CRC as soon as CRC allows the produced gas back in. Carbon has also been in communication with CRC regarding the potential for tying into an alternative SoCal Gas sales line. CRC is currently in the process of permitting additional equipment with the District and Ventura County Planning that will enable Carbon to feed natural gas into the line to CRC in the near term and before the completion of the SoCal Gas project. CRC is working with the County of Ventura to ensure that this alternative be permitted as soon as possible. CRC notified Carbon that this alternative gas line may be available for Carbon to access as soon as October. In addition, CRC recently completed a project involving a high-pressure line that has facilitated Carbon's natural gas transmission into that line from the temporarily shut-in Sespe Field Leases and the flaring at that site associated with this unexpected event has already ceased.

RULE REQUIREMENTS AND VIOLATIONS

The operations at the facility are subject to California statutes and District Rules and Regulations. The following District Rule is applicable to this Interim Variance.

District Rule 29.C, Conditions on Permits - Violation of Permit Conditions, requires permit holders to comply with the conditions on their permits. Carbon's PO No. 00939, Condition 3 states in part:

> *"Gas consumption for the emergency flare shall not exceed 11.8 million cubic feet (MMCF) of gas per year for any planned flaring events. There is no limit for emergency use. Emergency use is defined as disposal of process gasses in the event of unavoidable process upsets.... If a process upset (emergency use) cannot be rectified in a reasonable amount of time, the use of the flare may be determined to be a planned flaring event."*

If Carbon continues to operate the oil production equipment at the Clark and West Leases, Timber Canyon, natural gas will be produced and must be controlled through flaring. Continued operation of the Clark and West Leases will exceed PO Number 00939, Condition 3 flaring limit and Carbon will be in violation of District Rule 29.C until the pipelines to CRC are available for processing.

GOOD CAUSE

The SoCal Gas line shut down and "force majeure" event was unexpected and completely out of Carbon's control. Carbon has no control of the pipeline and both CRC and SoCal Gas' schedule is beyond Carbon's control. Carbon must wait for the pipeline to go back into service before Carbon can resume sale to CRC through the pipelines. Carbon currently has no other alternative means to dispose of the produced gas.

An interim variance is required for Carbon to maintain its existing operations, which include other wells in the Ojai Field Leases that are also affected by the SoCal Gas project, and to ensure that Carbon meets its financial obligations, including lease payments and remaining in business. If Carbon is not granted an interim variance, it will have to shut-in all the well casings to prevent further flaring of the produced gas until such time that permit authorizations allow further flaring (i.e., when higher months of flared gas drop off from the rolling 12-months), which will cause approximately $100,000 in daily economic loss for Carbon for all of the affected fields as well as lost time for operations staff and contractors.

The Timber Canyon field produces approximately $300,000 in revenue each month. This is approximately 12-percent of Carbon's total revenue for California productions. Combined with the shut-in of the Ojai Field Leases (that are also under force majeure) shutting in the wells would be detrimental to Carbon's business. If this variance (along with the Ojai variance petition) is not granted, 90-percent of Carbon's active wells would be shut in, which would put Carbon out of business because it would not be able to fulfill its financial obligations.

Furthermore, there are currently 11 Carbon field employees who work in the Ojai/Timber Canyon fields that would be laid-off if Carbon's pending interim variance petitions are not granted. Carbon operations also include approximately 15 support companies that provide services to the Ojai/Timber Canyon field operations.

The overall cost of continued shut-in would result in $3 million per month loss for Carbon. This would be detrimental to its business, force employee layoffs and risk potential closure. Requiring immediate compliance would result in an unreasonable taking of property or the practical closing of a lawful business. Requiring immediate compliance would result in an unreasonable taking of property or the practical closing of a lawful business.

Carbon has given consideration to curtailing operations in lieu of obtaining a variance but for the following reasons it has been unable to do so: (1) the only option to flaring in this case is to shut-in the producing wells, (2) shutting in the producing wells, even temporarily, can result in a buildup of corrosion, scale, and, when the well is brought back online, there is a high risk of sand entering the well bore, which can cause mechanical problems with the pump, (3) the cost to correct each aforementioned issue can range from $20,000 - $40,000 per well and (4) there would also be additional exhaust emissions attendant to the servicing equipment that would be necessary to address.

Flaring is the only feasible solution that will reduce excess emissions to the maximum extent feasible during the variance period pursuant to District Rule 71.1.C, Crude Oil Production and Separation, Requirements - Produced Gas, which requires that emissions of produced gas shall be controlled at all times using a properly maintained and operated system that directs all produced gas, except gas used in a tank battery vapor recovery system, to one of the following: a fuel or sales gas system, a flare that combusts reactive organic compounds, or a device with an ROC destruction or removal efficiency of at least 90 percent by weight.

Carbon will continue monitoring of the flared gas via a Total Flow meter and quantify the emissions via emission factors for a flare. Carbon will submit flaring data to the District with weekly reports.

The flare at issue in this variance petition is located in a remote area north of the City of Santa Paula in Ventura County. The southern boundary of the oilfield is approximately 3 miles from the city. The closest residence to the flare has been reported to be 1.2 miles away and the closest school 2.85 miles away. A nuisance as specified in Rule 51 is not expected to occur during this flaring event. Continued operation is not likely to create an immediate threat or hazard to public health or safety.

FINDINGS OF FACT

The Hearing Board found that there was good cause to grant an interim variance because pursuant to Health and Safety Code Section 42352, and District Rule 123, "Findings, Variance or Abatement Order," the following findings have been made:

1. The petitioner is, or will be, in violation of Health and Safety Code Section 41701 or District Rule 29.C.

2. The violation is due to conditions beyond the reasonable control of the petitioner.

3. Requiring immediate compliance would result in either an arbitrary or unreasonable taking of property or the practical closing of a lawful business.

4. The closing or taking would be without a corresponding benefit in reducing air contaminants.

5. Petitioner has given consideration to curtailing operations in lieu of obtaining a variance.

6. Petitioner will reduce excess emissions to the maximum extent feasible during the variance period.

7. Petitioner will monitor or otherwise quantify emission levels from the equipment during the variance period, if requested to do so by the District, and report theses emission levels to the District pursuant to a schedule established by the District.

8. A nuisance as specified in Rule 51 is not expected to occur.

9. Continued operation is not likely to create an immediate threat or hazard to public health or safety.

   Further evidence shall be provided by the petitioner regarding items 2 through 9 at the noticed hearing that will be scheduled on or before November 22, 2019.

CONCLUSIONS AND ORDER

NOW, THEREFORE, the HEARING BOARD FINDS AND CONCLUDES THAT GOOD CAUSE HAS BEEN SHOWN AND ORDERS that Carbon is granted an Interim Variance from Rule 29, Conditions on Permits, Section C, Violation of Permit Condition 3 for its Clark and West Leases 18.0 MMBTU/hr Waste Gas Flare. This order will remain in effect until the Hearing Board holds a regular variance hearing and either grants or denies the matter in Petition Number 879, or until compliance is demonstrated, whichever is sooner. A regular variance hearing will be scheduled on or before November 22, 2019. This variance is subject to the following conditions:

THE PETITIONER SHALL:

A. Increments of Progress

1. Carbon will continue monitoring of the flared gas via a Total Flow meter and quantify the emissions via emission factors for a flare. Carbon will submit flaring data to the District with weekly reports.

2. Carbon will provide weekly progress reports on the progress of CRC allowing Carbon's natural gas production back into the pipelines; the first report will be due by September 2, 2019.

3. Carbon will curtail gas production to the maximum extent feasible and notify the District which wells have been curtailed. Carbon will include details in weekly reports.

4. Carbon will attend a regular variance hearing on or before November 22, 2019.

B. Reporting Requirements

2. Carbon will monitor natural gas consumption during the variance and report this data to the District by December 9, 2019. Excess emissions and excess emission fees will be based on the data submitted in this report.

3. As required by District Rule 42.N, "Flaring Excess Emission Fee," payment of excess emission fees shall be submitted to the District no later than 60 days after receiving the bill.

4. All submittals and notifications to the District pursuant to this Variance Order shall be made to Ms. Michelle Wood, Ventura County Air Pollution Control District, 669 County Square Drive, Ventura, CA 93003.

C. General

1. Except as provided in this order, compliance with this Order shall not relieve Petitioner from liability under the District's Rules for any violation,

thereof, and shall not preclude the District from pursuing remedies in accordance with the Health and Safety Code in the event of any violation.

2. The failure to abide by any condition of this decision and Order shall subject Carbon to penalties set forth in Health and Safety Code Section 42402.

3. Each day during which a violation occurs is a separate offense.

4. Petitioner shall retain the obligation to comply with all other local, state and federal regulations not specifically referenced in this Variance Order.

5. Petitioner shall pay the Hearing Board fees specified in District Rule 41.

Stephen Craig Hurlock	AYE
Daniel Joseph Murphy	AYE
Michael David Stubblefield, Chair	AYE

8/30/2019

VENTURA COUNTY AIR POLLUTION CONTROL DISTRICT
MICHAEL DAVID STUBBLEFIELD, HEARING BOARD CHAIR

DATE

HBCaseNumber878

EXHIBIT 13

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COUNTY COUNSEL

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CHIEF ASSISTANT

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Eric Walts
Marty Wolter

September 10, 2019

Board of Supervisors
County of Ventura
800 South Victoria Avenue
Ventura, California 93009

SUBJECT: Report Back and Seek Board Direction Regarding Potential Amendments to the County's Zoning Ordinances Regarding Oil and Gas Development; All Supervisorial Districts

RECOMMENDATIONS:

1. Receive and file report back regarding new oil and gas development under antiquated permits; and

2. Provide direction to County staff on potential amendments to the County's zoning ordinances to: (a) require discretionary approval of new oil and gas development; and (b) clarify the applicability of the County's oil development standards.

FISCAL/MANDATES IMPACTS: None.

DISCUSSION:

On April 9, 2019, the Board of Supervisors ("Board") gave two directions to staff. One, your Board directed staff to prepare an interim urgency ordinance for your Board's consideration regarding the drilling of new wells, and the re-drilling of existing wells, that would utilize steam injection in the vicinity of potable groundwater aquifers. On April 23 and June 4, 2019, your Board approved and then extended an interim urgency ordinance prohibiting County approval of such new oil wells, and the re-drilling of such existing wells, on a portion of the Oxnard Plain overlying the Fox Canyon aquifer. This interim urgency ordinance will remain in effect until December 7, 2019, unless further extended by your Board.

County of Ventura
Planning Commission Hearing
PL19-0003 and PL19-0041
Exhibit 24 - 9-10-19 Report to BOS re Potential Amendments to Ordinances for Oil and Gas Development

Two, your Board directed staff to "study potential amendments to the County's zoning ordinances to require discretionary approval of new development under antiquated oil and gas permits." The purpose of this Board item is to provide an overview of the legal issues and legislative options regarding this second recommendation, and seek direction for further actions, if any.

A. COUNTY PERMITTING OF OIL AND GAS DEVELOPMENT

1. County's Antiquated Oil and Gas Permits

Oil and gas exploration and production activities and structures have been subject to a discretionary permitting requirement from the County since adoption of the County's first zoning ordinance in 1947. Over time the County's zoning ordinances and standard permits have become more stringent and detailed in their regulation of this land use. Approximately 125 County discretionary permits for oil and gas exploration and production are currently active.

From 1947 through approximately 1966, the County granted discretionary "special use permits" (the predecessor to the County's "conditional use permits") authorizing oil and gas exploration and production. These permits describe in very general terms the oil and gas-related activities and structures that are authorized within often large permit areas. They typically contain some variation of the following grant of authority:

> Drilling for and extraction of oil, gas and other hydrocarbon substances and installing and using buildings, equipment, and other appurtenances accessory thereto, including pipelines, but specifically excluding processing, refining and packaging, bulk storage or any other use specified in Division 8, Ventura County Ordinance Code, requiring review and Special Use Permit.

The permits typically do not state the maximum number or exact location of allowable wells or other structures, nor do they contain expiration dates (i.e., dates by which the land use must end unless extended by the County). Because these permits were granted before enactment of the California Environmental Quality Act ("CEQA") in 1970, none of the projects underwent CEQA review prior to initial permitting. The oil and gas permits granted by the County during this era are hereinafter referred to as "antiquated permits." A representative antiquated permit is attached as Exhibit 1.

When a permittee seeks to add new wells or otherwise engage in new development under antiquated permits, the new development may only require a ministerial zoning clearance from the County.

2. County's Modern-Era Oil and Gas Permits

From approximately 1966 through the 1970's, the County utilized a new discretionary conditional use permit form with more detailed and stringent conditions as compared to the antiquated permits. The conditional use permits from this era typically only authorize the drilling and operation of a limited number of drill sites, wells and/or other structures; require discretionary County approval for all subsequent development; and contain permit expiration dates. Beginning in the early 1980's and continuing to present, the County's conditional use permits typically specify the exact number and location of all authorized wells and other appurtenant structures; impose more detailed and comprehensive conditions; and contain permit expiration dates.

When a permittee seeks to add new wells or otherwise engage in new development under conditional use permits granted by the County from approximately 1966 to present ("modern-era permits"), the new development typically requires a discretionary permit modification.

3. Ministerial Versus Discretionary Decisions

The distinction between ministerial and discretionary land use decisions is important to a full understanding of the County's regulation of oil and gas development. A ministerial decision is made by determining whether the request conforms to objective standards without the exercise of judgment or opinion by the decision-maker. In contrast, a discretionary decision is made by applying broader subjective standards through the exercise of judgment and opinion by the decision-maker. CEQA can apply to discretionary, but not to ministerial, land use decisions. Consequently, only discretionary permitting decisions can require some level of environmental review under CEQA. In addition, only discretionary permitting decisions involve the public noticing of, and a public hearing regarding, the permit request. Discretionary permitting decisions, unlike ministerial ones, also enable the County to impose permit conditions and mitigation measures to address environmental, land use compatibility, and other issues regarding the proposed development.

4. County's Approval of New Oil and Gas Development

Under the County's current zoning ordinances, a brand-new oil and gas development must be authorized by a discretionary conditional use permit. (See Non-Coastal Zoning Ordinance ["NCZO"], §§ 8105-4 and 8105-5, under heading "Mineral Resource Development," and subheading "Oil and Gas Exploration and Production"; Coastal Zoning Ordinance ["CZO"], § 8174-5, under heading "Oil and Gas: Exploration and Production.") Likewise, any material change to an existing modern-era oil and gas permit requires County discretionary approval in the form of a permit modification. (See NCZO, § 8111-6.1; CZO, § 8181-10.4.)

In contrast, requests to conduct new oil and gas development under active antiquated permits may only be subject to the County's ministerial zoning clearance process.[1] The primary standard for determining if a zoning clearance is to be issued in this context is whether the proposed development is consistent with and authorized by the underlying antiquated permit, and complies with the County's applicable zoning ordinance provisions and General Plan policies. (See NCZO, § 8111-1.1.1b; CZO, § 8181-3.1a). Making the permit consistency determination requires a fact-intensive analysis regarding each antiquated permit and zoning clearance request, which can be challenging given the age of the antiquated permits, potential uncertainty over a permit's status (i.e., whether it is active or has been abandoned), the fact that permit boundaries often overlap, and the fact that some antiquated permits may only authorize oil production at certain subsurface depths. Nonetheless, many new oil and gas development requests meet the consistency standard (and comply with applicable zoning provisions and General Plan policies) because, as explained above, antiquated permits typically broadly authorize oil and gas exploration and production structures and activities within the permit area.

Similarly, requests for new oil and gas development under antiquated permits often do not require a discretionary permit modification under the County's existing zoning ordinances because, unlike the County's more modern oil and gas permits (i.e., those granted from approximately 1966 to present), antiquated permits typically do not limit the number of wells and other structures, do not contain expiration dates, and do not contain other express limiting terms and conditions that must be changed in order to authorize the requested development. Consequently, the County often issues ministerial zoning clearances authorizing new oil and gas development under antiquated permits.

B. COUNTY'S ABILITY TO REQUIRE DISCRETINARY APPROVAL OF NEW DEVELOMENT UNDER ANTIQUATED PERMITS

1. General Rule on Vested Rights

The County has a good legal argument that it can, in general, require newly proposed oil and gas development under antiquated permits to obtain authorization through a discretionary permit modification. Holders of antiquated permits may argue otherwise by claiming to possess vested rights to expand the oil and gas operations without the need for discretionary County approval. The County, however, has a good legal position that holders of typical antiquated permits generally do not have vested

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[1] Some antiquated permits have been modified over time and now include more modern conditions, such as specific well limits and expiration dates. New development proposed under such modified permits typically must be approved through the discretionary permit modification process.

rights to engage in new oil and gas development based solely on the original antiquated permits, as explained below.[2]

Vested rights are based on a permittee's reasonable reliance on a government permit or approval describing a specific development project. Once a permittee has obtained the permit or approval, and has commenced work on the development, the government is estopped (i.e., prohibited) from preventing completion of the work pursuant to subsequently enacted legislation. The seminal California case on vested rights is *Avco Community Developers, Inc. v. South Coast Regional Commission* (1976) 17 Cal.3d 785 ("*Avco*").[3]

Under *Avco* and subsequent cases, a developer acquires a vested right to complete a particular work of improvement, regardless of a subsequent change in the law, when: (1) the appropriate government agency reviews, approves and issues a grant of authority or permit that specifically describes the particular work of improvement; and (2) the developer thereafter performs substantial work and expends substantial funds and/or incurs liabilities in good faith reliance on the grant or permit.

A permittee has the legal burden of establishing the existence and scope of vested rights. If a permittee establishes a vested right, the government may not, by virtue of a change in the laws, prohibit or impair development authorized by the permit or approval, unless the development presents a threat of harm, danger, menace or nuisance.[4] Vested rights claims are fact-specific and determined on a case-by-case basis.

The above-stated requirement for a permit or approval to specifically describe the development project in order to create a vested right is a critical factor. The *Avco* court held that a governmental permit may only give rise to vested rights if the permit affords "substantially the same specificity and definition to a project as a building permit." (*Avco*, *supra*, 13 Cal.3d at p. 794.) *Avco*'s "functional equivalent of a building permit"

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[2] While the government can be found to have unlawfully impaired a permittee's vested rights merely by enacting a law subjecting a previously permitted development to a discretionary approval process, the permittee must possess vested rights in the proposed development in the first instance before it can be found that the government impaired vested rights in this way.

[3] The court in *Avco* found the developer did not have vested rights despite spending millions of dollars in reliance on a final tract map and local zoning regulations. In response to the harsh effect *Avco's* holding had on developers, the Legislature authorized local governments to enter into binding development agreements with developers regarding project approvals. (See Gov. Code, §§ 65864 et seq.)

[4] Even when a permittee has established vested rights, the County possesses constitutional land use authority to regulate the subject development, including by requiring compliance with most of the County's oil development standards, as explained below.

requirement is based on balancing the developer's need for certainty regarding its development proposal without unduly impairing the government's ability to address environmental concerns and regulate land use. The federal Ninth Circuit Court of Appeals has summarized this balance as follows:

> "If the public is to be deprived of its power to control pollution and other problems caused by overdevelopment, it should be deprived only to the extent necessary to ensure private parties a reasonable degree of certainty about the legal status of their investments." (*Lakeview Dev. Corp. v. City of S. Lake Tahoe* (9th Cir. 1990) 915 F.2d 1290, 1299.)

2. Lack of Specificity

Given the typical antiquated permits' lack of specificity regarding the scope and composition of the development authorized by the permits, the County has a good argument the permits no longer confer vested rights to engage in *new* development. Again, these permits do not state the number or exact location of any wells or other structures that are authorized by the permits; instead, they generally authorize the permittee to conduct oil and gas exploration and production activities within the permit area. The permits are thus analogous to general zoning designations – which do not give rise to vested rights – in that they generally allow a land use to occur within an often-large area without specifying the details of a specific facility, structure, equipment or operation. Consequently, holders of these permits cannot cite to any particularly described oil and gas project as being authorized by the permits in order to satisfy this critical vested rights requirement.

On the other hand, permittees have a good position that they have acquired vested rights to continue operating *existing* oil and gas facilities that have been developed pursuant to antiquated permits. Even though the antiquated permits themselves do not specifically describe the projects that may be developed under the permits, the County has long required permittees to obtain a zoning clearance and/or building permit for each new well and related structure. Permittees with antiquated permits presumably possess vested rights to continue operating such equipment as particularly described in these zoning clearances and/or building permits in accordance with *Avco*. Permittees also have a good position that they possess vested rights to continue operating oil facilities that were lawfully established before the County began requiring a CUP, zoning clearance and/or building permit.

3. Time Period for Development

Even if vested rights in a permit are acquired, a lengthy delay by the permittee to proceed with the project on a pace reasonably close to that contemplated when the project was approved may cause the vested rights to be lost. If, contrary to our view, broadly worded antiquated permits did convey vested rights to engage in some level of oil and gas development once perfected (absent subsequently issued zoning clearances and/or building permits more particularly describing the associated structures), the County has a good argument that the time periods for permittees to exercise these rights by building out new development under the initial antiquated permits have now expired. The antiquated permits were granted between approximately 53 and 72 years ago. Thus, permittees have had decades to build out the oil and gas projects under the initial approvals. The County has a good argument that permittees are not entitled to construct any new oil and gas development, without first obtaining discretionary County approval, because the permittees' vested rights have lapsed through unreasonable delay in completing the initially approved projects.

4. Prior County Counsel Opinion

In 2014, County Counsel addressed the issue of vested rights and antiquated permits in a memorandum attached as Exhibit 2. The issue then presented was the County's authority to impose new conditions on *existing* oil and gas operations subject to antiquated permits. For purposes of addressing that specific issue, the memorandum assumes that permittees possess some level of vested rights in antiquated permits and proceeds to explain how such vested rights constrain the County's ability to impose new permit conditions on the *existing* operations. The memorandum does not, however, address the threshold issue now presented: Whether typical antiquated permits – i.e., those with broad authorizing language that do not specify the number and location of allowable wells or other structures – give rise to vested rights in and of themselves. For the reasons stated above, County Counsel believes they typically do not.

This vested rights issue is nuanced. Even though typical antiquated permits do not confer vested rights to engage in *new* development for the reasons stated above, permittees who have developed oilfield facilities under them have presumably obtained vested rights in their *existing* wells and other structures. Consequently, the 2014 County Counsel memorandum accurately recognizes permittees' presumptive vested rights in *existing* oilfield facilities and explains how these vested rights constrain the County's ability to impose new conditions on *existing* operations.

C. POTENTIAL ZONING ORDINANCE AMENDMENTS

1. Requiring Discretionary Approval of New Development under Antiquated Permits

The County's zoning ordinances contain specific regulations for oil and gas exploration and production. (NCZO, § 8111-5; CZO, § 8175-5.7.) These regulations could be amended to require a discretionary permit modification to authorize new development proposed under typical antiquated permits, and any other discretionary County permits, that do not specifically describe and authorize the newly proposed oilfield structures. This discretionary permit modification requirement would be in addition to the County's existing permit modification requirement which, as explained above, applies whenever a permittee seeks to change the terms and conditions of an existing discretionary permit.

Applying the County's discretionary permit modification process to new development proposed under antiquated permits would require some level of CEQA review of the proposed development and the provision of public notice and a public hearing by the County's decision-making authority regarding the request. In order to approve the proposed development, the County's decision-making authority would need to find that the proposed development meets the County's general permit approval standards (see NCZO, § 8111-1.2.1.1a; CZO, § 8181-3.5) including, among others, that the proposed development would not be detrimental to the public interest, health, safety, convenience, or welfare; would not be obnoxious or harmful; and is compatible with existing and potential land uses in the general area.

This discretionary permitting process would thereby provide the County with the ability to: (1) fully investigate and publicly disclose the potential environmental impacts of the proposed development under CEQA; (2) weigh the merits of the proposed development against its potential negative impacts in deciding whether to approve the new development; and (3) impose permit conditions on approved development to mitigate potential environmental impacts and to address relevant land use issues, including conditions developed pursuant to the County's oil development guidelines and design standards set forth at NCZO section 8107-5.5 and CZO section 8175-5.7.7.

2. Clarifying Applicability of County's Oil Development Standards

The County's oil and gas regulations could also be amended to clarify another issue implicated by antiquated permits: the applicability of the County's oil development standards. These standards regulate various operational issues such as well and equipment siting, grading, lighting, waste handling, noise, site maintenance and site restoration. (See NCZO, § 8107-5.5; CZO, § 8175-5.7.8.) The County's current zoning ordinances state that the oil development standards apply to "permits" granted or modified by the County on or after March 24, 1983, the date upon which many of the County's current oil and gas standards were adopted. However, it is sometimes not clear what County oil development standards apply to oilfield structures and operations conducted pursuant to permits granted or issued before March 24, 1983.

This issue can be clarified by amending the County's zoning ordinances to state that the County's oil development standards uniformly apply to all oil and gas exploration and production operations to the extent: (i) such standards would impose more stringent restrictions than those set forth in existing permit conditions, laws, or regulations applicable to the operation; and (ii) application of such standards would not impair any vested right of an operator under California law. The latter vested rights exception is needed because certain oil development standards, such as the oil structure siting and setback requirements, could not be applied to existing facilities without potentially impairing a permittee's vested rights.

These potential zoning ordinance amendments are reflected in a draft revised version of NCZO section 8107-5.2 attached as Exhibit 3, which can be compared to the existing version of this section attached as Exhibit 4. This NCZO section, and its counterpart at section 8175-5.7.2 in the CZO, address the applicability of the County's oil and gas regulations.

This board item has been reviewed by the County Executive Office, the Auditor-Controller's Office and the Resource Management Agency Planning Division. If you have any questions, please call me at (805) 654-2581.

Very truly yours,

LEROY SMITH
County Counsel

Attachments:
Exhibit 1 – Special Use Permit 393 Granted in 1955
Exhibit 2 – 2014 County Counsel Memorandum
Exhibit 3 – Draft Revised NCZO section 8107-5.2
Exhibit 4 – Current NCZO section 8107-5.2

EXHIBIT 14

The 2013–2016 induced earthquakes in Harper and Sumner Counties, southern Kansas

Bulletin of the Seismological Society of America
By: Justin L. Rubinstein , William L. Ellsworth , and Sara L. Dougherty

https://doi.org/10.1785/0120170209

Links

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Abstract

We examine the first four years (2013–2016) of the ongoing seismicity in southern Kansas using high-precision locations derived from a local seismometer network. The earthquakes occur almost exclusively in the shallow crystalline basement, below the wastewater injection horizon of the Arbuckle Group at the base of the sedimentary section. Multiple lines of evidence lead us to conclude that disposal of wastewater from the production of oil and gas by deep injection is the probable cause for the surge of seismicity that began in 2013. First, the seismicity correlates in space and time with the injection. We observe increases in seismicity subsequent to increases in injection and decreases in seismicity in response to decreases in injection. Second, the

earthquake-rate change is statistically improbable to be of natural origin. From 1974 through the time of the injection increase in 2012, no M_L 4 or larger earthquakes occurred in the study area, while six occurred between 2012 and 2016. The probability of this rate change occurring randomly is ~0.16%. Third, the other potential industrial drivers of seismicity (hydraulic fracturing and oil production) do not correlate in space or time with seismicity. Local geological conditions are important in determining whether injection operations will induce seismicity, as shown by absence of seismicity near the largest injection operations in the southwest portion of our study area. In addition to local operations, the presence of seismicity 10+ km from large injection wells indicates that regional injection operations also need to be considered to understand the effects of injection on seismicity.

Study Area

Additional publication details

Publication type	Article
Publication Subtype	Journal Article
Title	The 2013–2016 induced earthquakes in Harper and Sumner Counties,

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Series title	Bulletin of the Seismological Society of America
DOI	10.1785/0120170209
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Description	16 p.
First page	674
Last page	689
Country	United States
State	Kansas
County	Harper County, Sumner County

EXHIBIT 15

Studies link earthquakes to fracking in the Central and Eastern US

Date: April 26, 2019

Source: Seismological Society of America

Summary: Small earthquakes in Ohio, Pennsylvania, West Virginia, Oklahoma and Texas can be linked to hydraulic fracturing wells in those regions, according to researchers.

FULL STORY

Small earthquakes in Ohio, Pennsylvania, West Virginia, Oklahoma and Texas can be linked to hydraulic fracturing wells in those regions, according to researchers speaking at the SSA 2019 Annual Meeting.

While relatively rare compared to earthquakes caused by wastewater disposal in oil and gas fields in the central United States, Michael Brudzinski of Miami University in Ohio and his colleagues have identified more than 600 small earthquakes (between magnitude 2.0 and 3.8) in these states.

Brudzinski said these earthquakes may be "underappreciated" compared to seismicity related to wastewater disposal since they appear to happen less frequently. He and his colleagues are studying the trends related to the likelihood of induced seismicity from hydraulic fracturing or fracking, which could help industry and state regulators better manage drilling practices.

Unconventional U.S. oil production, which extracts oil from shales and tight rocks using a variety of drilling techniques, has been linked to an increase in human-induced earthquakes across the mid-continent of the United States for nearly a decade. Researchers studying the increase in places such as Oklahoma think that the main driver of this increase in seismicity is the injection of wastewater produced by extraction back into rock layers, which increases pore pressure within rocks and can affect stress along faults in layers selected for disposal.

Hydraulic fracturing uses pressurized liquid to break apart or create cracks within a rock formation through which petroleum and natural gas can flow and be more easily extracted.

In the eastern half of Ohio and other parts of the Appalachian Basin, where there has been a dramatic rise in natural gas production over the past two decades, fracking wells are more prevalent than wastewater disposal wells, in part because the geological layers that contain oil and gas are not as wet as in places like Oklahoma, reducing the need for wastewater disposal.

The numerous fracking wells in eastern Ohio prompted Brudzinski and his colleagues to take a closer look at whether small earthquakes in the region could be connected to fracking operations. "The wells are more widely spaced when they're active, and there isn't as much wastewater disposal going on," Brudzinski explained, "so you can see a bit more specifically and directly when wastewater disposal is generating seismicity and when hydraulic fracturing is generating seismicity in the Appalachian Basin."

The scientists used a technique called multi-station template matching, which scans through hundreds of seismic signals to find those that match the "fingerprint" of known earthquakes. The technique allowed them to detect small earthquakes that might have otherwise been overlooked, and to compare the more complete earthquake catalog in a region to information on the timing and location of regional fracking well operations.

Seismologists identify earthquakes as being caused by hydraulic fracture wells when they are tightly linked in time and space to fracking operations. Fracking-related seismicity also tends to look different from seismicity caused by wastewater disposal, Brudzinski said.

"The [fracking] seismic signature when you look at it in a sort of timeline shows these bursts of seismicity, hundreds or sometimes thousands of events over a couple of days or weeks, and then it's quiet again. You don't tend to see that pattern with wastewater disposal," he explained.

Brudzinski and his colleagues are now using their dataset from Oklahoma to look at how a variety of variables might affect the likelihood of fracking-induced earthquakes, from the volume and viscosity of the injected liquid to the depth of the rock layers targeted by fracking.

"The one that has stuck out to us the most is that the depth of the well is more tied to likelihood of seismicity than we expected," Brudzinski said.

It isn't just the deeper the well, the more likely it is to be closer to basement rock and mature faults that are likely to slip, he said, although that might still play a role in these earthquakes. Instead, overpressuring appears to have a stronger correlation with fracking-induced seismicity. Overpressuring occurs when there is high fluid pressure within rocks buried deep in a basin by many overlying rock layers. "It's one of the strongest trends we saw," said Brudzinski.

The researchers have discussed some of their findings with colleagues in Canada and China, where induced seismicity from fracking operations are being studied closely. "We are doing that kind of international comparison to get a better handle on the salient features and trends that aren't just tied to a specific location," said Brudzinski.

Story Source:

Materials provided by **Seismological Society of America**. *Note: Content may be edited for style and length.*

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Apr. 7, 2016 — Unconventional oil and gas operations combine directional drilling and hydraulic fracturing, or 'fracking,' to release natural gas and oil from underground rock. Studies have centered on ... **read more** »

Lower Birth Weight Associated With Proximity of Mother's Home to Gas Wells

June 3, 2015 — Pregnant women living close to a high density of natural gas wells drilled with hydraulic fracturing were more likely to have babies with lower birth weights than women living farther from such ... **read more** »

Fracking? Injecting Wastewater? New Insight on Ground Shaking from Human-Made Earthquakes

Apr. 23, 2015 — Significant strides in science have been made to better understand potential ground shaking from induced earthquakes, which are earthquakes triggered by human practices. Earthquake activity has ... **read more** »

EXHIBIT 16

Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)

Sixth Edition

June 2019

Fracking rigs off of Interstate 20
West of Midland, Texas, in the Permian Basin ©2018 Julie Dermansky

The Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (the Compendium) is a fully referenced compilation of evidence outlining the risks and harms of fracking. It is a public, open-access document that is housed on the websites of Concerned Health Professionals of New York (www.concernedhealthny.org) and Physicians for Social Responsibility (www.psr.org).

The five earlier editions of the Compendium have been used and referenced all over the world. The Compendium has been twice translated into Spanish: independently in 2014 by a Madrid-based environmental coalition, followed by an official translation of the third edition, which was funded by the Heinrich Böll Foundation and launched in Mexico City in May 2016. The Compendium has been used in the European Union, South Africa, the United Kingdom, Australia, Mexico, and Argentina.

About Concerned Health Professionals of New York

Concerned Health Professionals of New York (CHPNY) is an initiative by health professionals, scientists, and medical organizations for raising science-based concerns about the impacts of fracking on public health and safety. CHPNY provides educational resources and works to ensure that careful consideration of science and health impacts are at the forefront of the fracking debate.

About Physicians for Social Responsibility

Working for more than 50 years to create a healthy, just, and peaceful world for both present and future generations, Physicians for Social Responsibility (PSR) uses medical and public health expertise to educate and advocate on urgent issues that threaten human health and survival, with the goals of reversing the trajectory towards climate change, protecting the public and the environment from toxic chemicals, and addressing the health consequences of fossil fuels. PSR was founded by physicians concerned about nuclear weapons, and the abolition of nuclear weapons remains central to its mission.

Contents

About this Report

The Compendium is organized to be accessible to public officials, researchers, journalists, and the public at large. The reader who wants to delve deeper can consult the reviews, studies, and articles referenced herein. In addition, the Compendium is complemented by a fully searchable, near-exhaustive citation database of peer-reviewed journal articles pertaining to shale gas and oil extraction, the Repository for Oil and Gas Energy Research, that was developed by PSE Healthy Energy and which is housed on its website (https://www.psehealthyenergy.org/our-work/shale-gas-research-library/).

For this sixth edition of the Compendium, as before, we collected and compiled findings from three sources: articles from peer-reviewed medical or scientific journals; investigative reports by journalists; and reports from, or commissioned by, government agencies. Peer-reviewed articles were identified through databases such as PubMed and Web of Science, and from within the PSE Healthy Energy database. We included review articles when such reviews revealed new understanding of the evidence.

Written in non-technical language, our entries briefly and plainly describe studies that document harm, or risk of harm, associated with fracking and summarize the principal findings. Entries do not include detailed results or a critique of the strengths and weaknesses of each study. Because much of medicine's early understanding of new diseases and previously unsuspected epidemiological correlations comes through assessment of case reports, we have included published case reports and anecdotal reports when they are data-based and verifiable.

The studies and investigations referenced in the dated entries catalogued in the Compilation of Studies & Findings are current through April 1, 2019. The footnoted citations here in the front matter represent studies and articles that are not referenced in the Compendium itself or which appeared as we went to press in June 2019.

Within the compiled entries, we have also provided references to articles appearing in the popular press, when available, that describe the results of the corresponding peer-reviewed study and place them in context with the results of other studies. For this purpose, we sought out articles that included comments by principal investigators on the significance of their findings. In such cases, footnotes for the peer-reviewed study and the matching popular article appear together in one entry. We hope these tandem references will make the findings more meaningful to readers.

Acronyms are spelled out the first time they appear in each section.

News articles appearing as individual entries signify reports that contain original research. In many cases, this reportage is based on data collected by industry or government agencies that were ferreted out by investigative journalists and not otherwise known to the scientific community.

While advocacy organizations have compiled many useful reports on the impacts of fracking, these, with few exceptions, do not appear in our Compendium unless they provide otherwise inaccessible data. We also excluded papers that focused purely on methodologies or instrumentation. For some sources, cross-referenced footnotes are provided, as when wide-ranging government reports or peer-reviewed papers straddled two or more topics.

In our review of the data, seventeen compelling themes emerged, and these serve as the organizational structure of the Compendium. Readers will notice the ongoing upsurge in reported problems and health impacts, making each section top-heavy with recent data. In accordance, the Compendium is organized in reverse chronological order within sections, with the most recent information first.

The Compendium focuses on topics most closely related to the public health and safety impacts of unconventional gas and oil drilling and fracking. These necessarily include threats to climate stability.

Additional risks and harms arise from associated infrastructure and industrial activities that necessarily accompany drilling and fracking operations. A detailed accounting of all these ancillary impacts is beyond the scope of this document. Nevertheless, we include in this edition a section on impacts from fracking infrastructure that focuses on

- compressor stations and pipelines;
- silica sand mining operations;
- natural gas storage facilities;
- the manufacture and transportation of liquefied natural gas (LNG), and
- natural gas power plants.

(Research on gas-fired power plants appears in this edition for the first time. Note that threats from flare stacks are included in the section on air pollution.)

Many other relevant concerns—such as disposal of solid waste drill cuttings and the use of fracked gas as a feedstock in petrochemical manufacturing—are not included here. We hope to take up these issues in future editions.

Similarly, this edition of the Compendium does not examine the harms and risks posed by other forms of unconventional oil and gas extraction, such as cyclic steaming (which uses pressurized, superheated water to release oil), microwave extraction (which points microwave beams into shale formations to liquefy oil), and artificial lift (which uses gases, chemicals, or pumps to extract natural gas).

Given the rapidly expanding body of evidence related to the harms and risks of unconventional oil and gas extraction, we plan to continue revising and updating the Compendium approximately every year. It is a living document, housed on the websites of Concerned Health Professionals of New York and Physicians for Social Responsibility, which serves as an educational tool in important ongoing public and policy dialogues.

The Compendium is generally a volunteer project and has no dedicated funding; it was written utilizing the experience and expertise of numerous health professionals and scientists who have been involved in this issue for years.

We thank our external peer readers for their comments and suggestions: Casey Crandall; Laura Dagley, BSN, RN; Barbara Gottlieb; Robert Gould, MD; Jake Hays, MA; Douglas Hendren, MD, MBA; Lee Ann Hill, MPH; Robert Howarth, PhD; Anthony Ingraffea, PhD, PE;

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We welcome your feedback and comments.

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Foreword to the Sixth Edition

The Compendium in Historical Context

The release of the first edition of the Compendium by Concerned Health Professionals of New York in July 2014 coincided with a meteoric rise in the publication of new scientific studies about the risks and harms of fracking. A second edition was released five months later, in December 2014, and included new studies that further explicated recurrent problems.

Almost concurrently, on December 17, 2014, the New York State Department of Health (NYS DOH) released its own review of the public health impacts of fracking. (See footnote 655.) That document served as the foundation for a statewide ban on high-volume hydraulic fracturing (HVHF), announced by New York Governor Andrew Cuomo on the same day. Its conclusions—

> [I]t is clear from the existing literature and experience that HVHF activity has resulted in environmental impacts that are potentially adverse to public health. Until the science provides sufficient information to determine the level of risk to public health from HVHF and whether the risks can be adequately managed, HVHF should not proceed in New York State.

The third edition of the Compendium, released in October 2015 and compiled as a joint effort with Physicians for Social Responsibility, included new peer-reviewed studies as well as the results of the first substantive government reports on the impacts of fracking. One of these was the New York State Department of Environmental Conservation's final environmental impact statement and attendant Findings Statement that incorporated the earlier health review into a larger analysis of the impacts of fracking. (See footnote 482.) The Findings Statement made clear that no known regulatory framework can adequately mitigate the multiple risks of fracking:

> Even with the implementation of an extensive suite of mitigation measures…the significant adverse public health and environmental impacts from allowing high-volume hydraulic fracturing to proceed under any scenario cannot be adequately avoided or minimized to the maximum extent practicable….

In December 2015, the third edition became the basis of invited testimony at conferences taking place concurrently with the United Nations' climate talks in Paris. Those international negotiations resulted in an historical international accord, the Paris Agreement, which recognizes climate change as a grave threat to public health and establishes as a key goal the need to limit global temperature increases to 2° Celsius, or, ideally, 1.5° C, above pre-industrial times. As such, the treaty articulates a vision for energy by compelling nations to monitor their greenhouse gas emissions and set increasingly ambitious targets and timetables to reduce them.

The Compendium's fourth edition was released in November 2016, just as the Paris Agreement went into force and as several new studies conclusively demonstrated that expansion of shale gas and oil extraction was incompatible with climate stability and the goal of rapid decarbonization that it requires. All together, these data show that because of increasing emissions of methane—a powerful heat-trapping gas—the United States was on track to miss its pledge under the Paris Agreement to reduce greenhouse gas emissions 26-28 percent by 2025. (See footnotes 977 and

978.) The evidence showed that methane leaks from U.S. oil and gas operations were significantly higher than previously estimated, as were U.S. methane emissions overall. (See footnotes 979-981, 987, 998, and 999.)

The fifth edition, released in March 2018, was launched in a time of deep environmental retrenchment by the U.S. government. The Trump administration had announced an era of "energy dominance" based on surging domestic production of oil and natural gas, most of it extracted via fracking. References to climate change were removed altogether from some government websites. Greenhouse gas emissions were no longer to be considered in National Environment Policy Act reviews. The White House announced its intent to withdraw from the Paris Agreement even as the American Meteorological Society released a major report that identified climate change as a contributor to several recent extreme weather events and even as the Fourth National Climate Assessment—a quadrennial report compiled by 13 federal agencies—confirmed human activities as the dominant cause for ongoing global warming.[1, 2]

Included in the federal environmental rules rescinded during this period were many that governed drilling and fracking operations. The Bureau of Land Management's (BLM) Waste Prevention Rule, requiring companies drilling on public and tribal lands to reduce methane leaks and cut back on flaring and venting, was suspended. The U.S. Environmental Protection Agency (EPA) canceled a system for existing oil and gas facilities to report methane leaks and delayed implementation of a rule that would have limited methane emissions from new oil and gas drilling sites. The U.S. Department of the Interior rescinded a rule to require disclosure of chemicals in fracking fluid on public lands and tighten standards for well construction and wastewater disposal. The White House revoked policies that had prevented the construction of the Dakota Access Pipeline. That pipeline now carries fracked oil from the Bakken Shale in North Dakota to an oil storage hub in Illinois.[3, 4]

This current sixth edition of the Compendium arrives at a time of starkly contradictory trends.

On the one hand, aggressive attacks on regulatory oversight of U.S. oil and gas extraction continue and now extend to the science underlying the targeted regulations. A recent EPA directive has banned scientists who received EPA funding from sitting on panels that advise the agency on scientific matters.[5] An order issued by the White House-appointed director of the U.S.

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[1] Herring, S. C., Christidis, N., Hoell, A., Kossin, J. P., Schreck III, C. J., & Stott, P. A. (2017). Explaining extreme events of 2016 from a climate perspective. *Bulletin of the American Meteorological Society*, *99*(1), S1–S157. doi: 10.1175/BAMS-ExplainingExtremeEvents2015

[2] U.S. Global Change Research Program. (2017). *Climate science special report: Fourth National Climate Assessment, Volume I.* Retrieved from https://www.globalchange.gov/browse/reports/climate-science-special-report-fourth-national-climate-assessment-nca4-volume-i

[3] Harvard University Environmental Law Program. (2019). Environmental regulation rollback tracker. http://environment.law.harvard.edu/policy-initiative/regulatory-rollback-tracker/

[4] Mooney, C. (2017, December 29). To round out a year of rollbacks, the Trump administration just repealed key regulations on fracking. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2017/12/29/to-round-out-a-year-of-rollbacks-the-trump-administration-just-repealed-key-regulations-on-fracking/?utm_term=.f16b4db99128

[5] Stempel, J. (2019, June 3). U.S. EPA is sued for ousting scientists from advisory panels. *Reuters.* Retrieved from https://www.reuters.com/article/us-epa-lawsuit/us-epa-is-sued-for-ousting-scientists-from-advisory-committees-idUSKCN1T42H8

Geological Survey (USGS) now prohibits that agency's scientists from generating climate models beyond the year 2040.[6]

The feverish pace of U.S. oil and gas extraction also continues. Unimpeded by federal regulations and driven by fracking, U.S. oil and gas production has reached record levels, which, in turn, has spurred a massive build-out of fracking infrastructure. The Federal Energy Regulatory Commission (FERC) has eased the process to build new pipelines, and even more public lands have been opened to oil and gas extraction.[7] One executive order has impeded the ability of states to block pipeline construction, while another has transferred power for international pipeline approval from the U.S. State Department to the President.[8] As the U.S. Energy Information Administration (EIA) forecasts record build-out of natural gas pipelines, the Pipeline and Hazardous Materials Safety Administration (PHMSA) has urged Congress to expand a law that treats some kinds of citizen protests against pipeline construction as federal crimes.[9]

The White House policy of energy dominance also continues apace. In the face of flattening domestic demand for gas, the ongoing fracking boom is increasingly directed at export markets.[10] The United States is on track to become the world's largest international seller of natural gas. As of this writing, three liquefied natural gas (LNG) export terminals are operational with more than a dozen new LNG terminals in the planning or development stage. Exports of LNG from the United States to the European Union alone have increased by 181 percent since July 2018.[11] In May 2019, the U.S. Department of Energy introduced the terms "freedom gas" and "molecules of U.S. freedom" to refer to LNG exports.[12] In June 2019, as we went to press, the Delaware River Basin Commission approved a plan to construct an LNG terminal on the Delaware River in Gibbstown, New Jersey with the aim of exporting natural gas extracted from shale gas wells in Pennsylvania.[13, 14] The gas would be trucked to the export terminal from a new LNG liquefaction plant planned for Pennsylvania's Bradford County.[15]

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6 Davenport, C. (2019, May 27). Trump administration hardens its attack on climate science. *New York Times.* Retrieved from https://www.nytimes.com/2019/05/27/us/politics/trump-climate-science.html

7 Leven, R., (2018, November 13). Drilling overwhelms agency protecting America's lands. *Associated Press.* Retrieved from https://www.apnews.com/dac08562077c41a8a08845a291cbfb6c

8 Kusnetz, N. (2019, April 11). Trump aims to speed pipeline projects by limiting state environmental reviews. *Inside Climate News*. Retrieved from https://insideclimatenews.org/news/11042019/trump-pipeline-executive-order-environmental-review-keystone-xl-clean-water-act-states-rights

9 Budryk, Z. (2019, June 3). Transportation Department seeks to crackdown on pipeline protests: Report. *The Hill.* Retrieved from https://thehill.com/policy/transportation/446765-transportation-department-seeks-to-crack-down-on-pipeline-protests

10 Proctor, D. (2019, April 1). Plenty of natural gas around—it just needs a market. *Power Magazine.* Retrieved from https://www.powermag.com/plenty-of-natural-gas-to-go-around-it-just-needs-a-market/

11 European Commission. (2018, March 8). EU-U.S. joint statement: Liquified Natural Gas (LNG) imports from the U.S. continue to rise, up by 181% [Press release.] Retrieved from http://europa.eu/rapid/press-release_IP-19-1531_en.htm

12 U.S. Department of Energy (2019, May 29). Department of Energy authorizes additional LNG exports from Freeport LNG [Press release]. Retrieved from https://www.energy.gov/articles/department-energy-authorizes-additional-lng-exports-freeport-lng

13 Maykuth, A. (2019, June 12). Contentious plan to remake N.J. dynamite plant into shale-gas export terminal is approved *Phlidelphia Inquirer.* https://www.inquirer.com/business/lng-export-terminal-philadelphia-repauno-fortress-approved-20190612.html

Similarly, by September 2018, the United States had become the world's leading oil producer, surpassing both Russia and Saudi Arabia.[16] U.S. oil production is forecast to increase by 30 percent by 2023, with much of that growth driven by fracking operations in the Permian Basin of West Texas and eastern New Mexico. The Permian is now the leading source of U.S. crude oil exports.[17]

On the other hand, the ongoing U.S. fracking boom and its protracted deregulation are at odds with the emerging scientific consensus on the scale and tempo of necessary climate change mitigation and with rising public alarm about the impending climate crisis that this consensus has amplified. In some cases, Trump-era rollbacks have been reversed. In March 2019, a U.S. district judge blocked leasing of public lands for fracking in Wyoming on the grounds that the BLM had not considered greenhouse gas emissions.[18] (Physicians for Social Responsibility was a party to this lawsuit.) The National Aeronautics and Space Administration's (NASA) Carbon Monitoring System, targeted by the White House for elimination in 2018, was refunded by Congress in 2019.[19]

In October 2018, in its first commissioned report under the Paris Agreement, the United Nations Intergovernmental Panel on Climate Change (IPCC) announced that emissions from oil and gas must decline swiftly within the next decade—a trend not compatible with further build-out of oil and gas infrastructure. Specifically, the IPCC found that global warming above 1.5^{o} C is likely to result in irreversible points of no return and cascading, uncontrollable harms, including wholesale loss of coral reefs, loss of ocean fish stocks, widespread crop failures, flooding of coastal cities, multiple public health crises, and social disruption. To avoid the worst of these outcomes, the world needs to reduce greenhouse gas emissions by 45 percent by 2030 and reach net zero by 2050.[20, 21]

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[14] Hurdle, J. (2019, June 15). Delaware River Basin Commission confirms plan to build LNG expoert terminals at new South Jersey port. *State Impact Pennsylvania*. Retrieved from https://stateimpact.npr.org/pennsylvania/2019/06/15/delaware-river-basin-commission-confirms-plan-to-build-lng-export-terminal-at-new-south-jersey-port/

[15] Maykuth, A. (2019, June 9). The 'hidden' plan to remake an old dynamite factory near Philly into a major gas export terminal. *Philadelphia Inquirer*. Retrieved from https://www.inquirer.com/business/energy/philadelphia-lng-export-terminal-delaware-river-fortress-20190609.html

[16] U.S. Energy Information Administration. (2018, September 12). The United States is now the largest global crude oil producer. *Today in Energy.* Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=37053

[17] Collier, K., Hopkins, J. S., & Leven. R. (2018, October 11). As oil and gas exports surge, West Texas becomes the world's "extraction colony." *Texas Tribune* and Center for Public Integrity. Retrieved from https://www.texastribune.org/2018/10/11/west-texas-becomes-worlds-extraction-colony-oil-gas-exports-surge/

[18] Groom, N. (2019, March 20). U.S. judge blocks drilling over climate change, casting doubt on Trump agenda. *Reuters*. Retrieved from https://www.reuters.com/article/us-usa-drilling-lawsuit/u-s-judge-blocks-drilling-over-climate-change-casting-doubt-on-trump-agenda-idUSKCN1R11YL

[19] Popkin, G. (2019 February 28). New budget bill rescues NASA's carbon monitoring program. *Eos*. Retrieved from https://eos.org/articles/new-budget-bill-rescues-nasas-carbon-monitoring-system

[20] Masson-Delmotte, V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J. Shukla, P. R., . . . Waterfield, T. (eds.). (2018). Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. World Meteorological Organization. Retrieved from https://www.ipcc.ch/sr15/

[21] Davenport, C. (2018, October 7). Major climate report describes a strong risk of crisis as early as 2040. *New York Times.* Retrieved from https://www.nytimes.com/2018/10/07/climate/ipcc-climate-report-2040.html

These findings were confirmed and expanded upon in another landmark paper published in April 2019 by an international team of scientists who warned that "it has become clear that beyond 1.5^{o} C, the biology of the planet becomes gravely threatened because ecosystems literally begin to unravel."[22]

In May 2019, a joint appeal from the leaders of the United Nations System organizations urged world political leaders "with great urgency" to accelerate mitigation efforts in order to limit the global temperature to 1.5^{o} C above pre-industrial levels, referring to this limit as a "moral, economic imperative."[23]

The ongoing fracking boom is also at odds with trends in the economics of renewable energy. The ongoing build-out of natural gas pipelines has been accompanied by an ongoing wave of natural gas power plant construction across the United States. In 2018, 35 percent of electricity in the United States was generated in gas-fired power plants—a figure that is forecast to rise to 38 percent by 2020.[24] At the same time, rapid declines in the cost of wind, solar, and battery storage prices have now made renewable energy a cheaper alternative than coal and gas in most major economies.[25] A new analysis shows that a 100 percent renewable energy system in the United States would reduce electricity costs.[26]

Indeed, renewables are already replacing existing gas plants in some cases. In 2018, three large gas-fired power plants closed in California, with more retirements planned as wind and solar replace gas for electrical generation.[27, 28] In March 2019, Florida Power and Light announced it would retire two natural gas plants and replace them with a massive solar-powered battery bank.[29] In April 2019, Indiana regulators rejected a proposal to replace three retiring coal plants

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22 Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., . . . Wikramanayake, E. (2019). A global deal for nature: guiding principles, milestones, and targets. *Science Advances, 5*(4), 1-17. doi: 10.1126/sciadv.aaw2869

23 United Nations Development Program (2019, May 10). Climate action summit: A joint appeal from the UN system to the Secretary-General's climate action summit. Retrieved from https://www.undp.org/content/undp/en/home/news-centre/speeches/2019/climate-action-summit.html

24 U.S. Energy Information Administration. (2019, May 7). Short-term energy outlook. Retrieved from https://www.eia.gov/outlooks/steo/report/

25 Lazard. (2018, November 8). Levelized cost of energy and levelized cost of storage 2018. Retrieved from https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/

26 Aghahosseini, A., Bogdanov, D., Barbosa, L. S. H. S., & Breyer, C. (2019) Analysing the feasibility of powering the Americas with renewable energy and inter-regional grid interconnections by 2030. *Renewable and Sustainable Energy Reviews, 105,* 187-205. doi: 10.1016/j.rser.2019.01.046

27 Specht, M. (2019, February 25). Natural gas power plant retirements in California. Union of Concerned Scientists. Retrieved from https://blog.ucsusa.org/mark-specht/gas-retirements-california

28 Groom, N. (2019, February 12). Los Angeles abandons new natural gas plants in favor of renewables. *Reuters*. https://www.reuters.com/article/us-usa-california-natgas/los-angeles-abandons-new-natural-gas-plants-in-favor-of-renewables-idUSKCN1Q12C9

29 Geuss, M. (2019, March 29). Florida utility to close natural gas plants, build massive solar-powered battery. *Ars Technica.* Retrieved from https://arstechnica.com/information-technology/2019/03/florida-utility-to-close-natural-gas-plants-build-massive-solar-powered-battery/

with a massive natural gas plant over concerns that gas was a risky investment "if alternatives decline in price."[30]

With an economic lifespan of between 30 and 50 years, new gas and oil infrastructure projects are now at risk for becoming stranded assets. Evidence shows that, even in the absence of new climate policies, continuing investments in fossil fuel exports may substantially harm the U.S. economy.[31]

Expanding Knowledge Base

Even as we compiled entries for this sixth edition, the authors of the Compendium continued to see evidence of, and appreciate, the rapid expanse of our knowledge base. The Compendium exists within a moving stream of data.

As is revealed in the Repository for Oil and Gas Energy Research (ROGER), the database of literature maintained by PSE Healthy Energy, the number of peer-reviewed publications relevant to assessing the environmental, socioeconomic, and public health impacts of shale gas development doubled between 2011 and 2012. It doubled again between 2012 and 2013.[32]

This trend continues. More than half of the peer-reviewed scientific papers on the risks and harms of fracking have been published since January 2016. Indeed, 20 percent (355 studies) of the now more than 1,700 available studies were published in 2018 alone.

As of April 16, 2019, there were 1,778 published peer-reviewed studies that pertain to shale and tight gas development archived in the ROGER database.[33]

This body of evidence clearly reveals both potential and actual harms. Specifically, PSE's statistical analysis of the scientific literature available from 2009 to 2015 demonstrates that:

- 69 percent of original research studies on water quality found potential for, or actual evidence of, fracking-associated water contamination,
- 87 percent of original research studies on air quality found significant air pollutant emissions, and
- 84 percent of original research studies on human health risks found signs of harm or indication of potential harm.[34]

[30] Bade, G. (2019, April 25). Indiana regulators reject Vectren gas plant over stranded asset concerns. *Utility Dive.* Retrieved from https://www.utilitydive.com/news/indiana-regulators-reject-vectren-gas-plant-over-stranded-asset-concerns/553456/

[31] Mercure, J.-F., Pollitt, H., Viñuales, J. E., Edwards, N. R., Holden, P. B., Chewpreecha, U., . . . & Knobloch. F. (2018). Macroeconomic impact of stranded fossil fuel assets. *Nature Climate Change 8*, 588-593. doi: 10.1038/s41558-018-0182-1

[32] PSE Healthy Energy (2016, April 20). The science on shale gas development [infographic]. Retrieved from http://www.psehealthyenergy.org/data/PSE_FrackingStudy_Summary_Infographic_4-20-2016_00.jpg

[33] PSE Healthy Energy. Repository for Oil and Gas Research (ROGER). https://www.psehealthyenergy.org/our-work/shale-gas-research-library/

A follow-up analysis using the same criteria for inclusion found that 90.3 percent of all original research studies published from 2016-2018 on the health impacts of fracking found a positive association with harm or potential harm.[35]

Timeline of Bans and Moratoria

As a response to the proliferating evidence of the risks and harms of fracking—augmented by increasing concern about the many remaining uncertainties—various countries, states, and municipalities have instituted bans and moratoria.

France banned fracking in July 2011 and Bulgaria in January 2012.

In May 2012, the state of Vermont banned fracking and prohibited the storage and treatment of fracking waste.

In July 2012, a revision of environmental laws in Austria prompted the main Austrian oil and gas group to announce a stop to its shale gas plans in the country.

In April 2013, the Luxembourg parliament passed a motion against shale gas exploration in a decision that has not been revisted since.

In July 2014, the Flanders region of Belgium temporarily banned fracking. This ban is still valid.

The California counties of Santa Cruz, San Benito, and Mendocino counties all banned fracking in 2014.

New York State banned fracking in December 2014.

In January 2015, Scotland became the first country in Great Britain to impose a formal moratorium on fracking. In 2016, as part of the ongoing moratorium process, the government of Scotland released a series of reports that reconfirmed the evidence for potential contamination of air and water, threats to worker health from silica dust exposure, and risks to the health of nearby residents. It further noted that the pursuit of unconventional oil and gas extraction would make it more difficult for Scotland to achieve its climate targets on greenhouse gas emissions.[36, 37] Scotland's moratorium was extended "indefinitely" in October 2017. In March 2019, a decision to solidify that prohibition into a full legislative ban was delayed.

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[34] Hays, J., & Shonkoff, S. B. C. (2016). Toward an understanding of the environmental and public health impacts of shale gas development: An analysis of the peer-reviewed scientific literature, 2009-2015. *PLOS One, 11*(4), e0154164. doi: 10.1371/journal.pone.0154164

[35] Ferrar, K., Jackson, E., & Malone, S. (2019). Categorical review of health reports on unconventional oil and gas development: Impacts in Pennsylvania. FracTracker Alliance Issue Paper. Retrieved from https://www.delawareriverkeeper.org/sites/default/files/FracTrackerAlliance_DRKHealthReview_Final_4.25.19_0.pdf

[36] Health Protection Scotland. (2016, November). *A health impact assessment of unconventional oil and gas in Scotland,* vol. 1. Retrieved from http://www.hps.scot.nhs.uk/resourcedocument.aspx?resourceid=3102

[37] Committee on Climate Change. (2016, August). *Scottish unconventional oil and gas: Compatibility with Scottish greenhouse gas emissions targets*. Retrieved from http://www.gov.scot/Resource/0050/00509324.pdf

In February 2015 the government of Wales declared a moratorium on fracking "until it is proven safe." In July 2018, the Welsh government confirmed that shale gas was not compatible with decarbonization targets and said it would not support applications for fracking.

In March 2015, the Canadian province of New Brunswick declared a moratorium on fracking.

In July 2015, the Netherlands banned all shale gas fracking until 2020 on the grounds that "research shows that there is uncertainty" about impacts. In October 2018, the Dutch government announced that gas extraction of all kinds in the Groningen gas field would entirely cease by 2030 after public outcry over continuing earthquakes in the region. Gas production has already been cut by 60 percent since its peak in 2013. On May 22, 2019, Groningen was hit with a magnitude 3.4 earthquake that damaged multiple homes.[38]

In September 2015, Northern Ireland effectively banned fracking via strategic planning policies.

In December 2015, the plenary of the European Parliament affirmed the incompatibility of shale gas extraction via hydraulic fracturing with the European Union's commitment to decarbonization, and it acknowledged public concerns about the environmental and health impacts of fracking. While falling short of an outright EU-wide moratorium on fracking, the report states that "it is questionable whether hydraulic fracturing can be a viable technology in the European Union."[39]

In Florida, 90 municipalities have either banned fracking outright or passed resolutions opposing it. In the past three legislative sessions, a bipartisan coalition of lawmakers has introduced statewide ban legislation. During his 2018 campaign, Governor Ron DeSantis pledged publicly to issue a statewide ban. As of this publication, he has yet to do so.

Also in 2016, New Brunswick extended its moratorium on fracking "indefinitely," citing unresolved problems with the disposal of fracking wastewater, and in the Canadian province of Newfoundland and Labrador, where a moratorium had been in place since 2013, a government-appointed panel recommended that fracking remain "paused," citing data gaps and unresolved questions about the underlying geology.

In June 2016, Germany adopted a moratorium on "unconventional fracking" until 2021 but will permit exploratory drilling research projects.

Also in 2016, California's Butte and Alameda counties banned fracking, along with Monterey County, which also banned all new oil drilling.

In August 2016, the Australian state of Victoria declared a permanent ban on fracking on the grounds that the risks outweighed any potential benefits.

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[38] (2019, May 22). Groningen hit by strong earthquake as gas extraction impact continues. *DutchNew.nl.* Retrieved from https://www.dutchnews.nl/news/2019/05/groningen-hit-by-strong-earthquake-as-gas-extraction-impact-continues/

[39] Committee on Industry, Research and Energy. (2015, November 24). *Report on Towards a European Energy Union*, A8-0341/2015. Retrieved from http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2015-0341+0+DOC+XML+V0//EN

In September 2016, a California judge, arguing that the agency had failed to consider the dangers of fracking, struck down a bid by the BLM to open one million acres of public land in central California to oil drilling.

In November 2016, Winona County, Minnesota banned the mining of frack sand, a decision that was upheld in district court in November 2017. That ruling is now before the Minnesota Supreme Court.[40]

In December 2016, the Portland City Council in Oregon approved zoning code changes that banned the construction of new fossil fuel projects, including terminals for storing and transporting natural gas, and also prohibited the expansion of pre-existing facilities, including an LNG plant.

In March 2017, the Spanish region of Castilla Leon signed a political agreement to give up on shale gas exploration. This decision followed the implementation of several other regional bans in Spain or laws that otherwise made fracking unviable. These regions include Cantabria (April 2013), La Rioja (May 2013), Catalonia (February 2014), Basque Country (June 2015), and Castillo La Mancha (March 2017).

In April 2017, Maryland became the third U.S. state to ban fracking when Governor Larry Hogan signed a ban bill that was overwhelmingly approved by the state legislature. Maryland's ban followed a two-and-a-half-year statewide moratorium.

Also in April 2017, Entre Ríos passed the first province-wide ban on fracking in Argentina. This ban follows 50 individual municipal bans and is intended to protect the Guarani Aquifer, which extends beneath parts of Argentina, Brazil, Paraguay, and Uruguay.

In June 2017, France expanded its fracking ban to include a ban on all new oil and gas exploration.

In July 2017, Ireland banned fracking when legislation was signed into law by the president.

Also in October 2017, Canada's Prince Edward Island included a prohibition on fracking as part of its Water Act.

According to campaigners, Albania enacted a national ban on fracking in 2017, but these reports remain unconfirmed by official sources.

In December 2017, Uruguay prohibited fracking for four years.

In March 2018, the Australian state of Tasmania extended its moratorium on fracking until 2025.

In November 2018, the Delaware River Basin Commission—which consists of governors from the four states of New York, New Jersey, Pennsylvania, and Delaware together with the U.S. Army Corps of Engineers—released a proposed rule to ban fracking in the Delaware River watershed on the grounds that fracking exposes its waters to "significant, immediate, and long-term risks." As currently drafted, the rule provides for importation of wastewater from fracking

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[40] Rogers, C. (2019, April 17). Supreme Court considers frac ban. *Winona Post*. Retrieved from http://www.winonapost.com/Article/ArticleID/63818/Supreme-Court-considers-frac-ban

operations located outside the Basin for storage, processing, and discharge within the Basin. It also provides for water withdrawals from the Delaware River and its tributaries for export and use in such operations.[41, 42] The longest free-flowing river in the Northeast, the Delaware River provides drinking water to more than 15 million people (approximately five percent of the U.S. population). About one-third of the river system flows through shale formations. A de facto moratorium on fracking in the Delaware River Basin has been in place since 2010.

In December 2018, the newly elected president of Mexico announced a suspension of all further energy auctions for three years, temporarily halting permits for new fracking operations. This announcement is widely seen as a possible step by President Obrador toward fulfilling a campaign promise to ban fracking in Mexico.[43]

On May 8, 2019, Washington State enacted a statewide ban on fracking.

On May 29, 2019, the Oregon Senate passed a five-year fracking moratorium. On June 17, Governor Kate Brown signed the bill into law.

In Connecticut, where no fracking or potential fracking takes place, ordinances prohibiting the storage or use of imported fracking waste have been passed in 56 municipalities. As we went to press in June 2019, the State House of Representatives, in a near-unanimous vote, passed a bill that enacts a permanent statewide ban on the disposal of oil and gas extraction waste, following a unanimous vote by the Connecticut Senate in May. The bill now goes to Governor Ned Lamont for signing.

Also, as we went to press, the New York State Senate voted for a bill that would end special exemptions from hazardous waste laws that allow fracking waste to be imported from out of state and dumped in municipal waste landfills and wastewater treatment plants. The bill now goes to the State Assembly for consideration. In spite of the statewide fracking ban, seven different landfills across New York State accept liquid and solid fracking waste from Pennsylvania. Seven New York county legislatures have banned that practice.

In sum, as evidence continues to mount of its environmental and public health costs, legislative and governmental bodies are increasingly apprehensive about the risks and harms of fracking.

Nevertheless, in several notable cases, hard-won bans and other restrictions on fracking have been overturned.

A fracking ban passed by the city of Denton, Texas in November 2014 was invalidated in June 2015 by a state law, pushed by the oil and gas industry, that prohibits Texas municipalities from passing local bans.

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[41] Delaware River Basin Commission. (2017, November 30). Proposed new 18 CFR part 440—hydraulic fracturing in shale formations. Retrieved from http://www.nj.gov/drbc/library/documents/HydraulicFracturing/18CFR440_HydraulicFracturing_draft-for-comment_113017.pdf

[42] Hurdle, J. (2017, November 30). Fracking ban proposed for Delaware River basin; 'significant risks' cited. *StateImpact Pennsylvania.* Retrieved from https://stateimpact.npr.org/pennsylvania/2017/11/30/fracking-ban-proposed-for-delaware-river-basin-significant-risks-cited/

[43] Bertram, R. (2019, April 17). Will fracking be banned in Mexico? *Energy Transition*. Retrieved from

In June 2015, citing concerns about noise impacts and the industrialization of rural landscape, the county of Lancashire in northwest England halted plans for a major British fracking operation. Years previously, two wells—the first and only pair ever drilled in Lancashire—had suffered well integrity failures and caused earthquakes. However, in 2016, the national government overturned Lancashire's ban, and drilling began in October 2017 despite widespread, ongoing public opposition.

In May 2016, the Colorado Supreme Court struck down local fracking bans in the cities of Fort Collins and Longmont. A statewide ballot measure to increase well setback distances in Colorado subsequently failed in November 2018. In January 2019, the Colorado Supreme Court ruled against a case brought by six youth that would have halted new drilling permits pending a comprehensive study of health and environmental impacts. The ruling allows Colorado to continue to weigh costs and technical feasibility against adverse public health impacts. However, in April 2019, the Colorado State legislature passed a bill that grants municipalities more regulatory authority over fracking activities.

In December 2017, Australia's Northern Territory government delayed a decision on whether or not to extend or lift its own moratorium on fracking after a draft final report identified multiple risks to water, land, tourism, and indigenous culture. In April 2018, it lifted this moratorium.

In November 2018, the statewide moratorium in Western Australia was lifted over intense opposition, highlighting the limitations of aboriginal land rights. However, local bans in heavily populated areas of the state were left in place.

Introduction to Fracking

Since the end of the 20th century, horizontal drilling has been combined with high-volume hydraulic fracturing to create a novel approach to extracting dispersed oil and natural gas, primarily from shale bedrock, that would otherwise not flow to the surface. Typically, these unconventional extraction methods (collectively known as “fracking”) take place on clustered multi-well pads where individual wellbores extend vertically down into the shale formation and then turn horizontally, tunneling through the shale in various directions. These lateral tunnels can extend as far as two miles underground.

To liberate the gas (methane) or oil trapped inside the shale, many small explosive charges followed by high volumes of pressurized fluid are sent into the shale layer to expand and extend its many naturally occurring cracks, bedding planes, and faults. Silica sand grains (or sometimes ceramic beads) are carried by the pressurized fluid into these spaces and remain there after the pressure is released, acting to prop open these now-widened fissures in the shale and allowing the methane or oil trapped within to flow up the well.

Fracking fluid consists of millions of gallons of fresh water to which is added a sequence of chemicals that include biocides, lubricants, gelling agents, anti-scaling, and anti-corrosion agents. Some of the water used to frack wells remains trapped within the fractured zone and, as such, is permanently removed from the hydrologic cycle. The remainder travels back up to the surface. This flowback fluid contains not only the original chemical additives, many of which are toxic, but also harmful substances carried up from the shale zone, which often include brine, heavy metals, and radioactive elements.

Once in production, a fracked well continues to generate liquid throughout its lifetime. This produced water, which contains many of the same toxic substances as flowback fluid, is a second component of fracking waste, and it also requires containment and disposal. In addition, fracking waste includes solid drilling cuttings, which are typically laced with various chemical substances used to aid the drilling process. These cuttings, which can also contain radioactive elements, are typically disposed in municipal waste landfills. Fracking waste is exempt from federal hazardous waste regulations that would otherwise prohibit this practice.

Downstream elements of fracking infrastructure, which lie between the wellhead and the point of combustion, include processing plants, transport infrastructure such as pipelines and compressor stations, distribution lines storage facilities, gas-fired power plants, and LNG liquefaction plants and export terminals. Upstream elements include silica sand mining operations and water withdrawal operations.

As fracking operations in the United States have increased in frequency, size, and intensity, and as the transport of extracted materials has expanded, a significant body of evidence has emerged to demonstrate that these activities are dangerous to people and their communities in ways that are difficult—and may prove impossible—to mitigate. Risks include adverse impacts on water, air, agriculture, public health and safety, property values, climate stability, and economic vitality, as well as earthquakes.

Researching these complex, large-scale industrialized activities and the ancillary infrastructure that supports them takes time and has been hindered by institutional secrecy. Nonetheless, research is gradually catching up to the last decade's surge in fracking from shale. A growing body of peer-reviewed studies, accident reports, and investigative articles has detailed specific, quantifiable evidence of harm and has revealed fundamental problems with the entire life cycle of operations associated with unconventional drilling, fracking, and fracked-gas infrastructure. Industry studies, as well as independent analyses, indicate inherent engineering problems including uncontrolled and unpredictable fracturing, induced seismicity, extensive methane leakage, and well casing and cement failures that cannot be prevented with currently available materials and technologies.

Fracking-related problems also originate from sources independent of engineering. These include habitat destruction; inadequate solutions for wastewater disposal; the presence of abandoned wells or vertical fault lines that can serve as pathways for fluid migration into aquifers; and standard operational industry norms (venting, flaring, blowdowns) that contribute to methane releases and air pollution.

Earlier scientific predictions are now bolstered by extensive empirical data, confirming that the public health risks from unconventional gas and oil extraction are real, the range of adverse environmental impacts wide, and the negative economic consequences considerable. **Our examination of the peer-reviewed medical, public health, biological, earth sciences, and engineering literature uncovered no evidence that fracking can be practiced in a manner that does not threaten human health.**

Despite this expanding body of knowledge, industry secrecy continues to thwart scientific inquiry, leaving many potential problems—especially cumulative, long-term risks—unidentified, unmonitored, and largely unexplored. This problem is compounded by non-disclosure agreements, sealed court records, and legal settlements that prevent families and their doctors from discussing injuries and illnesses that result from fracking and frack-related operations. Consequently, no quantitative and comprehensive inventory of human hazards yet exists.

The long-entrenched problem of secrecy shows no sign of resolving. The identity of chemicals used in fracking fluids remains proprietary and lies beyond the reach of federal right-to-know legislation that governs other industries. The nation's largest public database on chemicals used in fracking operations, FracFocus, operates on a voluntary basis, and while 23 states have adopted it to serve as a *de facto* chemical disclosure registry, its data has, over time, become increasingly less, rather than more, comprehensive and transparent. As documented in a 2016 study by a Harvard University team, rates of withheld information and claims of trade secrecy have increased since FracFocus was first launched in 2011. (See footnotes 1445, 1446.)

The incomplete picture created by lack of transparency in regard to chemicals used, produced, emitted, or created during the drilling and fracking process complicates the task of identifying potential hazards and exposure pathways. Nevertheless, the evidence to date indicates that fracking operations pose severe threats to health, both from water contamination and from air pollution.

In the United States, more than two billion gallons of water and fracking fluids are injected daily under high pressure into the earth for the purpose of enabling oil and gas extraction via fracking or, after the fracking is finished, to flush the extracted wastewater down any of the more than 187,000 disposal wells across the country that accept oil and gas waste. All of that two billion daily gallons of fluid is toxic, and the wells that ferry it pass through our nation's groundwater aquifers on their way to the deep geological strata below, where the injection of fracking waste demonstrably raises the risk for earthquakes.

In the air around drilling and fracking operations and their attendant infrastructure, researchers have measured strikingly high levels of toxic pollutants, including the potent carcinogen benzene and the chemical precursors of ground-level ozone (smog). In some cases, concentrations of fracking-related air pollutants in communities where people live and work exceed federal safety standards. Research shows that air emissions from fracking can drift and pollute the air hundreds of miles downwind. (See footnotes 182-184.)

About one-third of the natural gas inventory in the United States is used to generate electricity, and, enabled by fracking, natural gas has, as of 2016, exceeded coal as the nation's leading source of electricity.[44] With hydraulically fractured wells now producing 70 percent of U.S. natural gas and half of U.S. crude oil, and with hydraulic fracturing used in 95 percent of new wells, the "unconventional" techniques of fracking can no longer be considered atypical nor can the question of their public health risks be considered inconsequential.[45, 46]

Drilling and fracking operations and their ancillary infrastructure have profoundly altered Earth's landscape. The flare stacks and artificial lights from major shale plays are visible from space,[47] as is the upward buckling of Earth's surface that is caused by the high-pressure injection of fracking wastewater into disposal wells.[48]

The dramatic increase in fracking over the last decade in the United States has pushed oil and gas extraction operations into heavily populated areas. In the Marcellus Shale alone, which underlies much of the Mid-Atlantic United States, 15,939 wells were drilled and fracked between 2008 and 2018.[49] More than 11,000 of these wells are in Pennsylvania.

At least six percent of the U.S. population—17.6 million Americans—now live within a mile of an active oil or gas well, a number that includes 1.4 million young children and 1.1 million

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[44] Magill, B. (2016, May 6). Fracking hits milestone as natural gas use rises in U.S. *Climate Central*. Retrieved from http://www.climatecentral.org/news/fracking-milestone-as-natural-gas-use-rises-20330

[45] U.S. Energy Information Administration. (2016, May 5). Hydraulically fractured wells provide two-thirds of U.S. natural gas production. *Today in Energy.* Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=26112

[46] U.S. Energy Information Administration. (2016, March 15). Hydraulic fracturing accounts for about half of current U.S. crude oil production. *Today in Energy*. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=26112

[47] NASA Earth Observatory. (2016, March 23). Shale revolution: As clear as night and day. Retrieved from http://earthobservatory.nasa.gov/IOTD/view.php?id=87725&src=eoa-iotd

[48] Coglan, A. (2016, September 22). You can see fracking's impact on Earth's surface from space. *New Scientist.* Retrieved from https://www.newscientist.com/article/2106886-you-can-see-frackings-impact-on-earths-surface-from-space/

[49] Jacquet, J. B., Junod, A. N., Bugden, D., Wildermuth, G., Fergen, J. T., Jalbert, K., . . . Ladlee, J. (2018). A decade of Marcellus Shale: Impacts to people, policy and culture from 2008 to 2018 in the Greater Mid-Atlantic region of the United States. *Extractive Industries and Society, 5*(4), 596-609. doi: 10.1016/j.exis.2018.06.006

elderly people.[50, 51] About 8.6 million people are served by a drinking water source that is located within a mile from an unconventional well. (See footnote 302.) Understanding the potential for exposure and accompanying adverse impacts is a public health necessity.

Emerging Trends

1) Regulations are simply not capable of preventing harm.

Studies reveal inherent problems in the natural gas and oil extraction process, such as well integrity failures caused by aging or the pressures of fracking itself, and in the waste disposal process. These issues lead to water contamination, greenhouse gas emissions, air pollution with carcinogens and other toxic chemicals, earthquakes, and a range of environmental and other stressors inflicted on communities.

Some of fracking's many component parts—which include the subterranean geological landscape itself—are simply not controllable.

Compounding the innate unpredictability of the fracking process: The number of wells and their attendant infrastructure continue to proliferate, creating burgeoning cumulative impacts, and the size of individual wells keep growing. With the horizontal portions of a single well now extending as far as two miles or more underground, fluid injections, once typically three to five million gallons per fracked well, now can easily reach 10 to 20 million gallons per well.

The injection of ever-increasing volumes of fluids into an ever-increasing number of wells creates significant deformations in the shale. These are translated upwards, a mile or more, to the surface. Along the way, these "pressure bulbs" can impact, in unpredictable ways, faults and fissures in the overlying rock strata, including strata that intersect fresh water aquifers. Such pressure bulbs may mobilize contaminants left over from previous drilling and mining activities. (See footnotes 370, 371.) No set of regulations can obviate these potential impacts to groundwater.

No set of regulations can eliminate earthquake risks. (See footnote 752.) In spite of growing knowledge about the mechanics of how fracking and the underground disposal of fracking waste trigger earthquakes via activation of faults, no model can predict where or when earthquakes will occur or how powerful they will be. New research demonstrates that induced earthquakes can occur many miles from fracking sites. (See footnote 73.)

Regulations cannot prevent air pollution. The state of California determined that fracking can have "significant and unavoidable" impacts on air quality, including driving pollutants to levels that violate air quality standards. (See footnote 173.) In northeastern Colorado, ambient levels of atmospheric hydrocarbons have continued to increase even with stricter emission standards. (See

[50] Czolowski, E. D., Santoro, R. L., Srebotnjak, T., & Shonkoff, S. B. C. (2017). Toward consistent methodology to quantify populations in proximity to oil and gas development: A national spatial analysis and review. *Environmental Health Perspectives, 125*(8). doi: 10.1289/EHP1535
[51] Konkel, L. (2017). In the neighborhood of 18 million: Estimating how many people live near oil and gas wells. *Environmental Health Perspectives, 125*(8). doi: 10.1289/EHP2553

footnote 188.) Tighter state regulations and tougher enforcement, including unannounced visits by state health inspectors equipped with infrared cameras, have reduced leaking methane and toxic vapors at individual well sites, but total air emissions continue to rise as the total number of wells continues to increase. At this writing, there are 53,000 active oil and gas wells in Colorado.[52]

Leakage rates among active wells are wildly variable: Four percent of wells nationwide are responsible for fully half of all methane emissions from drilling and fracking-related activities. Predicting which wells will become "super-emitters" is not possible, according to a 2016 survey of 8,000 wells using helicopters and infrared cameras. Further, much of this leakage is engineered into the routine operation of fracking extraction, processing, and transport infrastructure, as when vapors are vented through release valves in order to regulate pressure. (See footnotes 994, 995.)

Long after they are decommissioned, well sites continue to leak in ways that are not always fixable. Abandoned wells are a significant source of methane leakage into the atmosphere, and, based on findings from New York and Pennsylvania, may exceed cumulative total leakage from oil and gas wells currently in production. Plugging abandoned wells does not always reduce methane emissions, and cement plugs themselves deteriorate over time. (See footnote 475.)

Further, countless abandoned wells are unmapped and their locations unknown. Many have no apparent owner. Across the nation, there are as many as three million abandoned wells. Pennsylvania alone is home to 200,000 to 750,000 abandoned wells, most of which are not charted or even visible on the surface.[53] No state or federal agency routinely monitors methane leakage from abandoned wells. (See footnotes 854, 859.) In Alberta, Canada, there are roughly 90,000 inactive wells in need of plugging, a number that is expected to double in the next eleven years. The Alberta Energy Regulator has estimated that the time required to plug and prepare 180,000 wells for clean-up and reclamation is 126 years. Another 77,000 wells in Alberta are plugged but not yet reclaimed.[54]

2) Fracking and natural gas are incompatible with climate solutions.

On the grounds that natural gas emits, when combusted, only 53 percent of the carbon dioxide emitted by coal, early promoters of fracking argued that natural gas could serve as a "bridge fuel" while renewable energy sources ramp up. Scientific evidence now disproves these claims and shows that natural gas is as damaging to the climate as coal, and may be worse.

Natural gas is 85-95 percent methane, a short-lived but much more potent greenhouse gas than formerly appreciated. The Intergovernmental Panel on Climate Change estimates that, over a 20-

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[52] Finley, B. (2019, April 21). Colorado's unannounced air-pollution inspections at oil and gas sites are showing results—yet emissions are up as production continues. *Denver Post*. Retrieved from https://www.denverpost.com/2019/04/21/colorado-air-pollution-oil-gas-sites/

[53] Lee, M. (2019, May 20). Millions of abandoned wells spark climate, safety fears. *E&E News*. Retrieved from https://www.eenews.net/stories/1060364121

[54] Riley, S. J. (2019, April 8). Regulator projects Alberta's inactive well problem will double in size by 2030, documents reveal. *The Narwhal*. Retrieved from http://thenarwhal.ca/regulator-projects-albertas-inactive-well-problem-will-double-in-size-by-2030-documents-reveal/

year time frame—longer than the dozen years remaining to limit global warming to 1.5^{o} C—methane can, pound for pound, trap 86 times more heat than carbon dioxide. (See footnote 1045.)

Real-world methane leakage rates from drilling and fracking operations greatly exceed earlier estimates. Methane escapes into the atmosphere from all parts of the extraction, processing, and distribution system, all the way to the burner tip. In the heavily drilled Barnett Shale of northeastern Texas, methane emissions were shown to be 50 percent higher than the EPA had estimated. Fracking operations and associated infrastructure contributed 71-85 percent of the methane emissions in the region. A 2018 analysis of methane leaks from the U.S. oil and gas supply chain as a whole found leakage rates were 60 percent higher than reported by the EPA, and a 2019 study in southwestern Pennsylvania found shale gas emissions that were underreported by a factor of five when compared to EPA estimates. (See footnotes 944, 962.)

Much of the methane emitted from drilling and fracking activities and associated infrastructure originates not from accidental leaks but from purposeful losses that are inherent to the design of the industry's machinery or to normal operating use and are, therefore, not possible to mitigate. (See footnotes 1147-1149.) Methane is vented into the atmosphere during routine maintenance on compressor stations and pipelines; to create evaporative cooling for LNG storage and transport; during the flowback period after a well is fracked; and as an emergency procedure to control pressures. Inactive, abandoned wells are also significant methane emitters. Methane leakage at the levels now being documented, using multiple approaches in measurement and modeling, negates previously hypothesized benefits from burning methane instead of coal in most existing power plants.

Rising methane levels in the atmosphere make increasingly difficult the urgent task of limiting global warming to below levels called for in the Paris Agreement, which was based on older presumptions that global methane levels had plateaued. Instead, methane levels began to rise in 2007 and then shot up sharply in 2014.

At this writing, the cause of this ongoing methane surge is a subject of scientific debate. One hypothesis holds fossil fuel sources as the major driver. Another attributes the increase to biogenic sources, especially ruminant livestock. A third possibility is that rising global temperatures may be triggering methane release from wetlands, particularly in the southern tropics. Alternatively, the atmosphere's ability to break methane molecules apart may have become impaired, slowing the natural decay rate of methane.[55]

The fossil fuel hypothesis is supported by a major 2017 study led by NASA researchers using satellite measurements and isotopic analysis that can distinguish methane produced by microbes from methane emissions arising from oil and gas extraction. (See footnote 963.) Building on this research in a forthcoming study, Cornell University earth systems scientist Robert Howarth used isotopic analysis to identify shale gas and oil extraction as the source of at least one-third of total

[55] Fletcher, S. E. M., & Shaefer, H. (2019). Rising methane: A new climate challenge. *Science, 364*(6444), 932-933. doi: 10.1126/science.aax1828

methane emissions, showing that the North American fracking boom is globally important in the current rise in global methane levels and “may well be the leading cause of the increased flux.”[56]

Climate researcher Euan Nisbet, who has called for a renewed emphasis on reducing methane emissions to combat climate change, notes that, whatever the relative contribution of its various sources, fossil fuel extraction represents a powerful lever for intervention. “If the increased methane burden is driven by increased emissions from natural sources, and if this is a climate feedback—the warming feeding the warming—then there is urgency to reduce anthropogenic emissions, which we can control.” Reducing methane emissions from fossil fuels is the highest priority because they are relatively large and “thus offer attractive targets for rapid reduction, which are essential if the Paris Agreement aims are to be attained.” (see footnote 952.)

3) Fracking and the disposal of fracking waste threaten drinking water.

Cases of drinking water sources contaminated by drilling and fracking activities, or by associated waste disposal, are proven. Contamination occurs through three confirmed pathways: spills; discharge of fracking waste into rivers and streams; and underground migration of chemicals, including gas, into drinking water wells.

Methane and fracking-related contaminants can reach drinking water sources through cracks in well casings, through spaces between the casing and the wellbore, through naturally occurring fractures and fissures connecting shale layers with aquifers, and through abandoned wells. Methane migration into drinking water aquifers can change water chemistry in ways that mobilize metals or release hydrogen sulfide. (See footnote 248.)

Researchers working in Texas found 19 different fracking-related contaminants—including cancer-causing benzene—in hundreds of drinking water samples collected from the aquifer overlying the heavily drilled Barnett Shale, thereby documenting widespread water contamination. In Pennsylvania, a solvent used in fracking fluid was found in drinking water wells near drilling and fracking operations known to have well casing problems. In California, state regulators admitted that they had mistakenly allowed oil companies to inject drilling wastewater into aquifers containing clean, potable water. (See footnotes 352, 356, 360.) A 2017 study found that fracking wastewater discharged into rivers and streams through treatment plants created dozens of brominated and iodinated disinfection byproducts that are particularly toxic and “raise concerns regarding human health.” (See footnote 286.)

Fracking also threatens drinking water supplies through water depletion, especially in arid regions. According to a 2019 report, the volume of water used for fracking U.S. oil wells has more than doubled since 2016. (See footnote 245.) Oil and gas operations in the arid Permian Basin used eight times more water for fracking in 2018 as they did in 2011, threatening groundwater supplies. (See footnote 17.) In Arkansas, researchers found that water withdrawals for fracking operations deplete streams used for drinking water and recreation.

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[56] Howarth, R. W. (2019). Is shale gas a major driver of recent increase in global atmospheric methane? *Biogeosciences.* Manuscript under review. doi: 10.5194/bg-2019-131

With increasing volumes of wastewater now exceeding the storage capacity for underground injection wells—and with underground injection linked to earthquake risk—Texas, Colorado, and New Mexico are now petitioning the EPA to allow release of fracking wastewater into rivers and streams and to allow its use for irrigation and watering livestock. These practices further imperil drinking water sources.[57]

The trend toward mega-fracking, with longer and more extensive horizontal wellbores per well pad, coupled with the ongoing proliferation in the number of wells, has pushed the demand for water use in fracking operations ever higher, exacerbating both the problem of drinking water depletion and the problem of how to dispose of ever-increasing amounts of toxic fracking wastewater. A 2018 study found that water used for U.S. fracking operations increased by 770 percent per well between 2011 and 2016, while the amount of wastewater generated increased by 1,440 percent. (See footnote 259.)

As we went to press, a new study in Pennsylvania shows that, of the wastewater that remains in-state, 52 percent is reused in additional extraction operations, a practice that further concentrates chemical contaminants, including radioactive substances. The final destination for 35 percent of the total volume of liquid oil and gas waste generated in Pennsylvania from 1991-2017 is unknown because of gaps in reporting systems.[58]

4) Drilling and fracking contribute to toxic air pollution and ground-level ozone at levels known to have health impacts.

More than 200 airborne chemical contaminants have been detected near drilling and fracking sites. Of these, 61 are classified as hazardous air pollutants, including carcinogens; 26 are endocrine-disrupting compounds that have been linked to reproductive, developmental, and neurological damage. (See footnotes 134, 146.) Drilling and fracking operations emit fine particles and vapors that combine to create ground-level ozone (smog). Exposure to these pollutants is known to cause premature death, exacerbate asthma, and contribute to poor birth outcomes and increased rates of hospitalization and emergency room visits.

Of the lower 48 states, six states (Texas, Oklahoma, Colorado, North Dakota, West Virginia, and Pennsylvania) produce nearly 70 percent of the nation's natural gas and over 74 percent of onshore crude oil. These six states experience the highest levels of ground-level ozone and fine particle pollution attributable to oil and gas extraction activities.

Volatile organic compounds (VOCs) from drilling and fracking operations, together with nitrogen oxides, are responsible for 17 percent of locally produced ozone in Colorado's heavily drilled Front Range. (See footnote 160.) Colorado has exceeded federal ozone limits for the past decade, a period that corresponds to a boom in oil and gas drilling (See footnote 158.) Air

[57] Lee, M. (2018, December 20). Oil patch states want authority for wastewater solutions. *E&E News.* Retrieved from https://www.eenews.net/stories/1060110201

[58] Hill, L. A. L., Czolowski, E. D., DiGiulio, D., & Shonkoff, S. B. C. (2019). Temporal and spatial trends of conventional and unconventional oil and gas waste management in Pennsylvania, 1991-2017. *Science of the Total Environment, 674*, 623-636. doi: 10.1016/j.scitotenv.2019.03.475

pollution near drilling and fracking operations is high enough in some Colorado communities to raise cancer risks, according to a 2018 study. (See footnote 145.)

Living near drilling and fracking operations significantly increases asthma attacks for residents of Pennsylvania. Those living near active gas wells are 1.5-4 times more likely to suffer from asthma attacks than those living farther away, with the closest group having the highest risk. (See footnotes 636, 637.)

In California, fracking occurs disproportionately in areas already suffering from serious air quality problems and can drive ozone and other federally regulated air pollutants to levels that violate air quality standards. (See footnotes 172, 173.) This increased air pollution and smog formation poses a serious risk to all those already suffering from respiratory issues, such as children with asthma. With an average of 203 high-ozone days a year, intensely fracked Kern County, California, is the fifth-most ozone-polluted county in the nation, according to the American Lung Association.

Several studies have documented a sharp uptick in atmospheric ethane, a gas that co-occurs with methane and whose presence is attributable to emissions from oil and gas wells. This trend reverses a previous, decades-long decline. Ethane is a potent precursor to ground-level ozone (See footnote 162-164.)

The United States leads the world in the number of drill site flaring operations. Flares are used to control pressure but, more frequently, to burn off natural gas as waste during oil drilling in places that lack infrastructure for gas capture and transport. The ongoing boom in domestic oil production enabled by fracking has caused natural gas flaring to proliferate. Emissions from flare stacks contribute to ozone creation and include several carcinogens, notably benzene and formaldehyde. Flaring also releases carbon monoxide, soot, and toxic heavy metals. In 2016, the EPA acknowledged that it had dramatically underestimated health-damaging air pollutants from flaring operations. (See footnotes 156, 157.) A 2017 study of plume samples from gas flares in North Dakota found that incomplete combustion from flaring is responsible for 20 percent of the total emissions of methane and ethane from the Bakken shale fields—more than double the expected value. (See footnote 152.) Results of a 2019 study of flaring in the Eagle Ford Shale region of Texas suggest that flaring may be a significant environmental exposure in counties where flare stacks are concentrated. (See footnote 137.)

5) Public health problems associated with drilling and fracking include poor birth outcomes, reproductive and respiratory impacts, and cancer risks.

Poor pregnancy outcomes and exacerbation of asthma have been linked to fracking activities in multiple studies in multiple locations using a variety of methodologies. (See footnote 1410.)

Studies of mothers living near oil and gas extraction operations consistently find impairments to infant health, including elevated risks for low birth weight and preterm birth. A 2017 study that examined birth certificates for all 1.1 million infants born in Pennsylvania between 2004-2013 found indicators of poorer infant health and significantly lower birth weights among babies born to mothers living near fracking sites. A 2015 Pennsylvania study found a 40 percent increase in the risk of preterm birth among infants born to mothers who lived nearby active drilling and fracking sites, while a 2014 Colorado study found elevated incidence of neural tube defects and congenital heart defects. New studies in Texas and Colorado likewise found associations with infant deaths, high-risk pregnancies, and low birth weight. A 2017 pilot study in British Columbia found elevated levels of muconic acid—a marker of benzene exposure—in the urine of pregnant women living near fracking sites. (See footnotes 625, 627, 642, 664.)

As we went to press, a new pilot study reported elevated levels of barium and strontium in urine and hair samples of indigenous women living in an area of intense fracking activity in northeastern British Columbia. These trace metals, known to be released during hydraulic fracturing, are known developmental toxicants.[59]

An emerging body of evidence, from both human and animal studies, shows harm to fertility and reproductive success from exposure to oil and gas operations, at least some of which may be linked to the dozens of known endocrine-disrupting chemicals used in hydraulic fracturing. (See footnotes 642, 1438, 1443, 1444.)

Other documented adverse health indicators among residents living near drilling and fracking operations variously include exacerbation of asthma as well as increased rates of hospitalization, ambulance runs, emergency room visits, self-reported respiratory problems and rashes, motor vehicle fatalities, trauma, drug abuse, and gonorrhea. Pennsylvania residents with the highest exposure to active fracked gas wells were nearly twice as likely to experience a combination of migraine headaches, chronic nasal and sinus symptoms, and severe fatigue. (See footnote 634.)

A 2017 Colorado study found higher rates of leukemia among children and young adults living in areas dense with oil and gas wells, while a Yale University research team reported that carcinogens involved in fracking operations had the potential to contaminate both air and water in nearby communities in ways that may increase the risk of childhood leukemia. The Yale team identified 55 known or possible carcinogens that are known to be used in fracking operations and that may be released into the air and water. Of these, 20 are linked to leukemia or lymphoma. (See footnotes 632, 1424.)

As we went to press, the *Pittsburgh Post-Gazette* documented 27 cases of Ewing's sarcoma, a rare bone cancer that tends to strike young people, in four counties in southwestern Pennsylvania that are at the center of the Marcellus Shale fracking boom.[60] Six cases occurred in the same school district. (The typical rate is 250 cases of Ewing's sarcoma per year in the United States as a whole. The cancer has no known cause.) There are also high numbers of other childhood cancers in the region, which is home to several polluting legacy industries. The Pennsylvania Department of Health reported "no conclusive findings" of a cancer cluster in the Canon-

[59] Caron-Beaudoin, ., Bouchard, M., Wendling, G., Barroso, A., Bouchard, M. F., Ayotte, P., . . .Verner, M. A. (2019). Urinary and hair concentrations of trace metals in pregnant women from Northeastern British Columbia: A pilot study. *Journal of Exposure Science & Environmental Epidemiology.* Advance online publication. doi: 10.1038/s41370-019-0144-3

[60] Templeton, D., & Hopey, D. (2019, May 14). Are the 27 cases of Ewing's sarcoma near Pittsburgh a cluster? *Pittsburgh Post-Gazette.* Retrieved from https://newsinteractive.post-gazette.com/blog/ewing-sarcoma-cancer-cluster-pittsburgh-washington-westmoreland/

McMillan School District and Washington County, but as additional cases have come to light, calls for more comprehensive investigations are ongoing.[61, 62, 63, 64, 65]

6) Occupational health and safety risks for workers are severe and include both physical and chemical hazards.

Drilling and fracking operations are exempt from federal Occupational Safety and Health Administration (OSHA) standards designed to prevent catastrophic releases of toxic, flammable, or explosive chemicals in workplaces. They are also exempt from OSHA rules written for the construction industry designed to prevent falls and other accidents on the job. Although announced by the agency as forthcoming in 1983, federal safety regulations for the oil and gas industry have never materialized.[66, 67] Instead, inspectors can only apply the "general duty clause" which is widely recognized as grossly inadequate for an industry with unique hazards and a fatality rate far above the national average. Fatality rate data for the oil and gas industry are limited, but available data in the seven years leading up to 2015 show fatality rates in oil and gas extraction that are four to seven times the national fatality rate. In 2017, the most recent year for which data are available, 81 oil and gas extraction workers died on the job, accounting for 72 percent of the fatal work injuries in the mining sector, which overall has a fatality rate nearly four times the national average.[68, 69]

Studies in specific states, as well as some national studies, have provided additional details on regional rates and circumstances of injuries and deaths. Fatality rates among workers in the oil and gas extraction sector in North Dakota were seven times the national fatality rates in this industry, which itself has more deaths from fires and explosions than any other private industry.

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[61] Templeton, D., & Hopey, D. (2019, March 28). CDC, state officials investigating multiple cases of rare cancer in southwestern Pa. *Pittsburgh Post-Gazette.* Retrieved from https://www.post-gazette.com/news/health/2019/03/28/Ewing-sarcoma-Washington-Westmoreland-cancer-Canon-McMillan-school-cecil-pennsylvania/stories/201903280010

[62] Templeton, D. (2019, April 23). No Ewing sarcoma cluster in the Canon-McMillan School District, state says. *Pittsburgh Post-Gazette.* Retrieved from https://www.post-gazette.com/news/health/2019/04/23/Ewing-sarcoma-cluster-Canon-McMillan-Pennsylvania-Health-Department/stories/201904230128

[63] Schiller, M. (2019, April 24). Families affected by rare cancer demand answers after Pa. health dept. investigation results in "no conclusive findings." *KDKA2, CBS Pittsburgh.* Retrieved from https://pittsburgh.cbslocal.com/2019/04/24/families-demand-answers-pa-health-dept-cancer-cluster-findings/

[64] Templeton D., & Hopey, D. (2019, May 14). The human toll—risk and exposure in the gas lands. *Pittsburgh Post-Gazette.* Retrieved from https://newsinteractive.post-gazette.com/blog/childhood-cancer-pittsburgh-pennsylvania-canon-mcmillan-pollution/

[65] Editorial Board (2019, May 22). Young lives at stake: Rural areas deserve answers on child cancers. *Pittsburgh Post-Gazette*. Retrieved from Young lives at stake: rural areas deserve answers on child cancers

[66] Jones, C. (2018, February 3). OSHA standards moot in Quinton rig explosion because of exemption for oil-and-gas industry. *Tulsa World*. Retrieved from http://www.tulsaworld.com/news/state/osha-standards-moot-in-quinton-rig-explosion-because-of-exemption/article_162d0efa-7860-5f4b-b982-ebdeb142c075.html

[67] Lee, M. (2019, June 13). Feds: Deadliest drilling accident in a decade 'preventable.' *E&E News.* Retrieved from https://www.eenews.net/stories/1060564501

[68] AFL-CIO. (2019). *Death on the job: The toll of neglect.* 28th Edition, Retrieved from https://aflcio.org/sites/default/files/2019-05/DOTJ2019Fnb_1.pdf

[69] Bureau of Labor Statistics. (2018). *Injuries, illnesses, and fatalities.* U.S. Department of Labor. Retrieved from https://www.bls.gov/iif/oshwc/cfoi/cfoi-chart-data-2017.htm

An increase in workplace deaths likewise accompanied the initial fracking boom period in West Virginia.

Between 2011 and 2016, at least 60 workers at oil and gas drilling sites in Oklahoma were killed on the job. In January 2018, a natural gas rig exploded in southeastern Oklahoma, killing five workers when natural gas exploded during the drilling process. A "factual update" issued in August 2018 as part of an ongoing investigation by the U.S. Chemical Safety Board (CSB), determined that a piece of safety equipment was unable to fully close on the day of the accident and that other safety corners had been cut (See footnotes 532, 533, 537.) As we went to press, the CSB, released the final report on the accident, emphasizing that, in fact, two preventive barriers designed to prevent uncontrolled gas blowouts had failed as a consequence of significant lapses in safety protocols. Warning alarms did not sound. All five workers who died were trapped inside the driller's cabin when fire blocked both exit doors. This problem, inherent to the design of the cabin, is not exceptional. The CSB investigation found that "there is no guidance to ensure that an emergency evacuation option is present onboard these rigs or can protect workers in the driller's cabin from fire hazards."[70, 71]

Pipeline construction workers also suffer elevated rates of injuries and fatalities, dying on the job 3.5 times more than workers in other industries.

All together, according to a 2018 investigation, 1,566 U.S. workers in the oil and gas drilling industry died from on-the-job injuries in the decade between 2008 and 2017.

A University of Tennessee study assessed the occupational inhalation risks from the hazardous and carcinogenic air pollutants emitted from various sources around fracking wells and found that chemical storage tanks presented the highest cancer risk. Benzene has been detected in the urine of welllpad workers in Colorado and Wyoming. The National Institute for Occupational Safety and Health named oil and gas extraction industry workers among those at risk for silicosis, an incurable lung disease caused by exposure to silica dust, from the silica sand that is used extensively in fracking operations. (See footnotes 548, 586, 594.)

7) Earthquakes are a proven consequence of both fracking and the underground injection of fracking waste.

Injection of fracking wastewater into underground disposal wells is a known trigger of earthquake swarms in multiple locations, as demonstrated by several major studies, using different methodologies. Newer research in Canada, Oklahoma, and China links the practice of fracking itself to earthquakes, including some that take place many miles from well sites and

[70] U.S. Chemical Safety and Hazard Investigation Board. (2019, June 12). *Gas blowout and fire at Pryor Trust Well 1H-9.* Investigation Report No. 2018-01-I-OK. Retrieved from Pryor_Trust_Report_FINAL_FOR_PUBLICATION.pdf
[71] U.S. Chemical Safety and Hazard Investigation Board (2019, June 12). CBS issues final report into fatal gas well blowout [Press release]. Retrieved from https://www.csb.gov/csb-issues-final-report-into-fatal-gas-well-blowout/

many years later, suggesting that seismic risks have been previously underestimated with much larger areas at risk and for longer periods of time.[72, 73]

A 2017 study of the Fort Worth Basin showed that a recent swarm of small earthquakes in northern Texas was originating in long-inactive fault lines in deep formations where fracking wastewater was being injected. Human activity is the only plausible explanation. (See footnote 499.) Another study using satellite-based radar imagery provided proof that the migration of fracking wastewater into faults increased pressures in ways that triggered a 4.8-magnitude earthquake in east Texas in 2012, while a third study documented the rupture of a fault plane that set off a 4.9-magnitude earthquake in Kansas in 2014 immediately following a rapid increase in fracking wastewater injection nearby. (See footnotes 747, 748.)

The number of earthquakes of magnitude 3.0 or higher skyrocketed in Oklahoma starting with the advent of the fracking boom—with fewer than two per year before 2009 and more than 900 in 2015. The 5.8 earthquake that struck near Pawnee on September 3, 2016 was the strongest in Oklahoma's history and prompted an order from state regulators to shut down 67 wastewater disposal wells in the area. (See footnotes 745, 746.) In October 2016, the EPA recommended a moratorium on the underground injection of fracking wastewater in certain earthquake-prone parts of Oklahoma because regulations had not solved the problem. (See footnote 743.) Earthquake frequency began to decline in the state in 2017. In February 2018, after a new cluster of earthquakes, the state further restricted fracking activities.[74]

There is no evidence that fracking-induced earthquakes can be prevented solely by limiting the rate or volume of injected fluid. A 2018 analysis of shale basins across the United States found that shallower disposal wells can help lower the risk of earthquakes. However, injection of fracking waste into shallow formations increases the risk of groundwater contamination. (See footnote 707.)

In China's Sichuan Province, a series of recent earthquakes have been linked to fracking, including one in December 2018 with a magnitude of 5.7, the largest fracking-induced earthquake to date. The likely cause was reactivation of unmapped faults by underground fluid pressure.[75] In February 2019, three additional earthquakes, all with a magnitude of over four, struck Sichuan Basin, killing two people, injuring 13, and damaging 20,000 homes. The government temporarily suspended fracking operations in the area.[76]

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[72] Bhattacharya, P., & Viesca, R. C. (2019). Fluid-induced aseismic fault slip outpaces pore-fluid migration. *Science, 364*(6439), 464-468. doi: 10.1126/science.aaw7354

[73] Foulger, G. (2019, May 14). Fracking can cause earthquakes a long way from its site. *Cosmos*. Retrieved from https://cosmosmagazine.com/geoscience/fracking-can-cause-earthquakes-a-long-way-from-its-site

[74] Wethe, D. (2018, February 28). Oklahoma toughens oil fracking rules after shale earthquakes. *Bloomberg*. Retrieved from https://www.bloomberg.com/news/articles/2018-02-27/oklahoma-toughens-oil-fracking-rules-as-shale-earthquakes-climb

[75] Lei, X., Wang, Z., & Su, J. (2019). The December 2018 M_L 5.7 and January 2019 M_L 5.3 earthquakes in south Sichuan Basin induced by shale gas hydraulic fracturing. *Seismological Research Letters*, *90*(3), 1099-1110. doi: 10.1785/0220190029

[76] Myers, S.L. (2019, March 8). China experiences a fracking boom, and all the problems that go with it. *New York Times.* https://www.nytimes.com/2019/03/08/world/asia/china-shale-gas-fracking.html

8) Fracking infrastructure poses serious potential exposure risks to those living nearby.

Drilling and fracking activities are relatively short-term operations, but compressor stations are semi-permanent facilities that pollute the air 24 hours a day as long as gas is flowing through pipelines. Day-to-day emissions from compressor stations are subject to highly episodic variations due to pressure changes and maintenance-related deliberate releases and can create periods of potentially extreme exposures. Compressor stations generally have shorter emissions stacks than other polluting facilities such as power plants, which means their harmful emissions are more concentrated at ground level than if released from a greater height. As we went to press, a new study of air emissions from 74 compressor stations in New York State found 39 chemicals known to be human carcinogens and documented large releases of greenhouse gases.[77]

Because of their high pressures, compressor station explosions can have catastrophic consequences. On January 30, 2019, a compressor station in rural Michigan malfunctioned during a period of extreme cold and released a large amount of methane gas that ignited and exploded. On May 13, 2019, Boston-area physicians released a report detailing safety-related risks at a proposed natural gas compressor station in Weymouth, Massachusetts. In a worst case scenario explosion, injuries could extend for thousands of feet into densely populated residential neighborhoods, ignite an nearby industrial diesel fuel storage tank, and kill motorists driving on an adjacent highway.[78]

Pipelines themselves can freeze, corrode, break, and leak. Low-pressure flow lines alone are responsible for more than 7,000 spills and leaks since 2009. (See footnote 1120.)

Significant pipeline accidents happen roughly 300 times each year in the United States and, between 1998 and 2017, killed 299 people and injured 1,190 others, according to the Pipeline and Hazardous Materials Safety Administration (PHMSA). In May 2019, PHMSA sent a warning to pipeline operators about increased risks of leaks and explosions caused by more frequent flooding, sinkholes, and severe rainfall patterns in the eastern United States.[79] In September 2018, heavy rains and landslides triggered the explosion of a pipeline in Beaver County, Pennsylvania, destroying a house.[80] All together, landslides have caused six pipeline explosions in the Appalachian region since early 2018.[81]

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[77] Russo, P. N., & Carpenter, D. O. (2019). Air emissions from natural gas facilities in New York State. *International Journal of Environmental Research and Public Health, 16*(9), E1591. doi: 10.3390/ijerph16091591

[78] Baker, A., Bivens, M., Clapp, R., LaRocque, R., & Lundberg, B. (2019, May 13). Flammable, high-pressure industry in a populated coastal flood zone? Public safety and emergency response aspects of a proposed methane gas compressor in Weymouth. Greater Boston Physicians for Social Responsibility. Retrieved from https://www.psr.org/blog/resource/flammable-high-pressure-industry-in-a-populated-coastal-flood-zone/

[79] Pipeline Hazardous Materials Safety Administration. (2019, May 2). Pipeline safety: Potential for damage to pipeline facilities caused by earth movement and other geological hazards. *Federal Register.* Retrieved from https://www.federalregister.gov/documents/2019/05/02/2019-08984/pipeline-safety-potential-for-damage-to-pipeline-facilities-caused-by-earth-movement-and-other

[80] Phillips, S. (2019, May 21). Federal pipeline safety regulators issue warning on floods and subsidence. *StateImpact Pennsylvania.* Retrieved from https://stateimpact.npr.org/pennsylvania/2019/05/21/federal-pipeline-safety-regulators-issue-warning-on-floods-and-subsidence/

[81] Soraghan, M. (2019, June 4). Landslides, explosions spark fear in pipeline country. *E&E News.* Retrieved from https://www.eenews.net/stories/1060472727

Gas-fired power plants are major emitters of carbon monoxide and nitrogen oxides, which contribute to smog.

In the Upper Midwest, Wisconsin residents living near silica sand mining operations that service the fracking industry reported dust exposure and respiratory problems. Silica dust is a known cause of silicosis and lung cancer. West Texas is also experiencing a fracking sand boom where roughly 20 new sand mines have opened since July 2017. (See footnote 17.)

Fracking infrastructure in the United States also includes 400 underground gas storage facilities in 31 states, with aging equipment and scant federal oversight. The four-month leak at the nation's fifth largest facility, Aliso Canyon in southern California, between October 2015 and February 2016 resulted in exposures of a large suburban population to an uncontrollable array of chemicals. With a release of nearly 100,000 metric tons of methane, it became the worst methane leak in U.S. history. (See footnote 1185.)

The Aliso Canyon blow-out exposed residents in the region to benzene spikes, high ongoing odorant releases, hydrogen sulfide at levels far above average urban levels, and many other contaminants of concern. More than 8,300 households were evacuated and relocated, with residents reporting multiple symptoms, including headaches, nosebleeds, eye irritation, and nausea. In May 2019, state investigators announced that the cause of the massive leak at Aliso Canyon was rupture of a well casing caused by microbial corrosion within a well that had been originally drilled in 1954. Over the years, the casing had come in contact with groundwater.[82] The report also faulted the operator, SoCalGas, for failure to monitor and investigate more than 60 previous leaks at the gas storage complex.[83]

In a 2018 analysis of the safety risks of all 14 facilities in California that store gas in depleted oil fields, the California Council of Science and Technology found that gas companies do not disclose the chemicals they are pumping underground nor do state regulators possess the necessary information to assess risks. Further, many wells servicing the storage fields are 60 to 90 years old with no regulatory limit to the age of the well. (See footnote 1178.)

LNG facilities—and the pipelines, coastal terminals, and ships that service them—are a rapidly growing component of fracking infrastructure as the shale gas boom has allowed the United States to seek long-term supply contracts for natural gas exports. In July 2017, the United Kingdom received its first delivery of LNG from the Sabine Pass export terminal in Louisiana. The Cove Point LNG export facility in Maryland sent its first shipments of Marcellus Shale gas, destined for Japan and India, in spring 2018. The United States is now a top international seller of natural gas with LNG exports expected to double by the end of 2019. At this writing, three LNG export terminals are in operation in the United States with another 22 in construction or approved for construction.[84, 85]

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[82] Blade Energy Partners. (2019, May 16). *Root cause analysis of the uncontrolled hydrocarbon release from Aliso Canyon. SS-25.* California Public Utilities Commission. Retrieved from ftp://ftp.cpuc.ca.gov/News_and_Outreach/SS-25%20RCA%20Final%20Report%20May%2016,%202019.pdf

[83] Zaveri, M. (2019, May 17). Corroded well lining caused Aliso Canyon gas leak that displaced thousands, report says. *New York Times.* Retrieved from https://www.nytimes.com/2019/05/17/business/porter-ranch-gas-leak.html

[84] Federal Energy Regulatory Commission. (2018, October 23). North American LNG import/export terminals—existing. Retrieved from https://www.ferc.gov/industries/gas/indus-act/lng/lng-existing.pdf

LNG is purified methane in the form of a bubbling, super-cold liquid. It is created through the capital-intensive, energy-intensive process of cryogenics and relies on evaporative cooling to keep the methane chilled during transport. Explosive and with the ability to flash-freeze human flesh, LNG creates acute security and public safety risks. Its greenhouse gas emissions are 30 percent higher than conventional natural gas due to refrigeration, venting, leaks, and flaring, which is used to control pressure during regasification. The need to strip volatile impurities such as benzene from the gas prior to chilling it also makes LNG liquefaction plants a source of toxic air pollutants. (See footnotes 1226-1242.)

Cheniere Energy's Sabine Pass terminal in Louisiana became the subject of a federal investigation in January 2019 after a steel storage tank cracked and escaping LNG quickly vaporized into a flammable cloud. Another tank was found to be leaking gas from multiple places. PHMSA ordered both tanks shut down.[86]

In May 2019, the state of Oregon denied a Clean Water Act permit for the proposed Jordan Cove LNG export terminal, and the fracked gas pipeline that would serve it, over concerns about likely harm to streams, estuaries, and wetlands. This infrastructure project cannot be built without the state permit, but the company has reapplied.[87]

9) Drilling and fracking activities bring naturally occurring radioactive materials to the surface.

Naturally occurring radioactive materials that occur in shale layers containing oil and natural gas are brought to the surface in the solid waste removed during drilling (drill cuttings) and in fracking wastewater. Radionuclides can also build up in pipes and equipment, and fracking itself can open pathways for the migration of radioactive materials. Exposure to increased radiation levels from fracking materials is a risk for both workers and residents.

Radon levels in Pennsylvania homes have risen since the advent of the fracking boom, and buildings in heavily drilled areas have significantly higher radon readings than areas without well pads—a discrepancy that did not exist before 2004. (See footnote 511.) As we went to press, a new study reported a similar pattern in Ohio.[88]

Also in Pennsylvania, a 2019 study measured levels of radium in drill cuttings that would exceed regulatory limits for disposal in landfills if drill cuttings were not exempt from federal regulations governing hazardous waste. Drill cuttings from Pennsylvania fracking operations are

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[85] U.S. Department of Energy (2018, November 26). Long term applications received by the DOE/FE to export domestically produced LNG from the lower 48 states. Retrieved from https://www.energy.gov/sites/prod/files/2018/12/f58/Summary%20of%20LNG%20Export%20Applications.pdf

[86] Mandel, J., & Zou, J. J. (2019, May 30). Leaks threaten safety—and success—of America's top natural gas exporter. *E&E News, Houston Chronicle*, and Center for Public Integrity. Retrieved from https://publicintegrity.org/environment/leaks-threaten-safety-and-success-of-americas-top-natural-gas-exporter/

[87] Oregon Department of Environmental Quality. (2019, May 6). DEQ issues a decision on Jordan Cove's application for 401 Water Quality Certification [Press statement]. Retrieved from https://www.oregon.gov/newsroom/pages/NewsDetail.aspx?newsid=3273

[88] Xu, Y., Sajia, M., & Kumar, A. (2019). Impact of the hydraulic fracturing on indoor radon concentrations in Ohio, a multilevel modeling approach. *Frontiers in Public Health, 7*, 76. doi: 10.3389/fpubh.2019.00076

routinely dumped in municipal waste landfills in Ohio and New York. (See footnote Swiedler, 2019.)

A variety of radioactive substances—including radium, thorium, and uranium—have been detected in fracking wastewater. A 2018 study in the Marcellus Shale region showed that extreme salinity, as well as the chemical composition of fracking fluid, interacts with the shale during the fracking process in ways that mobilize radium and make fracking wastewater radioactive. (See footnote 497.)

A 2018 simulation study of radium-226 in fracking wastewater from North Dakota's Bakken Shale found potential risk to human health from fracking wastewater spills into surface water. (See footnote 500.)

10) Drilling and fracking activities harm wildlife through multiple pathways.

Animals serve as sentinels for chemical exposures that may also affect human residents who share their environment. In addition, animals perform ecosystem services essential to human existence, as confirmed by a landmark United Nations report in May 2019.[89] For both reasons, harm to wildlife by fracking operations has consequences for public health.

Birds and other wildlife have been poisoned by fracking wastewater held in open pits, while spills and discharges of fracking waste have precipitated mass die-offs of fish, as documented in Ohio, Kentucky, and Pennsylvania. (See footnotes 406, 434.) Freshwater mussels, which are endangered throughout North America, accumulate contaminants, including strontium, when fracking wastewater is discharged through sewage treatment plants. (See footnote 255.) Chemicals in fracking waste are toxic to, or otherwise disrupt development in, many fish and amphibian species. (See footnotes 246, 326.) In remote locations in Pennsylvania, streams once classified as high-quality brook trout habitat had no fish at all after the arrival of drilling and fracking operations. (See footnote 311.) Overall, aquatic habitats impacted by fracking activities show decreased biodiversity.

Wildlife is harmed by fracking through loss of food resources. Water fleas (*Daphnia spp.*), the basis of freshwater aquatic food chains, become unable to vertically navigate through water columns upon exposure to trace amounts of fracking fluid. (See footnote 241.) In West Virginia, populations of Louisiana Waterthrush, which rely on aquatic food sources, have declined in areas of drilling and fracking. (See footnote 247.)

Light and noise pollution from oil and gas production disrupt wildlife behavior, including in protected areas and critical habitats of endangered species, and have been linked to mass die-offs of waterfowl and declines in songbird populations in Alberta, Canada and New Mexico. (See footnotes 678, 693.) Chronic noise from drilling and fracking operations interferes with the ability of birds to respond to acoustic cues. (See footnotes 1111, 1112.)

[89] IPBES. (2019, May 6). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* E. S. Brondizio, J. Settele, S. Díaz, & H. T. Ngo (eds). Advance unedited version. Bonn, Germany: IPBES Secretariat. Retrieved from https://www.ipbes.net/system/tdf/spm_global_unedited_advance.pdf?file=1&type=node&id=35245

Fracking harms wildlife through climate change and habitat destruction. Oil and gas infrastructure, including compressor stations, has caused declines in grassland songbirds in Canada. Sand mining operations in Texas are imperiling the dunes sagebrush lizard. The proposed route of the Atlantic Coast Pipeline cuts through critical habitat for four endangered species. A 2019 study found that forest disturbances driven by drilling and fracking activities are altering the abundance of songbird populations in central Appalachia, particularly harming species whose habitats are forest interiors.[90] Well pad construction hastens the spread of invasive non-native plant species which harms wildlife habitat. (See footnote 925.)

According to economists, the cost of wildlife habitat fragmentation due to fracking is $3.5-4.45 billion. (See footnote 1276.)

11) The risks posed by fracking in California are unique.

Hydraulic fracturing in California is practiced differently than in other states, making its risks different as well. Wells are more likely to be vertical rather than horizontal, and the oil-containing rock layer is shallower. Hence, much less water is used per well for fracking as compared to other states. However, the fracking fluid used is much more chemically concentrated, the fracking zones are located closer to overlying aquifers, and the risk of a fracture reaching groundwater is higher.

California is the only state that allows wastewater from oil fields to be held in unlined open pits, which creates risks for both air and groundwater contamination. As of July 2018, 1,086 such pits were operational in the Central Valley, with the vast majority in Kern County. An investigation by reporters for NBC Bay Area found additional pits not on the state's official list. In at least two instances, toxic wastewater from the pits had migrated underground for more than a mile.[91]

In 2014, the discovery that companies had, for years, been wrongly allowed to inject fracking waste directly into California's freshwater aquifers led to the closing of 175 disposal wells. Impacts on drinking water are unknown. (See footnotes 289, 290.)

Most new fracking operations in California take place in areas with a long history of oil extraction. A high density of old and abandoned wells provides potential leakage pathways, should fractures intersect with them. And although fracking requires considerably less water per well in California, it takes place disproportionately in areas of severe water shortages and can compete with municipal and agricultural needs for freshwater.

The combination of ongoing drought and lack of disposal options has resulted in the diversion of fracking wastewater to farmers for irrigation of crops, raising concerns about contaminated water potentially affecting food crops and draining into groundwater. Investigative reports in 2015

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[90] Farwell, L. S., Wood, P. B., Brown, D. J., & Sheehan, J. (2019). Proximity to unconventional shale gas infrastructure alters breeding bird abundance and distribution. *The Condor.* Advance online publication. doi: 10.1093/condor/duz020

[91] Stock, S., Campos, R., Horn, M., & Ettema, K. (2018, July 31). Toxic wastewater from oil fields endangers California's water supply, scientists tell NBC Bay Area. *NBC Bay Area.* Retrieved from https://www.nbcbayarea.com/investigations/Toxic-WasteWater-From-Oil-Fields-Endangers-Californias-Water-Supply-Scientists-Tell-NBC-Bay-Area-483089841.html

revealed that Chevron Corporation piped 21 million gallons of recycled oil and gas wastewater per day to farmers for crop irrigation. Tests showed the presence of several volatile organic compounds, including acetone, which is linked in lab studies to kidney, liver, and nerve damage. (See footnotes 924-926.)

These activities project fracking's impacts onto geographically distant populations, especially in cases where wastewater is used in crop irrigation and livestock watering. Food is a troubling possible exposure route to fracking chemicals, in part because so little is known about these chemicals. According to a hazard assessment of chemicals used in California oil drilling operations that reuse wastewater for livestock watering and other agricultural purposes, more than one-third of the 173 chemicals used are classified as trade secrets: Their identities are entirely unknown. Of the remainder, ten are likely carcinogens, 22 are toxic air contaminants, and 14 had no toxicity data available. Estimating risks to consumers of the food produced with wastewater irrigation is thus not possible. (See footnote 919.)

The other area in California where fracking is concentrated, the Los Angeles Basin, is located directly under one of the most populous cities in the world. As of 2018, there were 3,468 active and 1,850 inactive oil and gas wells in Los Angeles County. (LA Dept of Health 2018). At least 1.7 million people in Los Angeles live or work within one mile of an active oil or gas well. California does not currently limit how close to residences or schools drilling and fracking activities may be conducted. A 2017 study shows that many of the same chemicals used to stimulate wells during fracking operations are also used in urban oil wells located in densely populated areas of southern California. (See footnote 295.)

12) Fracking in Florida presents many unknowns.

Gas and oil drilling in Florida, now only a minor industry, is currently concentrated in two areas: the western Panhandle near Pensacola and the Everglades area of southwest Florida. So far, fracking has been used at least once—in 2013 at a test well located in the Corkscrew Swamp Sanctuary near Naples in Collier County. The Texas company that fracked this well, using high-pressure acid fracturing techniques to dissolve the bedrock, received a cease and desist order from the Florida Department of Environmental Protection.[92]

Renewed interest in oil and gas exploration in Florida has prompted public debate about fracking and whether to promulgate state regulations or prohibit it outright, possibly including a ban on the use of acid-dissolving technologies in addition to hydraulic fracturing *per se.* Bills that sought to ban fracking but not matric acidizing failed to pass in the Florida legislature in the 2019 legislative session.[93]

Florida has more available groundwater than any other state; it is the drinking water source for 93 percent of Florida's population. Groundwater is also pumped to irrigate crops and provide

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[92] Could leftover wastewater from balky oil well end up a health hazard? (2015, January 1). *Naples Daily News.* Retrieved from http://archive.naplesnews.com/news/local/could-leftover-wastewater-from-balky-oil-well-end-up-a-health-hazard-ep-853723380-335781721.html/

[93] Gross, S. J. (2019, April 17). Environmentalists cite report on Florida oil spills as bid to ban fracking stalls. *Miami Herald.* Retrieved from https://www.miamiherald.com/news/local/environment/article229355974.html

frost protection to winter crops. Most of this water is held in the Floridan Aquifer, which extends across the entire peninsula and into parts of Georgia, Alabama, and South Carolina. This aquifer provides drinking water to ten million people in both rural and urban communities, including residents of several major cities: Gainesville, Jacksonville, Orlando, Tallahassee, and Tampa. Overlain by smaller, shallower aquifers in southern Florida, it is a highly permeable, highly interconnected subterranean system, with water moving rapidly in multiple directions through massive shelves of limestone, which represent the dissolved shells and fossilized skeletons of prehistoric marine organisms. Honeycombed with pores, fissures, joints, and caves, the underground terrain of the Floridan Aquifer resembles a vast, brittle, sponge partly covered with sand and clay. Springs and sinkholes are common.[94, 95]

It is not known whether fracking in Florida could induce sinkholes to open up or whether alterations in underground pressures could cause springs to go dry. Certainly, Florida's porous geology makes it vulnerable to groundwater contamination. Crumbly, soluble limestone offers pathways for contaminants spilled on the surface to travel deep into the aquifer, where they can be dispersed over great distances by the aquifer's river-like currents. A 2003 experiment with a dye tracer showed the special susceptibility of Florida's groundwater to potential contamination; within a few hours, the red dye traveled through the aquifer a distance (330 feet) that researchers had presumed would take days.[96]

Compounding these risks, Florida's exposure to hurricanes makes it vulnerable to spills of fracking-related chemicals. In August 2017, flooding from Hurricane Harvey shut down fracking sites in Texas and triggered 31 separate spills at wells, storage tanks, and pipelines. (See footnotes 888-890.)

It is unclear where Florida would send any potential fracking wastewater for treatment and/or for underground injection. Florida currently injects other types of liquid waste into disposal wells that are located above, rather than below, oil- and gas-producing zones. The injection of fracking waste in these same shallower layers may make earthquakes less likely than, for example, in Oklahoma (where it is injected into deep formations), but it would also locate that waste closer to the aquifers, which are poorly mapped. To undertake the necessary study to determine how securely Florida's geological formations could contain wastewater from drilling and fracking operations and protect drinking water would be, in the words of two geophysicists, "a monumental task requiring full-time work…for decades."[97] There are reasons to be concerned. In

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[94] Johnson, R. H., & Bush, P. W. (2013, September 4). *Summary of the hydrology of the Floridan Aquifer System in Florida and in parts of Georgia, South Carolina, and Alabama.* U.S. Geological Survey Professional Paper 1403-A. Retrieved from https://sofia.usgs.gov/publications/papers/pp1403a/

[95] Tihansky, A. B., & Knochenmus, L. A. (2001, February 13). *Karst features and hydrogeology in west-central Florida. U.S.* Geological Survey Water-Resources Investigations Report 01-4011. Retrieved from https://water.usgs.gov/ogw/karst/kigconference/abt_karstfeatures.htm

[96] Miami-Dade County Wellfield Technical Work Group. (2017, July 31). *Final Report.* Retrieved from http://ecmrer.miamidade.gov:8080/reports/WellfieldTechnicalWorkgroupReportJuly2017.pdf

[97] Russo, R., & Screaton, E. (2016, May 9). Should Florida 'frack' its limestone for oil and gas? Two geophysicists weigh in. *University of Florida News.* Retrieved from http://news.ufl.edu/articles/2016/05/should-florida-frack-its-limestone-for-oil-and-gas-two-geophysicists-weigh-in.php

South Florida in the 1990s, 20 stringently regulated disposal wells failed and leaked sewage waste into the Upper Floridan Aquifer, a potential future source of drinking water for Miami.[98]

13) The economic instabilities of fracking exacerbate public health risks.

Fracking is not a stable business. Although the fracking boom has lifted U.S. oil and gas production to all-time highs, shale wells drilled in the past five years are pumping significantly less oil and gas than their operators predicted to their investors. Because the production of individual shale wells falls precipitously over the course of a few years, operators must continue drilling new wells at an ever-swifter pace to maintain growth targets—even as owners are under pressure to cut costs in the face of price declines.

The result is lack of profits, dependency on Wall Street financing and low interest rates, and asset sell-offs throughout the fracking industry as a whole. (See footnote Olson, Wall St. J., Jan 2, 2019.) Between 2008 and 2018, leading fracking companies spent $230 billion more than they earned, covering the gap with debt.[99]

Even as oil prices have rebounded somewhat during the past two years, fracking companies are, collectively, still spending more on drilling than they receive by selling oil and gas. By 2018, only five of the largest 20 fracking companies were making more cash than they spent, and the stock prices of all 29 shale producers fell.[100, 101]

These unstable economic fundamentals have multiple consequences for public health and safety as cumulative impacts mount from wells both old and new.

Pressures to cut costs incentivize cutbacks in safety measures and leave landscapes pock-marked by increasing numbers of hastily abandoned wells in need of remediation and long-term monitoring. Orphaned wells left behind by industry during energy price downturns or after bankruptcy are poorly monitored and, as conduits for gas and fluid leakage, become health and safety threats. Abandoned wells pose risks for soil and water contamination and can emit toxic air pollution and greenhouse gases. Some have exploded.[102, 103, 104]

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[98] Lustgarten, A. (2012, June 21). Injection wells: the poison beneath us. *ProPublica.* Retrieved from https://www.propublica.org/article/injection-wells-the-poison-beneath-us

[99] Crooks, E. (2018, March 4). Boom times for US shale oil producers. *Financial Times.* Retrieved from https://www.ft.com/content/2c7f6a38-1d37-11e8-956a-43db76e69936

[100] McLean, B. (2018, September 1). The next financial crisis lurks underground." *New York Times.* Retrieved from https://www.nytimes.com/2018/09/01/opinion/the-next-financial-crisis-lurks-underground.html

[101] Hiller, J. (2019, April 2). Cash flow still weak at U.S. shale firms, stock prices underperform. *Reuters*. Retrieved from https://www.reuters.com/article/usa-shale-finances/cash-flow-still-weak-at-u-s-shale-firms-stock-prices-underperform-idUSL1N211001

[102] Zoffos, J. (2018, January 16). 'Orphaned' oil and gas wells are on the rise." *High Country News*. Retrieved from http://www.hcn.org/articles/energy-industry-orphaned-oil-and-gas-wells-are-on-the-rise

[103] Cox, S. (2019 March 19). B.C. left holding massive bill for hundreds of orphan wells as frack companies go belly up. *The Narwhal.* Retrieved from https://thenarwhal.ca/b-c-left-holding-massive-bill-for-hundreds-of-orphan-gas-wells-as-frack-companies-go-belly-up/

In both North Dakota's Bakken Shale and western Texas' Permian Basin, cost-cutting pressures, coupled with a desperate rush to drill new oil wells to compensate for declining rates of production from older wells, have meant that waste natural gas generated as a byproduct of oil drilling is simply vented or flared rather than captured, in order to speed up the rate of oil drilling.[105, 106] By April 2019, the amount of natural gas burned off via flaring in the Permian oil fields had reached a record high and exceeded the amount of gas needed to power every residence in Texas.[107] Flaring, a leading source of toxic air pollution and smog, is a public health menace.[108]

Independent economic analyses also show that the promise of local job creation has been greatly exaggerated, with many jobs going to out-of-area workers. Reports show that oil and gas jobs increasingly will be lost to automation.

With the arrival of drilling and fracking operations, communities have experienced steep increases in rates of crime including sex trafficking, rape, assault, drunk driving, drug abuse, and violent victimization—all of which carry public health consequences, especially for women. Social costs include road damage, failed local businesses, loss of affordable rental housing, and strains on law enforcement and municipal services. School districts report increased stress. Economic analyses have found that drilling and fracking activities threaten property values and can diminish tax revenues for local governments. Additionally, drilling and fracking on private lands pose an inherent conflict with mortgages and property insurance due to the hazardous materials used and the associated risks.

14) Fracking raises human rights and environmental justice issues.

Inequalities in opportunities to participate in environmental decision-making and uneven impacts of environmental hazards along racial and socioeconomic lines are signature issues of environmental justice. In multiple regions where fracking is practiced, well pads and associated infrastructure are disproportionately sited in non-white, indigenous, or low-income communities.[109, 110]

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104 Riley, S. J. (2019, April 3). Notley vs. Kenney on how to deal with Alberta's 167,00 inactive and abandoned oil and gas wells. *The Narwhal.* Retrieved from https://thenarwhal.ca/notley-vs-kenney-on-how-to-deal-with-albertas-167000-inactive-and-abandoned-oil-and-gas-wells/

105 Ngai, C. (2018, October 9). Mind the drop: decline rates from maturing oil wells on the rise. *Bloomberg*. Retrieved from https://www.bloombergquint.com/business/mind-the-drop-decline-rates-from-maturing-oil-wells-on-the-rise

106 Lee, M. (2019, May 8). Gas glut spurs near-record flaring across shale states. *E&E News.* Retrieved from https://www.eenews.net/energywire/stories/1060292021

107 Hiller, J. (2019, June 4). Natural gas flaring hits record high in first quarter in U.S. Permian Basin. *Reuters*. Retrieved from https://www.reuters.com/article/us-usa-shale-flaring/natural-gas-flaring-hits-record-high-in-first-quarter-in-us-permian-basin-idUSKCN1T5235

108 Crowley, K., & Collins, R. (2019, April 11). Oil producers are burning enough gas to power every home in Texas. *Bloomberg*. Retrieved from https://www.bloomberg.com/news/articles/2019-04-10/permian-basin-is-flaring-more-gas-than-texas-residents-use-daily

109 Healy, N., Stephens, J. C., & Malin, S. A. (2019). Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains. *Energy Research & Social Science, 48,* 219-234. doi: 10.1016/j.erss.2018.09.016

A 2019 analysis of socio-demographic characteristics of people living close to drilling and fracking operations in the states of Colorado, Oklahoma, Pennsylvania, and Texas found strong evidence that minorities, especially African Americans, disproportionately live near fracking wells.[111]

Similarly, a pattern of racially biased permitting was documented in the heavily fracked Eagle Ford area of southern Texas where a public health research team showed that disposal wells for fracking wastewater were more than twice as common in areas where residents are more than 80 percent people of color than in majority white communities.[112] Since 2007, more than 1,000 waste disposal wells have been permitted in the Eagle Ford Shale region where groundwater is the primary source of drinking water.[113]

In intensely drilled Denton, Texas, a study found that those benefiting most from Denton's mineral wealth tended to live elsewhere, while the environmental burdens remained local and fell hardest on those who did not have a voice in mineral-leasing decisions. "Non-mineral owners are essentially excluded from the private decisions, as the mineral owners not only receive the direct monetary benefits, but also hold a great deal of state-sanctioned power to decide if and how [shale gas development] proceeds."[114]

Poor communities of color are disproportionately affected by drilling activities in California. Of Los Angeles residents living within a quarter-mile of a well, more than 90 percent are people of color. In November 2015, civic groups led by youth sued the city of Los Angeles for racial discrimination based on allegations of a preferential permitting process and unequal regulatory enforcement for oil wells located in neighborhoods of color. Together, these differential practices have resulted in a higher concentration of wells with fewer environmental protections in Black and Latino communities.[115] South Coast Air Quality Management District records show that oil drilling operations in Los Angeles neighborhoods released into the air 21 million pounds of toxic chemicals between June 2013 and February 2017. These emissions included crystalline silica, hydrofluoric acid, and formaldehyde.[116]

Across California, gas-fired power plants are disproportionately located in disadvantaged communities, as classified by an environmental justice screening tool developed by the state

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[110] Clough, E. (2018). Environmental justice and fracking: A review. *Current Opinion in Environmental Science & Health, 3*, 14-18. doi: 10.1016/coesh.2018.02.005

[111] Zwickl, K. (2019). The demographics of fracking: A spatial analysis for four U.S. states. *Ecological Economics, 161,* 202-215. doi: 10.1016/j.ecolecon.2019.02.001

[112] Johnston, J. E., Werder, E., & Sebastian, D. (2016). Wastewater disposal wells, fracking, and environmental justice in southern Texas. *American Journal of Public Health, 106*(3). doi: 10.2105/AJPH.2015.303000

[113] Bienkowski, B. (2016, February 3). Poor, minorities carry the burden of frack waste in South Texas. *Environmental Health News.* Retrieved from http://www.environmentalhealthnews.org/ehs/news/2016/feb/fracking-waste-eagle-ford-texas-hispanic-environmental-justice

[114] Fry, M., Briggle, A., & Kincaid, J. (2015). Fracking and environmental (in)justice in a Texas city. *Ecological Economics, 117*. doi: 10.1016/j.ecolecon.2015.06.012

[115] Reyes, E. A. (2015, November 6). Environmental advocates sue L.A., accusing it of "rubber stamping" oil drilling plans. *Los Angeles Times*. Retrieved from http://www.latimes.com/local/lanow/la-me-ln-lawsuit-oil-drilling-20151106-story.html

[116] Fleming, J. C., & Kim, C. (2017, December 13). Danger next door: The top 12 air toxics used for neighborhood oil drilling in Los Angeles. Center for Biological Diversity. Retrieved from http://www.biologicaldiversity.org/publications/papers/DangerNextDoor.pdf

Office of Environmental Health Hazard Assessment.[117] More than three-quarters of the 21,397 new oil wells drilled in California between 2011 and 2018 are located in low-income minority communities, according to state data.[118]

In Greeley, Colorado, a massive well pad housing 24 wells was sited near Bella Romera Academy, an elementary school in a low-income community where 82 percent of students are Latino, after earlier plans were scrapped for a site near a charter school where students are majority white and middle-class.[119]

In May 2018, community groups in North Carolina filed an environmental justice complaint against the Atlantic Coast Pipeline, alleging the project poses disproportionate risk of harm to people of color. Thirteen percent of those living along the pipeline route are Native Americans in a state where Native Americans make up only 1.2 percent of the population.[120, 121] A compressor station in Virginia that would service this pipeline is located in a historically African-American community.[122]

In Pennsylvania, evidence shows that gas-fired power plants are disproportionately located in low-income and minority communities.[123] A geographic study found a higher concentration of drilling and fracking operations in impoverished communities throughout the state of Pennsylvania as well as in localized areas of West Virginia, but it did not find differences with respect to race. "The results demonstrate that the environmental injustice occurs in areas with unconventional wells in Pennsylvania with respect to the poor population."[124] These findings are supported by census tract data in western Pennsylvania showing that among nearly 800 gas wells, only two were drilled in communities where home values exceeded $200,000.[125]

Similarly, in Ohio, geographic evidence reveals that disposal wells for fracking wastewater are

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[117] PSE Healthy Energy. (2017, April). *Natural gas power plants in California's disadvantaged communities.* Retrieved from https://www.psehealthyenergy.org/wp-content/uploads/2017/04/CA.EJ_.Gas_.Plants.pdf

[118] Center for Biological Diversity (2018, August 16). Analysis: Most oil wells approved by Gov. Brown are in low-income areas, communities of color [Press statement]. Retrieved from https://www.biologicaldiversity.org/news/press_releases/2018/california-oil-drilling-08-16-2018.php

[119] Turkewitz, J. (2018, May 31). In Colorado a fracking boom and a population explosion collide. *New York Times.* Retrieved from https://www.nytimes.com/2018/05/31/us/colorado-fracking-debates.html

[120] McKenna, P. (2018, May 18). Atlantic Coast Pipeline faces civil rights complaint after key permit is blocked. *Inside Climate News.* Retrieved from https://insideclimatenews.org/news/18052018/atlantic-coast-pipeline-natural-gas-civil-rights-environmental-justice-epa

[121] Emmanuel, R. E. (2017). Flawed environmental justice analysis. *Science, 375*(6348), 260. doi: 10.1126/science/aao2684

[122] Finley-Brook, M., Williams, T. L., Caron-Sheppard, J. A., & Jaromin, M. K. (2018). Critical energy justice in U.S. natural gas infrastructuring. *Energy Research & Social Sciences, 41*, 176-190. doi: 10.1016/j.erss.2018.04.019

[123] Nextgen Climate America, & PSE Healthy Energy. (2018). Our air: Health and equity impacts of Pennsylvania's power plants. Retrieved from https://nextgenpolicy.org/wp-content/uploads/2016/07/NGCA-PSE-Our-Air-Health-and-Equity-Impacts-PA-2016-0710-2.pdf

[124] Ogneva-Himmelberger, Y., & Huang, L. (2015). Spatial distribution of unconventional gas wells and human populations in the Marcellus Shale in the United States: Vulnerability analysis. *Applied Geography, 60*, 165-174. doi: 10.1016/j.apgeog.2015.03.011

[125] Frazier, R. (2016, June 30). Is fracking an environmental justice issue? *The Allegheny Front.* Retrieved from https://www.alleghenyfront.org/is-fracking-an-environmental-justice-issue/

disproportionately located in lower-income, rural communities.[126]

Apart from disparities circumscribed by race and income, fracking raises other fundamental questions of human rights. A comprehensive analysis that charts the international legal development of water rights as they apply to oil and gas extraction concluded that the right to water for residents living near fracking sites is "likely to be severely curtailed." Noting that access to clean and safe drinking water is codified by the United Nations General Assembly as a human right essential to the full development of life and all other human rights, the authors argue that, because the fracking industry does not face the true societal cost of water in their production decisions, ownership of this essential-to-life resource is effectively transferred from society to industry, with no protection for this essential human right. In the United States alone, "there is considerable evidence that the human right to water will be seriously undermined by the growth of the unconventional oil and gas industry, and given its spread around the globe this could soon become a global human rights issue."[127]

Three international human rights bodies have called for prohibitions on fracking. In February 2019, the Committee on Elimination of Discrimination Against Women, which monitors the implementation of the 1979 United Nations treaty that serves as an international bill of rights for women, called on the United Kingdom to ban fracking on the ground that fracking damages communities and imperils the climate in ways that disproportionately harm women and girls living in rural areas.[128, 129] In October 2018, the United Nations Committee on Economic, Social and Cultural Rights warned Argentina that its plans for large-scale fracking in the Vaca Muerta Shale region would create adverse economic and cultural rights impacts on the indigenous Mapuche people.[130] In May 2018, the Permanent People's Tribunal, a Rome-based forum focused on human rights violations, issued an advisory opinion based on a two-year investigation that collected testimonies and reports from scientists and fracking-impacted communities.

In the words of the court,

> The evidence clearly demonstrates that the processes of fracking contribute substantially to anthropogenic harm, including climate change and global warming, and involve massive violations of a range of substantive and procedural human rights and the rights of

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[126] Silva, G. S., Warren, J. L., & Deziel, N. C. (2018) Spatial modeling to identify sociodemographic predictors of hydraulic fracturing wastewater injection wells in Ohio census block groups. *Environmental Health Perspectives, 126*(6), 067008. doi: 10.1289/EHP2663

[127] Palmer, R. C., Short, D., & Auch, W. E. T (2018). The human right to water and unconventional energy. *International Journal of Environmental Research and Public Health, 15*(9), 1858. doi: 10.3390/ijerph15091858

[128] United Nations Committee on the Elimination of Discrimination Against Women (2018, July 27). List of issues in relation to the eighth periodic report of the United Kingdom of Great Britain and Northern Ireland. https://tbinternet.ohchr.org/_layouts/15/treatybodyexternal/Download.aspx?symbolno=CEDAW%2fC%2fGBR%2fCO%2f8&Lang=en

[129] Center for International Environmental Law (2018, March 13). UN body recommends UK consider complete fracking ban to protect human rights [Press statement]. Retrieved from https://www.ciel.org/news/un-body-recommends-uk-consider-complete-fracking-ban-to-protect-human-rights/

[130] Center for International Environmental Law (2018, October 19). CIEL statement on the Committee on Economic, Social, and Cultural Rights (CESCR)'s recommendations for the State of Argentina regarding its Vaca Muerta shale gas development [Press statement]. Retrieved from https://www.ciel.org/news/ciel-statement-on-the-committee-on-economic-social-and-cultural-rights-cescrs-recommendations-for-the-state-of-argentina-regarding-its-vaca-muerta-shale-gas-development/

> nature. Thus the industry has failed to fulfill its legal and moral obligations…. The dangers of fracking to the rights of people, communities, and nature are inherent in the industry….We will go beyond the call for a moratorium and recommend that fracking should be banned.[131]

15) Health professionals are increasingly calling for bans or moratoria on fracking, based on a range of health hazards and as reviews of the data confirm evidence for harm.

In May 2015, the Medical Society of the State of New York passed a resolution recognizing the potential health impacts of natural gas infrastructure and pledging support for a governmental assessment of the health and environmental risks associated with natural gas pipelines. (See footnote 856.) The American Medical Association (AMA) adopted a similar resolution that supports legislation requiring all levels of government to seek a comprehensive Health Impact Assessment regarding the health and environmental risks associated with natural gas pipelines. (See footnote 855.)

In May 2016, Physicians for Social Responsibility called for a ban on fracking. (See footnote 1079.)

In July 2016, the UK health professional organization Medact released an updated assessment of the potential health impacts of shale fracking in England, concluding that the United Kingdom should abandon its policy to encourage shale gas extraction and urged an "indefinite moratorium" on fracking. (See footnote 1077.)

In October 2016, a group of health care professionals in Massachusetts called for an immediate moratorium on major new natural gas infrastructure until the impact of these projects on the health of the communities affected could be adequately determined through a comprehensive Health Impact Assessment. (See footnote 1074.) The group noted that the operation of natural gas facilities increases the risk of human exposures to toxic, cancer-causing, and radioactive pollution due to the presence of naturally co-occurring contaminants, toxic additives to the hydraulic fracturing process, and through the operation of transmission pipelines.

Also in 2016, in a unanimous vote of the society's 300-member House of Delegates, the Pennsylvania Medical Society called for a moratorium on new shale gas drilling and fracking in Pennsylvania and an initiation of a health registry in communities with pre-existing operations. (See footnotes 1071, 1072).

In 2017, health officials in Los Angeles called for a comprehensive health study in the aftermath of the massive methane leak in Aliso Canyon. (See footnote 1068.)

In March 2019, Doctors for the Environment Australia announced the reinforcement of its position that no new gas extraction of any kind should occur in Australia.

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[131] Permanent People's Tribunal. (2018, May 14-18). Session on human rights, fracking and climate change—advisory opinion. Retrieved from http://permanentpeoplestribunal.org/wp-content/uploads/2019/04/AO-final-12-APRIL-2019.pdf

Concerned Health Professionals of New York, which provided scientific and medical guidance for the successful effort to ban fracking in New York State, has inspired affiliations of like-minded public health scientists and health care providers that have been advocating for moratoria or bans on fracking in various other regions. These include Concerned Health Professionals of Maryland, Concerned Health Professionals of Ireland, Concerned Health Professionals of Neuquén, Argentina, and Concerned Health Professionals UK.

Conclusion

All together, findings to date from scientific, medical, and journalistic investigations combine to demonstrate that fracking poses significant threats to air, water, human health, public safety, community cohesion, long-term economic vitality, biodiversity, seismic stability, and climate stability.

The rapidly expanding body of scientific evidence compiled and referenced in the present volume is massive, troubling, and cries out for decisive action. Across a wide range of parameters, from air and water pollution to radioactivity to social disruption to greenhouse gas emissions, the data continue to reveal a plethora of recurring problems and harms that cannot be sufficiently averted through regulatory frameworks. There is no evidence that fracking can operate without threatening public health directly and without imperiling climate stability upon which public health depends. The only method of mitigating its grave harm to public health and the climate is a complete and comprehensive ban on fracking.

In the words of investigative journalist Andrew Nikiforuk:

> Industry swore that its cracking rock technology was safe and proven, but science now tells a different story. Brute force combined with ignorance … has authored thousands of earthquakes … [and] called forth clouds of migrating methane…. The science is complicated but clear: cracking rock with fluids is a chaotic activity and no computer model can predict where those fractures will go. The regulatory record shows that they often go out of zone; extend into water; and rattle existing oil and gas wells, and these rattled wells are leaking more methane.[132]

In closing, we cite comments by epidemiologist Irena Gorski, co-author of the 2019 review of fracking's health concerns published in the Oxford Research Encyclopedia of Global Public Health. Her words speak for all who have contributed to this Compendium:

> What we found pushes back against the narrative we often hear that say we don't know enough about the health impacts yet. We have enough evidence at this point that these health impacts should be of serious concern to policymakers interested in protecting public health….As a fossil fuel, natural gas extraction and use is contributing to climate change, of course. But before conducting this study, I didn't realize the amount of evidence we have that it may be even worse than coal. We included this in our study because climate change has its own contributions to health impacts. These indirect impacts will take longer to appear than the direct health impacts, but they have the potential to be significant.[133]

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[132] Nikiforuk, A. (2016, October 16). Acceptance speech, USA National Science in Society Journalism Awards reception, San Antonio, Texas. Retrieved from http://www.ernstversusencana.ca/andrew-nikiforuk-wins-usa-national-science-in-society-award-slick-water-nasws-awards-honor-outstanding-investigative-interpretive-reporting-sciences-their-impact-for-good-and-ill/

[133] Marusic, K. (2019, April 15). After a decade of research, here's what scientists know about the health impacts of fracking. *Environmental Health News.* Retrieved from https://www.ehn.org/health-impacts-of-fracking-2634432607.html

Compilation of Studies & Findings

Air pollution

Air pollution associated with fracking is a grave concern with a range of impacts. Researchers have documented more than 200 different air pollutants near drilling and fracking operations. Of these, 61 are classified as hazardous air pollutants with known health risks, and 26 are classified as endocrine disruptors. Areas with substantial drilling and fracking build-out show high levels of ground-level ozone (smog), striking declines in air quality, and, in several cases, increased rates of health problems with known links to air pollution. Air sampling surveys find high concentrations of volatile organic compounds (VOCs), especially carcinogenic benzene and formaldehyde, both at the wellhead and at distances that exceed legal setback distances from wellhead to residence. In some cases, VOC concentrations exceeded federal safety standards by several orders of magnitude. In 2018, researchers in Colorado documented that air pollution increased with proximity to drilling and fracking operations and was sufficiently high to raise cancer risks in some cases. Exposure to emissions from natural gas flares and diesel exhaust from the 4,000-6,000 truck trips per well pad also pose respiratory health risks for those living near drilling operations. The United States leads the world in the number of flare stacks. Air pollutants from flaring operations include VOCs, polycyclic aromatic hydrocarbons, carbon monoxide, toxic heavy metals, formaldehyde, and soot.

Evidence implicates the U.S. shale gas boom in the recent global spike in atmospheric ethane and propane. Drilling and fracking operations in North Dakota's Bakken oil and gas field alone contribute two percent of global ethane emissions and directly impact air quality across North America. Like methane, ethane is both a greenhouse gas and a precursor for ozone formation. The accelerating pace of drilling and fracking activities and the current policy plan to reverse course on proposed regulations to reduce methane emissions are likely to exacerbate the air pollution problems that fracking creates, along with attendant health risks.

- April 1, 2019 – A University of California, Berkeley team undertook a comprehensive review of current peer-reviewed literature on hazardous air pollutants found near oil and gas extraction operations. Hazardous air pollutants are those known or suspected to cause cancer, reproductive harm, birth defects, or other serious health effects. Reviewing 37 studies, the team identified a total of 61 different hazardous air pollutants that have been detected and measured near oil and gas drilling and fracking operations. The sources of these dangerous pollutants include a wide range of equipment, activities, and facilities—from dehydrators and condensate tanks to well drilling, flowback treatment, and oil storage facilities. The team found that the production phase of oil and gas extraction has the potential to emit the highest concentrations and the most complex mixtures of hazardous air pollutants over the longest time. (During the production phase, raw oil or natural gas is flowing from the well and is processed within various ancillary equipment, all of which can emit hazardous pollutants, such as benzene.) The highest and most sustained concentrations of hazardous air pollutants were found in "regions rich in oil, wet gas, and condensate." Their results further suggest that "exposure risks can be much higher if production equipment is collocated with condensate storage and wastewater impoundments." The research team also uncovered an important disconnect between air pollution monitoring studies and those reporting on health impacts. In general, the levels of air pollution detected in the monitoring studies fell short of those known to cause health impacts and yet multiple health-based studies continue to find evidence of a spatial relationship between concentrations of hazardous air pollutants and incidence of health problems among people living near oil and gas operations. These findings suggest that existing air sampling methodologies may be under-reporting emissions or that prevailing health benchmarks are inadequate to identify health problems, especially when exposures include multiple chemicals.[134]

- March 14, 2019 – Approximately 1.7 million people live within one mile of an active oil or gas well in the Los Angeles metropolitan area. A University of California pilot study investigated air pollution around active wells in this densely populated urban area and showed that, even in neighborhoods where residents are exposed to complex mixtures of air pollution from multiple sources, levels of several volatile organic pollutants are higher in communities closer to wellheads and decrease in concentration with distance away from the wellheads. These include the carcinogen benzene and n-hexane. "We were able to identify gradient behavior along the transect downwind of the target oil/natural gas facility that was likely due, in part, to emissions from the facility."[135]

- February 15, 2019 – In the first modeling study of drilling and fracking-related air pollution to include criteria air pollutants, a University of Texas, Arlington team found that concentrations of pollutants in the Barnett Shale region in north Texas were varied by terrain, with strongly sloping terrain giving the highest maximum concentrations for criteria air pollutants compared to level and moderate terrain. (Regulated by the U.S. Environmental Protection Agency [EPA] via applicable standards, the criteria air pollutants are ozone, particulate matter, lead, carbon monoxide, sulfur oxides, and nitrogen oxides.) The highest benzene and methane concentrations occurred in flat terrain and exceeded health-based standards.[136]

- January 18, 2019 – Flaring is a widely used practice for disposal of waste natural gas during oil drilling, in places that lack infrastructure for its capture and transport. Enabled by fracking, domestic oil production is at an all-time high, and this upswing has outpaced the build-out of pipelines to contain the natural gas that accompanies the oil as it flows to the surface. Using satellite technology, researchers identified 43,887 distinct oil and gas

[134] Garcia-Gonzales, D. A., Shonkoff, S. B. C., Hays, J., & Jerrett, M. (2019). Hazardous air pollutants associated with upstream oil and natural gas development: A critical synthesis of current peer-reviewed literature. *Annual Review of Public Health, 40*, 283-304. doi: 10.1146/annurev-publhealth-040218-043715

[135] Garcia-Gonzales, D. A., Shamasunder, B., & Jerrett, M. (2019). Distance decay gradients in hazardous air pollution concentrations around oil and natural gas facilities in the city of Los Angeles: A pilot study. *Environmental Research, 173*, 232-236. doi: 10.1016/j.envres.2019.03.027

[136] Khalaj, F., & Sattler, M. (2019). Modeling of VOCs and criteria pollutants from multiple natural gas well pads in close proximity, for different terrain conditions: A Barnett Shale case study. *Atmospheric Pollution Research.* Advance online publication. Retrieved from https://doi.org/10.1016/j.apr.2019.02.007

flares in the Eagle Ford Shale region of south Texas from 2012 to 2016, with a peak in activity in 2014 and an estimated 4.5 billion cubic meters of total gas volume flared over the study period. Comparing these results with well permit data showed the majority of flares (82 percent) were linked to oil wells, with more than 90 percent associated with horizontally drilled wells. These flares were not equally distributed across the region. Just five of 49 counties in the Eagle Ford Shale area accounted for 71 percent of flaring. "Our results suggest flaring may be a significant environmental exposure in parts of this region." Air pollutants from flaring operations include VOCs, polycyclic aromatic hydrocarbons, carbon monoxide, toxic heavy metals, formaldehyde, and soot.[137]

- July 27, 2018 – A report written by the United Kingdom's Air Quality Expert Group found that shale gas operations would increase air pollution (nitrogen dioxides and VOCs) both nationally and locally within the United Kingdom. However, the report languished for three years and was finally released four days after shale gas extraction was officially approved for the Lancashire region of northwest England.[138, 139]

- July 16, 2018 – A team from the Colorado Department of Public Health and Environment used existing air monitoring data sets from disparate locations to determine if air pollution levels near drilling and fracking operations are sufficient to create health problems in Colorado residents who live more than 500 feet away from a well head. Overall, they found individual VOC levels below those that are known to pose cancer and non-cancer health risks. However, the authors could not evaluate the risk of possible intermittent spikes in emissions during different phases of operation and evaluated only a subset of all VOCs emitted from drilling and fracking operations at these different phases. "Future studies are greatly needed that focus on quantifying these acute, peak exposures to people living near oil and gas operations, with particular emphasis on characterization of the volatile organic compounds identified as posing the greatest potential public health concerns, such as benzene."[140]

- July 13, 2018 – Drilling and fracking operations emit pollutants that form ozone and fine particles. Because air pollution from oil and gas operations originate from a large number of small, diffuse sources, estimating the level and location of emissions is difficult. An EPA team used a national emissions inventory for the year 2011 to characterize oil and gas emissions over space and time and to estimate the future human health burden

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[137] Franklin, M., Chau, K., Cushing, L. J., & Johnston, J. E. (2019). Characterizing flaring from unconventional oil and gas operations in south Texas using satellite observations. *Environmental Science & Technology, 53*(4), 2220-2228. doi: 10.1021/acs.est.8b05355

[138] UK Air Quality Expert Group. (2018, July 27). *Potential Air Quality Impacts of Shale Gas Extraction in the UK*. Retrieved from https://cedrec.com/cedrec_images/1807251315_AQEG_Shale_Gas_Extraction_Advice_Note_vfinal_for_publishing.pdf

[139] Carrington, D. (2018, August 2). Buried UK government report finds fracking increases air pollution. *The Guardian.* Retrieved from https://www.theguardian.com/environment/2018/aug/02/buried-uk-government-report-finds-fracking-increases-air-pollution

[140] McMullin, T. S., Bamber, A. M., Bon, D., Vigil, D. I., & Van Dyke, M. (2018). Exposure and health risks from volatile organic compounds in communities located near oil and gas exploration and production activities in Colorado. *International Journal of Environmental Research and Public Health, 15*(7). doi: 10.3390/ijerph15071500

attributable to the oil and gas sector. For the year 2025, the authors projected that oil and gas extraction activities will cause 1000 deaths across the United States from exposure to fine particles and 970 deaths from ozone exposure, with the highest impacts in Colorado, Pennsylvania, Texas, and West Virginia.[141]

- June 13, 2018 – A British team used a new air quality forecasting model to simulate the health impacts of potential emissions from fracking operations in the United Kingdom, should large-scale fracking go forward. The results showed large projected increases in nitrogen oxides and volatile organic compounds across the UK airshed. These increases would contribute to approximately 110 extra premature deaths (with a range of 50-530 deaths) each year across the U.K.[142]

- May 29, 2018 – An Oregon State University team measured polycyclic aromatic hydrocarbon air pollutants near drilling and fracking operations in rural eastern Ohio. A known component of fracking-related air pollution, polycyclic aromatic hydrocarbons are linked to cancer risk, respiratory distress, and poor birth outcomes. Using both air samplers and wristbands to assess personal exposures of residents living near active or proposed well sites, the researchers found elevated air pollution levels near active well sites. Further, the wristbands from participants who lived in homes with well pads on their property registered higher levels of air pollutants than participants without wells. "These findings suggest that living or working near an active natural gas extraction well may increase personal polycyclic aromatic hydrocarbon exposure."[143]

- May 18, 2018 – A Canadian and U.S. research team monitored methane levels in urban Morgantown, West Virginia during various stages of hydraulic fracturing at a single well pad. They found that emissions at the site were greatest during the flow-back stage, a result that supports previous studies.[144]

- March 27, 2018 – A team led by University of Colorado School of Public Health scientists found that air pollution levels along Colorado's heavily drilled Front Range increased with proximity to drilling and fracking operations and were sufficiently high to raise cancer risks. For people living within 500 feet of a well, lifetime cancer risks were eight times higher than the EPA's upper threshold. Elevated levels of benzene and alkanes were of particular concern. "These findings indicate that state and federal

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[141] Fann, N., Baker, K. R., Chan, E. A. W., Eyth, A., Macpherson, A., Miller, E., & Snyder, J. (2018). Assessing human health $PM_{2.5}$ and ozone impacts from U.S. oil and natural gas sector emissions in 2025. *Environmental Science & Technology, 52*, 8095-8103. doi: 10.1021/acs.est.8b02050

[142] Archibald, A. T., Ordóñez, C., Brent, E., & Williams, M. L. (2018). Potential impacts of emissions associated with unconventional hydrocarbon extraction on UK air quality and human health. *Air Quality, Atmosphere & Health, 11*(6), 627-637. doi: 10.1007/s11869-018-0570-8

[143] Paulick, L. B., Hobbie, K. A., Rohlman, D., Smith, B. W., Scott, R. P., Kincl, L., . . . Anderson, K. A. (2018). Environmental and individual PAH exposures near rural natural gas extraction. *Environmental Pollution, 241*, 397-405. doi: 10.1016.j.envpol.2018.05.010

[144] Williams, P. J., Reeder, M., Pekney, N. J., Risk, D., Osborne, J., & McCawley M. (2018). Atmospheric impacts of a natural gas development within the urban context of Morgantown, West Virginia. *Science of the Total Environment, 639*, 406-416. doi: 10.1016/j.scitotenv.2018.04.422

regulatory policies may not be protective of health for populations residing near oil and gas facilities."[145]

- March 21, 2018 – Evaluating 48 peer-reviewed studies that sampled air near drilling and fracking operations, researchers identified more than 200 different airborne chemicals associated with oil and gas extraction. Ethane, benzene, and n-pentane were the three most frequently detected. Twenty-six of these 200 chemicals are classified as endocrine disruptors—chemicals that can interfere with hormone systems and may affect reproduction, development, and neurological functioning.[146]

- March 18, 2018 – There are now more than 22,000 active fracking wells in the rural Eagle Ford Shale region of Texas, which has undergone a 10-fold increase in oil and gas extraction since 2010. A research team from San Francisco State University and University of Southern California used remote sensing data that incorporated infrared observations of combustion sources to estimate exposure of local residents to hazardous air pollutants from associated flaring operations. Their method confirmed extensive flaring in close proximity to homes.[147]

- February 26, 2018 – The presence of ethane and propane in the atmosphere is an indication of leaks during fossil fuel extraction and distribution, including fracking and its attendant activities, especially venting and flaring. (Fossil fuel combustion is not a source of ethane or propane.) According to a study led by a University of York team that used data collected from 20 observatories around the world, global atmospheric levels of ethane and propane have been underestimated by more than 50 percent. These results mean that hydrocarbon emissions from fossil fuel extraction activities in general—including methane—may be two to three times higher than previously presumed. Both ethane and methane are ozone precursors and contribute to the creation of smog. The authors noted that enhanced ethane and propane emission results mean higher levels of health-damaging ozone in both rural and urban areas.[148] In related press materials about this research, Ally Lewis, a co-author of the study, said, "Levels of ethane and propane declined in many places in the 1980s and 1990s, but global growth in the demand for natural gas means these trends may be reversing. The effects of higher ozone would be felt in the rural environment where it damages crops and plants, and in cities on human health." Co-author Lucy Carpenter, said, "We know that a major source of ethane and propane in the atmosphere is from 'fugitive' or unintentional escaping emissions during

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[145] McKenzie, L. M., Blair, B., Hughes, J., Allshouse, W. B., Blake, N. J., Helmig, D., . . . Adgate, J.L., (2018). Ambient nonmethane hydrocarbon levels along Colorado's northern Front Range: Acute and chronic health risks. *Environmental Science & Technology, 52*(8), 4514-4525. doi: 10.1021/acs.est.7b05983
[146] Bolden, A. L., Schultz, K., Pelch, K. E., & Kwiatkowski, C. F. (2018). Exploring the endocrine activity of air pollutants associated with unconventional oil and gas extraction. *Environmental Health, 17*(26). doi: 10.1186/s12940-018-0368-z
[147] Cushing L., Johnston J., Franklin M., & Chau, K. (2018). Using satellite observations to estimate exposure to flaring: implications for future studies of the health impacts of unconventional oil and gas operations. *Occupational and Environmental Medicine, 75* (Suppl 1), A5-A6. doi: 10.1136/oemed-2018-ISEEabstracts.13
[148] Dalsøren, S. B., Myhre, G. Hodnebrog, Ø., Myhre, C. L., Stohl, A., Pisso, I., . . . Wallasch, M. (2018). Discrepancy between simulated and observed ethane and propane levels explained by underestimated fossil emissions. *Nature Geoscience, 11*, 178-184. doi: 10.1038.s41561-018-0073-0

fossil fuel extraction and distribution. If ethane and propane are being released at greater rates than we thought, then we also need to carefully re-evaluate how much of the recent growth of methane in the atmosphere may also have come from oil and natural gas development."[149]

- February 5, 2018 – The Tropospheric Ozone Assessment Report analyzes data from all available ozone monitors around the world. Its 2018 report found that, in the United States, levels of ground-level ozone (smog) dropped steadily between 2000 and 2014 except in rural areas of the Rocky Mountain west where levels remained steady or rose. Oil and gas drilling is likely responsible. Rural areas in the western United States have fewer emission sources and yet they have been experiencing high ozone levels, especially in the winter.[150]

- November 2, 2017 – In a review paper that explores how the U.S. fracking boom has contributed to air pollution in impacted communities, Texas A&M atmospheric scientist Gunnar W. Schade identified ozone and benzene as two important chemicals of concern. Documenting trends is challenging because fracking-related air pollutants typically originate in rural places without routine air pollution monitoring. A new air monitor in the Eagle Ford Shale region allowed researchers to use fingerprinting analysis to show that 60 percent of ambient benzene in the air now comes from drilling and fracking operations, including gas flares. Before the shale boom, the majority of benzene in the region came from tailpipe emissions. "In some areas, decades-long progress on ozone air quality has stalled; in others, particularly the Uintah basin in Utah, a new ozone problem has emerged due to the fracking industry's emissions." Downwind of the Eagle Ford Shale, San Antonio's ozone levels are now trending close to 75 ppb, which exceeds the new recommended limit of 70 ppb. "The shale boom has create a new source of large-scale, diffuse hydrocarbon emissions that adversely affect air toxics levels. . . . The continued growth of the fracking industry as well as plans to remove regulations on methane emissions will not alleviate high hydrocarbon emissions and associated regional ozone problems."[151]

- April 12, 2017 – Using aircraft, a University of Michigan-led team collected plume samples from 37 flare stacks in the Bakken Shale region of North Dakota to calculate emissions of black carbon (soot), methane, and ethane from natural gas flares. They

[149] University of York. (2018, February 26). Global fossil fuel emissions of hydrocarbons underestimated [press release]. Retrieved from https://www.york.ac.uk/news-and-events/news/2018/research/global-fossil-fuel-emissions-underestimated/

[150] Fleming, Z. L., Doherty, R. M., von Schneidemesser, E., Malley, C. S., Cooper, O. R., Pinto, J. P., . . . Feng, Z., (2018). Tropospheric Ozone Assessment Report: present-day ozone distribution and trends relevant to human health. *Elementa: Science of the Anthropocene, 6*(1), 12. doi: 10-1525/elementa.273

[151] Schade, G. W. (2017, November 2). How has the US fracking boom affected air pollution in shale areas? *The Conversation.* Retrieved from https://theconversation.com/how-has-the-us-fracking-boom-affected-air-pollution-in-shale-areas-66190

determined that flares contribute almost 20 percent of the total emissions of methane and ethane from the Bakken region, as measured by field studies.[152]

- December 29, 2016 – Exposure to air pollutants from well pads decreases quickly with distance. However, according to recent studies, people living kilometers away from actual drilling and fracking operations also show elevated risk of disease known to be linked to air pollution. This review paper investigated the possible role that exposure to diesel exhaust from fracking-related road traffic is playing in creating public health impacts in surrounding communities. "Road traffic generated by hydraulic fracturing operations is one possible source of environmental impact whose significance has, until now, been largely neglected . . . with 4,000-6,000 vehicles visiting the well pad during the operations." As a starting point for exposure assessment, the author recommended GIS modeling studies with a focus on traffic patterns and exacerbation of pediatric asthma.[153, 154]

- October 16, 2016 – A review of recent studies documenting harm to both public health and agricultural yields from rising ozone levels identified oil and gas fields as "a major and growing source of ozone in the United States."[155]

- October 16, 2016 – In response to a lawsuit, the EPA acknowledged that its 33-year-old formula for estimating emissions from flaring operations requires revision as it may dramatically underestimate levels of health-damaging air pollutants. Emissions from flare stacks typically include carbon monoxide, nitrogen oxides, benzene, formaldehyde, and xylene, but levels of these smog-forming compounds are seldom measured directly.[156, 157]

- October 5, 2016 – A review of recent studies documented connections between oil and gas development and worsening ozone levels in western states. Drilling and fracking operations have pushed Pinedale, Wyoming out of compliance with federal ozone standards. Colorado has exceeded federal ozone limits for the past decade, a period that corresponds to a statewide boom in oil and gas drilling.[158]

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[152] Gvakharia, A., Kort, E. A., Brandt, A., Peischl, J., Ryerson, T. B., Schwarz, J. P., . . . Sweeney, C. (2017). Methane, black carbon, and ethane emissions from natural gas flares in the Bakken Shale, North Dakota. *Environmental Science & Technology, 51*(9), 5317-5325. doi: 10.1021/acs.est.6b05183

[153] McCawley, M. A. (2017). Does increased traffic flow around unconventional resource development activities represent the major respiratory hazard to neighboring communities?: Knowns and unknowns. *Current Opinion in Pulmonary Medicine, 23*(2), 161-166. doi: 10.1097/MCP.0000000000000361

[154] Frazier, R. (2017, June 16). On health effects, blame the trucks, not the fracking? *Allegheny Front.* Retrieved from https://www.alleghenyfront.org/on-health-effects-blame-the-trucks-not-the-fracking/

[155] Robbins, J. (2016, October 16). In new ozone alert, a warning of harm to plants and to people. *Yale Environment 360.* Retrieved from http://e360.yale.edu/feature/ground_level_ozone_harming_plants_humans/3044/

[156] United States District Court for the District of Columbia. (2016, October 16). Air Alliance Houston, et al. v. Gina McCarthy, Administrator, United States Environmental Protection Agency. Consent decree. Case 1:16-cv01998. Retrieved from https://www.documentcloud.org/documents/3127584-Consent-Decree-on-Flares.html

[157] Hasemyer, D. (2016, October 13). EPA agrees that its emissions estimates from flaring may be flawed. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/12102016/epa-natural-gas-oil-drilling-flaring-emissions-estimates-flawed-fracking

[158] Boiko-Weyrauch, A. (2016, October 5). Ozone, asthma and the oil and gas connection. *Inside Energy.* Retrieved from http://insideenergy.org/2016/10/05/ozone-asthma-and-the-oil-and-gas-connection/

- September 1, 2016 – A NASA-led research team collected whole air samples throughout the Barnett Shale basin in Texas. Chemical analysis showed that they contained benzene, hexane, and toluene at levels 2-50 times greater than the local background and similar to those seen in other intensely drilled shale basins in Colorado and Utah. There is "some evidence to suggest that public concerns for potential chronic health risks are not unwarranted."[159]

- July 23, 2016 – A study conducted at the Boulder Atmospheric Observatory examined sources of summertime ozone formation (smog) in Colorado's Front Range and found that 17 percent of locally created ozone was created by VOCs from drilling and fracking operations.[160] Colorado has exceeded the federal ozone standard for the past nine years, a period of time that corresponds to a boom in oil and gas drilling in the Wattenberg Gas Field where the number of active wells has nearly doubled.[161]

- June 13, 2016 – Between 2009 and 2014, ethane emissions in the Northern Hemisphere increased by about 400,000 tons annually, the bulk of it from North American oil and gas activity, according to research by an international team led by the University of Colorado Boulder.[162] After peaking in the 1970s, global ethane emissions began declining, primarily due to stricter air quality emission controls. In 2009, however, that downward trend reversed itself. "About 60 percent of the drop we saw in ethane levels over the past 40 years has already been made up in the past five years…. If this rate continues, we are on track to return to the maximum ethane levels we saw in the 1970s in only about three more years. We rarely see changes in atmospheric gases that quickly or dramatically," said lead researcher Detlev Helmig.[163] Samples were collected from locations around the world, but the largest increases in ethane were documented over areas of heavy oil and gas activity in the central and eastern United States. Ethane contributes to the creation of ground-level ozone pollution (smog), a known human health hazard. The authors noted that "… ozone production from these emissions has led to air quality standard exceedances in the Uintah Basin, Utah, and Upper Green River Basin, Wyoming, [oil and natural gas] regions." Two scientists not involved in the study published an accompanying commentary, concluding, "There is a danger that these non-methane hydrocarbon emission changes can offset emission policies and controls aimed at

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[159] Marrero, J. E., Townsend-Small, A., Lyon, D. R., Tsai, T. R., Meinardi, S., & Blake, D. R. (2016). Estimating emissions of toxic hydrocarbons from natural gas production sites in the Barnett Shale Region of Northern Texas. *Environmental Science & Technology, 50*(19), 10756-10764. doi: 10.1021/acs.est.6b02827

[160] McDuffie, E.E., Edwards, P.M., Gilman, J.B., Lerner, B.M., Dubé, W.P., Trainer, M., . . . Brown, S.S. (2016). Influence of oil and gas emissions on summertime ozone in the Colorado Northern Front Range. *Journal of Geophysical Research: Atmospheres*. doi: 10.1002/2016JD025265

[161] University of Colorado at Boulder. (2016, August 8). Accounting for ozone: Study first to quantify impact of oil and gas emissions on Denver's ozone problem. *ScienceDaily*. Retrieved from https://www.sciencedaily.com/releases/2016/08/160808123832.htm

[162] Helmig, D., Rossabi, S., Hueber, J. Tans, P., Montzka, S. A., Masarie, K., . . . Pozzer, A. (2016). Reversal of global atmospheric ethane and propane trends largely due to US oil and natural gas production. *Nature Geoscience, 9,* 490–495. doi: 10.1038/ngeo2721

[163] Helmig, D. & Scott, J. (2016, June 13). Global ethane concentrations rising again, says study. *News Center University of Colorado Boulder.* Retrieved from http://www.colorado.edu/news/releases/2016/06/13/global-ethane-concentrations-rising-again-says-study

reducing ozone concentrations," and "[t]hese oil and gas operations are threatening to reverse what had been an important success story: decades of declining air pollution in North America."[164] (See also the entry dated April 2, 2016 in Threats to the Climate System.)

- June 1, 2016 – Existing data on air pollutants emitted from drilling and fracking operations "support precautionary measures to protect the health of infants and children," according to a review by a team of researchers (members of which include co-authors of this Compendium). Researchers focused on exposures to ozone, particulate matter, silica dust, benzene, and formaldehyde—all of which are associated with drilling and fracking operations—noting that all are linked to adverse respiratory health effects, particularly in infants and children. Benzene, for example, emitted from gas wells, production tanks, compressors, and pipelines, is a carcinogen also linked to serious respiratory outcomes in infants and children, including pulmonary infections in newborns. As the authors emphasized, this review did not consider other air pollutants commonly associated with drilling and fracking activities, namely hydrogen sulfide, polycyclic aromatic hydrocarbons, and oxides of nitrogen. Although improved exposure assessment, air monitoring, and long-term studies are still lacking, existing evidence was sufficient for the authors to "strongly recommend precautionary measures at this time."[165]

- April 26, 2016 – About two percent of global ethane emissions originate from the Bakken shale oil and gas field, which, according to research led by University of Michigan researchers, emits 250,000 tons of ethane per year.[166] "Two percent might not sound like a lot, but the emissions we observed in this single region are 10 to 100 times larger than reported in inventories. They directly impact air quality across North America. And they're sufficient to explain much of the global shift in ethane concentrations," according to Eric Kort, first author of the study.[167] Ethane is a gas that affects climate and decreases air quality. As a greenhouse gas, ethane is the third-largest contributor to human-caused climate change. Ethane contributes to ground-based ozone pollution as it breaks down and reacts with sunlight to create smog. This surface-level ozone is linked to respiratory problems, eye irritation, and crop damage. Global ethane levels were decreasing until 2009, leading the researchers to suspect that the U.S. shale gas boom may be responsible for the global increase in levels since 2010.

- April 5, 2016 – Helicopter-based infrared camera surveys of more than 8,000 oil and gas wells in seven U.S. regions found that well pads emit considerably more methane and VOCs than captured by earlier inventories. Moreover, these emissions were widely and

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[164] Hakola, H. & Hellén, H. (2016). The return of ethane. *Nature Geoscience, 9,* 475-476. doi: 10.1038/ngeo2736
[165] Webb, E., Hays, J., Dyrszka, L., Rodriguez, B., Cox, C., Huffling, K., & Bushkin-Bedient, S. (2016). Potential hazards of air pollutant emissions from unconventional oil and natural gas operations on the respiratory health of children and infants. *Reviews on Environmental Health, 31*(2), 225-243. doi: 10.1515/reveh-2014-0070
[166] Kort, E. A., Smith, M. L., Murray, L. T., Gvakharia, A. Brandt, A. R., Peischl, J., . . .Travis, K. (2016). Fugitive emissions from the Bakken shale illustrate role of shale production in global ethane shift. *Geophysical Research Letters, 43,* 4617–4623. doi: 10.1002/2016GL068703
[167] Moore, C. S., & Human K. (2016, April 26). One oil field a key culprit in global ethane gas increase. *Michigan News.* Retrieved from http://ns.umich.edu/new/multimedia/videos/23735-one-oil-field-a-key-culprit-in-global-ethane-gas-increase

unpredictably variable from site to site and from well to well. Over 90 percent of total airborne emissions from well pads originated with vents and hatches on aboveground storage tanks.[168] The inability to predict which well sites were "superemitters" (meaning that they leaked into the air more than 200 cubic feet of methane and VOCs per hour) implies that continuous, site-specific monitoring is required to regulate methane leaks from drilling and fracking operations. In a comment about the findings to *InsideClimate News*, Cornell University engineer Anthony Ingraffea, who was not an author of the paper, said, "It makes regulation very difficult. If you have all these possible sites where you can have leaks, you can never have enough inspectors with all the right equipment being in all the right places at all the right times. It's too complex a system."[169]

- February 19, 2016 – Legally enforced minimal distances between well sites and residences are based on political compromises rather than peer-reviewed science and "may not be sufficient to reduce potential threats to human health in areas where hydraulic fracturing occurs," according to the findings of an interdisciplinary team including medical professionals and other researchers. The team incorporated geography, current regulations, historical records of blowout incidents and evacuations, thermal modeling, direct air pollution measurement, and vapor cloud modeling within the Marcellus (PA), Barnett (TX), and Niobrara (Northeastern and Northwestern Colorado and parts of Wyoming, Kansas, and Nebraska) Shale regions. The authors focused solely on well sites and excluded pipelines and compressor stations, which limited the data on explosions and evacuations and restricted air pollution results. Even so, the results showed that current natural gas well setbacks in the three areas "cannot be considered sufficient in all cases to protect public health and safety." People living within setback distances are potentially vulnerable to thermal injury during a well blowout, and they are also susceptible to exposures of benzene and hydrogen sulfide at levels above those known to cause health risks.[170]

- August 1, 2015 – "[C]linicians should be aware of the potential impact of fracking when evaluating their patients," concluded a team writing on behalf of the Occupational and Environmental Health Network of the American College of Chest Physicians. Their article stated that the over 200,000 U.S. workers employed by well-servicing companies "… are exposed to silica, diesel exhaust, and VOCs, and, at some sites, hydrogen sulfide and radon, raising concerns about occupational lung diseases, including silicosis, asthma, and lung cancer." The authors went on to say, "[i]n addition to occupational exposures, workers and nearby residents are also exposed to air pollutants emitted from various stages of fracking, including nitrogen oxides (NOx), VOCs, ozone, hazardous air pollutants, methane, and fine particulate matter." Authors pointed to several recent

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[168] Lyon, D. R., Alvarez, R. G., Zavala-Araiza, D., Brandt, A. R., Jackson, R. B., & Hamburg, S. P. (2016). Aerial surveys of elevated hydrocarbon emissions from oil and gas production sites. *Environmental Science & Technology, 50*(9). doi: 10.1021/acs.est.6b00705

[169] McKenna, P. (2016, April 8). Researchers find no shortcuts for spotting wells that leak the most methane. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/07042016/big-methane-leaks-superemitters-oil-gas-production-climate-change-edf

[170] Haley, M., McCawley, M., Epstein, A. C., Arrington, B., & Bjerke, E. F. (2016). Adequacy of current state setbacks for directional high-volume hydraulic fracturing in the Marcellus, Barnett, and Niobrara Shale plays. *Environmental Health Perspectives.* Advance online publication. doi: 10.1289/ehp.1510547

reversals in progress on air quality owed to fracking-related activity, including significant emissions of nitrogen oxides, a precursor of ozone, and spikes in fine particulate matter in fracking-intensive areas of Pennsylvania.[171]

- July 9, 2015 – The California Council on Science and Technology, in collaboration with the Lawrence Berkeley National Laboratory, released the second and third volumes of an extensive, peer-reviewed assessment of fracking in California. Air quality impacts are the focus of volume 2, chapter 3. The assessment found that current inventory methods underestimate methane and volatile organic chemical emissions from oil and gas operations and that fracking occurs in areas of California—most notably in the San Joaquin Valley and South Coast Air Basins—that already suffer from serious air quality problems. Further, no experimental studies of air emissions from drilling and fracking operations have ever been conducted in California. Although California has well-developed air quality inventory methods, they are "not designed to estimate well stimulation emissions directly, and it is not possible to determine well stimulation emissions from current inventory methods."[172]

- July 1, 2015 – In accordance with California Senate Bill No. 4, the California Division of Oil, Gas, and Geothermal Resources released a three-volume environmental impact report on oil and gas well stimulation treatments in the state (which, in California, include fracking along with acidizing and other unconventional extraction technologies that break up oil- or gas-containing rock). The Division determined that fracking and related operations can have "significant and unavoidable" impacts on air quality, including increasing ozone and other federally regulated pollutants to levels that violate air quality standards or that would make those violations worse.[173, 174]

- May 29, 2015 – Each of stage of the drilling and fracking process "… has distinct operations that occur and particular sets of air emissions that may affect the respiratory tract," wrote West Virginia University researcher Michael McCawley. Some states do have setback requirements, which "… may provide a margin of safety for fire and explosions but [do] not necessarily assure complete dilution or negligible exposure from air emissions." His paper described the specific air contaminants associated with respiratory effects for each stage of operations. For example, the actual fracking stage potentially emits diesel exhaust, VOCs, particulate matter, ozone precursors, silica, and acid mists. McCawley reviewed the health effects linked to each of the contaminant types. Though many long-term effects may not yet be apparent in shale gas regions, "[a]t

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[171] Evans, R. B., Prezant, D., & Huang, Y. C. (2015). Hydraulic fracturing (fracking) and the Clean Air Act. *Chest, 148*(2), 298-300. doi: 10.1378/chest.14-2582

[172] Brandt, A., Millstein, D., Jin, L., & Englander, J. (2015, July 9). Air quality impacts from well stimulation. In: California Council on Science and Technology, *An Independent Scientific Assessment of Well Stimulation in California*, volume 2, chapter 3. Retrieved from http://ccst.us/publications/2015/vol-II-chapter-3.pdf

[173] California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (2015, July 1). *Analysis of Oil and Gas Well Stimulation Treatments in California, Volume II.* Retrieved from http://www.conservation.ca.gov/dog/SB4DEIR/Pages/SB4_DEIR_TOC.aspx

[174] Cart. J. (2015, July 1). State issues toughest-in-the-nation fracking rules. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/lanow/la-me-ln-state-issues-fracking-rules-20150701-story.html

a minimum, one would expect to see similar rates of respiratory disease to that found near highways with heavy traffic flow."[175]

- April 21, 2015 – In a study funded by the electric power industry, a research team found that fracking had diminished air quality in rural areas downwind of gas sites in two heavily drilled Pennsylvania counties but that concentrations of VOCs were not as high as expected based on results in other states. Methane levels were higher than previous research had found.[176] The extent to which the results can be generalized to the Marcellus basin as a whole, the authors emphasized, remains uncertain.[177]

- April 15, 2015 – In a review of the literature, Colorado researchers demonstrated that four common chemical air pollutants from drilling and fracking operations—benzene, toluene, ethylbenzene, and xylene (BTEX)—are endocrine disruptors commonly found in ambient air that have the ability to interfere with human hormones at low exposure levels, including at concentrations well below EPA recommended exposure limits. Among the health conditions linked to ambient level exposures to the BTEX family of air pollutants: sperm abnormalities, reduced fetal growth, cardiovascular disease, respiratory dysfunction, and asthma.[178] "This review suggests that BTEX may…have endocrine disrupting properties at low concentrations, presenting an important line of inquiry for future research. BTEX are used globally in consumer products, and are released from motor vehicles and oil and natural gas operations that are increasingly in close proximity to homes, schools, and other places of human activity."[179]

- March 31, 2015 – University of Wyoming researchers identified a wastewater treatment and recycling facility as an important contributor to high winter ozone levels in Wyoming's Green River Basin. The facility released a signature mixture of volatile hydrocarbons, including toluene and xylene, which are ozone precursors.[180] This study documented that recycling activities can transfer volatile pollutants from water into air when fracking wastewater is cleaned up for reuse and that water treatment emissions can serve as an important point source of air pollutants.[181]

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[175] McCawley, M. (2015). Air contaminants associated with potential respiratory effects from unconventional resource development activities. *Seminars in Respiratory and Critical Care Medicine 36*(3), 379-387. doi: 10.1055/s-0035-1549453

[176] Phillips, S. (2015, May 19). Study: Lower than expected air pollutants detected at Marcellus drilling sites. *State Impact Pennsylvania.* Retrieved from https://stateimpact.npr.org/pennsylvania/2015/05/19/study-lower-than-expected-air-pollutants-from-gas-drilling-sites/

[177] Goetz, J. D., Floerchinger, C., Fortner E. C., Wormhoudt, J., Massoli, P., Knighton, W. B., . . . DeCarlo, P.F. (2015). Atmospheric emission characterization of Marcellus Shale natural gas development sites. *Environmental Science & Technology, 49,* 7012-20. doi: 10.1021/acs.est.5b00452

[178] Bienkowski, B. (2015, April 15). Scientists warn of hormone impacts from benzene, xylene, other common solvents. *Environmental Health News.* Retrieved from http://www.environmentalhealthnews.org/ehs/news/2015/apr/endocrine-disruption-hormones-benzene-solvents

[179] Bolden, A. L., Kwiatkowski, C. F., & Colborn, T. (2015). New look at BTEX: Are ambient levels a problem? *Environmental Science & Technology, 49,* 5261-76. doi: 10.1021/es505316f

[180] Field, R. A., Soltis, J., McCarthy, M. C., Murphy, S., & Montague, D. C. (2015). Influence of oil and gas field operations on spatial and temporal distributions of atmospheric non-methane hydrocarbons and their effect on ozone formation in winter. *Atmospheric Chemistry and Physics*, *15,* 3527-3542. doi: 10.5194/acp-15-3527-2015

[181] Peterka, A. (2015, April 2). Study links Wyo. winter ozone to drillers' wastewater plant. *Greenwire*. Retrieved from http://www.eenews.net/stories/1060016205

- March 26, 2015 – Fracking can pollute air hundreds of miles downwind from the well pad, according to the results of a study from University of Maryland. Researchers took hourly measurements of ethane in the air over Maryland and the greater Washington, DC area, where fracking does not occur, and compared them to ethane data from areas of West Virginia, Pennsylvania, and Ohio where it does. They found month-to-month correlations, indicating that the ethane pollution in the air over Maryland appears to be coming from drilling and fracking operations in these other states. Ethane, a minor component of natural gas, rose 30 percent in the air over the Baltimore and Washington DC area since 2010, even as other air pollutants declined in concentration. By contrast, no increase in ethane levels were found in Atlanta, Georgia, which is not downwind of fracking operations.[182, 183] Given this evidence for widespread ethane leakage, the paper's lead author asked how much methane and other, more reactive emissions might be escaping from wells, noting that "a substantial amount of hydrocarbons" are emitted as a result of flowback procedures following the fracturing process.[184]

- February 27, 2015 – A team of researchers from University of Texas, funded in part by the gas industry, examined ozone (smog) production resulting from natural gas extraction and use in Texas. Previous research by this team had found that the increased use of natural gas for generating electricity, as a replacement for coal, contributed to overall reductions in daily maximum ozone concentrations in northeastern Texas. By contrast, the results of this study found an increase in ozone in the Eagle Ford Shale area of south Texas. The Eagle Ford Shale is upwind from both Austin and San Antonio.[185] A potent greenhouse gas, methane is also a precursor for ground-level ozone and hence a contributor to smog formation.

- January 16, 2015 – Researchers from a number of universities, including the University of New Hampshire and Appalachian State University, used a source apportionment model to estimate the contribution of natural gas extraction activities to overall air pollution, including ozone, in heavily drilled southwest Pennsylvania. This regional air sampling effort demonstrated significant changes in atmospheric chemistry from drilling and fracking operations there. The researchers found that drilling and fracking operations may affect compliance with ozone standards.[186]

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[182] Vinciguerra, T. Yao, S., Dadzie, J., Chittmans, A., Deskins, T., Ehrman, S., & Dickerson, R. R. (2015). Regional air quality impacts of hydraulic fracturing and shale natural gas activities: evidence from ambient VOC observations. *Atmospheric Environment, 110,* 144-50. doi: 10.1016/j.atmosenv.2015.03.056
[183] Valentine, K. (2015, April 30). Fracking wells could pollute the air hundreds of miles away. *ClimateProgress*. Retrieved from http://thinkprogress.org/climate/2015/04/30/3653252/fracking-air-pollution-downwind/
[184] Levine, F., & Tune, L. (2015, April 30). Emissions from natural gas wells may travel far downwind. *University of Maryland: UMD Right Now.* Retrieved from http://www.umdrightnow.umd.edu/news/emissions-natural-gas-wells-may-travel-far-downwind
[185] Pacsi, A. P., Kimura, Y., McGaughey, G., McDonald-Buller, E. C., & Allen, D. T. (2015). Regional ozone impacts of increased natural gas use in the Texas power sector and development in the Eagle Ford Shale. *Environmental Science & Technology, 49,* 3966-73. doi: 10.1021/es5055012
[186] Swarthout, R. F., Russo, R.S., Zhou, Y., Miller, B.M., Mitchell, B., Horsman, E., . . . Sive, B.C. (2015). Impact of Marcellus Shale natural gas development in southwest Pennsylvania on volatile organic compound emissions and regional air quality. *Environmental Science & Technology, 49,* 3175-84. doi: 10.1021/es504315f

- November 20, 2014 – The Texas Commission on Environmental Quality confirmed high levels of benzene emissions and other VOCs around an oil and gas facility in the Eagle Ford Shale. Symptoms reported by local residents were consistent with those known to be associated with exposure to such chemicals.[187]

- November 14, 2014 – A University of Colorado at Boulder research team found that residential areas in intensely drilled northeastern Colorado have high levels of fracking-related air pollutants, including benzene. In some cases, concentrations exceed those found in large urban centers and are within the range of exposures known to be linked to chronic health effects. According to the study, “High ozone levels are a significant health concern, as are potential health impacts from chronic exposure to primary emissions of non-methane hydrocarbons (NMHC) for residents living near wells.” The study also noted that tighter regulations have not resulted in lower air pollution levels, “Even though the volume of emissions per well may be decreasing, the rapid and continuing increase in the number of wells may potentially negate any real improvements to the air quality situation.”[188]

- October 30, 2014 – A research team assembled by University at Albany Institute for Health and the Environment identified eight highly toxic chemicals in air samples collected near fracking and associated infrastructure sites across five states: Arkansas, Colorado, Pennsylvania, Ohio, and Wyoming. The most common airborne chemicals detected included two proven human carcinogens (benzene and formaldehyde) and two potent neurotoxicants (hexane and hydrogen sulfide). In 29 out of 76 samples, concentrations far exceeded federal health and safety standards, sometimes by several orders of magnitude. Further, high levels of pollutants were detected at distances exceeding legal setback distances from wellheads to homes. Highly elevated levels of formaldehyde, for example, were found up to a half-mile from a wellhead. In Arkansas, seven air samples contained formaldehyde at levels up to 60 times the level known to raise the risk for cancer.[189] “This is a significant public health risk,” said lead author David O. Carpenter, MD, in an accompanying interview: “Cancer has a long latency, so you’re not seeing an elevation in cancer in these communities. But five, 10, 15 years from now, elevation in cancer is almost certain to happen.”[190]

- October 21, 2014 – Responding to health concerns by local residents, a research team from University of Cincinnati and Oregon State University found high levels of air

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[187] Davis, B. (2014, November 20). TCEQ memo proves toxic chemicals are being released in the Eagle Ford Shale. *KENS 5 Eyewitness News.* Retrieved from http://www.kens5.com/story/news/investigations/i-team/2014/11/20/benzene-oil-toxic-fumes/70020596/

[188] Thompson, C. R., Hueber J., & Helmig D. (2014). Influence of oil and gas emissions on ambient atmospheric non-methane hydrocarbons in residential areas of Northeastern Colorado. *Elementa: Science of the Anthropocene, 2*. doi: 10.12952/journal.elementa.000035

[189] Macey, G. P., Breech, R., Chernaik, M., Cox, C., Larson, D., Thomas, D., & Carpenter, D. O. (2014). Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. *Environmental Health, 13*(82). doi: 10.1186/1476-069X-13-82

[190] Neuhauser, A. (2014, October 30). Toxic chemicals, carcinogens skyrocket near fracking sites. *U.S. News and World Report*. Retrieved from http://www.usnews.com/news/articles/2014/10/30/toxic-chemicals-and-carcinogens-skyrocket-near-fracking-sites-study-says

pollution in heavily drilled areas of rural Carroll County, Ohio. Air monitors showed 32 different hydrocarbon-based air pollutants, including the carcinogens naphthalene and benzo[a]pyrene.[191] The researchers plan additional monitoring and analysis.

- October 21, 2014 – Using a mobile laboratory designed by NOAA, a research team from the University of Colorado at Boulder, the NOAA Earth System Research Laboratory, and the Karlsruhe Institute of Technology looked at air pollution from drilling and fracking operations in Utah's Uintah Basin. The researchers found that drilling and fracking emit prodigious amounts of volatile organic air pollutants, including benzene, toluene, and methane, all of which are precursors for ground-level ozone (smog). Multiple pieces of equipment on and off the well pad, including condensate tanks, compressors, dehydrators, and pumps, served as the sources of these emissions. This research shows that drilling and fracking activities are the cause of the extraordinarily high levels of winter smog in the remote Uintah basin—which regularly exceed air quality standards and rival that of downtown Los Angeles.[192]

- October 2, 2014 – A joint investigation by *InsideClimate News* and the Center for Public Integrity found that toxic air emissions wafting from fracking waste pits in Texas are unmonitored and unregulated due to federal exemptions that classify oil and gas field waste as non-hazardous.[193]

- October 1, 2014 – In a major paper published in *Nature*, an international team led by the National Oceanic and Atmospheric Administration demonstrated that exceptionally high emissions of VOCs explain how drilling and fracking operations in Utah's Uintah Basin create extreme wintertime ozone events even in the absence of abundant ultraviolet light and water vapor, which are typically required to produce ground-level ozone (smog). Current air pollution trends in the United States are toward lower nitrogen oxides from urban sources and power generation, but increasing methane and VOCs from oil and gas extraction activities threaten to reverse decades of progress in attaining cleaner air. According to the study, the consequences for public health are "as yet unrecognized."[194]

- September 6, 2014 – As part of a comparative lifecycle analysis, a British team from the University of Manchester found that shale gas extracted via fracking in the United Kingdom would generate more smog than any other energy source evaluated (coal,

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[191] Environmental Health Sciences Center, Oregon State University. (2014). List of 62 PAH analyzed in Carroll County, OH. Retrieved from http://ehsc.oregonstate.edu/air/62PAH

[192] Warneke, C., Geiger, F., Edwards, P. M., Dube, W., Pétron, G., Kofler, J., . . . Roberts, J. M. (2014). Volatile organic compound emissions from the oil and natural gas industry in the Uintah Basin, Utah: oil and gas well pad emissions compared to ambient air composition. *Atmospheric Chemistry and Physics, 14*, 10977-10988. doi: 10.5194/acp-14-10977-2014

[193] Hasemyer, D., & Hirji, Z. (2014, October 2). Open piles offer cheap disposal for fracking sludge, but health worries mount. *InsideClimate News* and the Center for Public Integrity. Retrieved from http://www.publicintegrity.org/2014/10/02/15826/open-pits-offer-cheap-disposal-fracking-sludge-health-worries-mount

[194] Edwards, P. M., Brown, S. S., Roberts, J. M., Ahmadov, R., Banta, R. M., deGouw, J.A., . . Zamora, R. (2014). High winter ozone pollution from carbonyl photolysis in an oil and gas basin. *Nature, 514*(7522), 351-354. doi: 10.1038/nature13767

conventional and liquefied gas, nuclear, wind, and solar). Leakage of vaporous organic compounds during the necessary removal of hydrogen sulfide gas, along with the venting of gas both during drilling and during the process of making the well ready for production, were major contributors. "In comparison to other technologies, shale gas has high [photochemical smog]. In the central case, it is worse than solar PV, offshore wind and nuclear power by factors of 3, 26 and 45, respectively. Even in the best case, wind and nuclear power are still preferable (by factors of 3.3 and 5.6 respectively)."[195]

- September 2014 – ShaleTest Environmental Testing conducted ambient air quality tests and gas-finder infrared video for several children's play areas in North Texas that are located in close proximity to shale gas development. The results showed a large number of compounds detected above the Method Reporting Limit (the minimum quantity of the compound that can be confidently determined by the laboratory). Air sampling found three known/suspected carcinogens, and a number of other compounds associated with significant health effects. Benzene results from Denton, Dish, and Fort Worth are particularly alarming since they exceeded the long-term ambient air limits set by the Texas Commission on Environmental Quality, and benzene is a known carcinogen. "Benzene was found at all but one sampling location …. This is particularly noteworthy as benzene is a known carcinogen (based on evidence from studies in both people and lab animals), AND because it exceeds [levels above which effects have the potential to occur.]"[196]

- August 24, 2014 – A *Salt Lake City Tribune* investigation found that evaporation from 14 fracking waste pits in western Colorado has added tons of toxic chemicals to Utah's air in the last six years. Further, the company responsible operated with no permit, underreported its emissions and provided faulty data to regulators.[197]

- August 2014 – A four-part investigation by the *San Antonio Express-News* found that natural gas flaring in the Eagle Ford Shale in 2012 contributed more than 15,000 tons of VOCs and other contaminants to the air of southern Texas—which is roughly equivalent to the pollution that would be released annually by six oil refineries. No state or federal agency is tracking the emissions from individual flares.[198]

- June 26, 2014 – Public health professionals at the Southwest Pennsylvania Environmental Health Project reported significant recurrent spikes in the amount of particulate matter in the air inside of residential homes located near drilling and fracking operations. Captured by indoor air monitors, the spikes tend to occur at night when stable atmospheric conditions hold particulate matter low to the ground. Director Raina Ripple emphasized

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[195] Stamford, L., & Azapagic, A. (2014). Life cycle environmental impacts of UK shale gas. *Applied Energy, 134*, 506-518. doi: 10.1016/j.apenergy.2014.08.063

[196] ShaleTest Environmental Testing. (2014, September). Project playground: Cleaner air for active kids. Retrieved from http://www.shaletest.org/wp-content/uploads/2014/09/ProjectPlaygoundPatagoniaReport-5-1.pdf

[197] Maffly, B. (2014, August 24). Utah grapples with toxic water from oil and gas industry. *Salt Lake City Tribune*. Retrieved from http://www.sltrib.com/sltrib/news/58298470-78/danish-flats-ponds-company.html

[198] Hiller, J., & Tedesco, J. (2014, August). Up in flames: Flare in Eagle Ford Shale wasting natural gas. *San Antonio Express News.* Retrieved from: http://www.expressnews.com/business/eagleford/item/Up-in-Flames-Day-1-Flares-in-Eagle-Ford-Shale-32626.php

that spikes in airborne particulate matter are likely to cause acute health impacts in community members. She added, “What the long-term effects are going to be, we’re not certain.”[199]

- May 8, 2014 – Researchers at NOAA found high levels of methane leaks as well as benzene and smog-forming VOCs in the air over oil and gas drilling areas in Colorado. Researchers found methane emissions three times higher than previously estimated and benzene and VOC levels seven times higher than estimated by government agencies. The *Denver Post* noted that Colorado’s Front Range has failed to meet federal ozone air quality standards for years.[200]

- April 26, 2014 – A Texas jury awarded a family $2.8 million because, according to the lawsuit, a fracking company operating on property nearby had “created a ‘private nuisance’ by producing harmful air pollution and exposing [members of the affected family] to harmful emissions of volatile organic compounds, toxic air pollutants and diesel exhaust.” The family’s 11-year-old daughter became ill, and family members suffered a range of symptoms, including “nosebleeds, vision problems, nausea, rashes, blood pressure issues.”[201] Because drilling did not occur on their property, the family had initially been unaware that their symptoms were caused by activities around them.

- April 16, 2014 – Reviewing the peer-review literature to date of “direct pertinence to the environmental public health and environmental exposure pathways,” a U.S. team of researchers concluded: “[a] number of studies suggest that shale gas development contributes to levels of ambient air concentrations known to be associated with increased risk of morbidity and mortality.”[202]

- April 11, 2014 – A modeling study commissioned by the state of Texas made striking projections about worsening air quality in the Eagle Ford Shale. Findings included the possibility of a 281 percent increase in emissions of VOCs. Some VOCs cause respiratory and neurological problems; others, like benzene, are also carcinogens. Another finding was that nitrogen oxides—which react with VOCs in sunlight to create ground-level ozone, the main component of smog—increased 69 percent during the peak ozone season.[203]

- March 29, 2014 – Scientists warn that current methods of collecting and analyzing emissions data do not accurately assess health risks. Researchers with the Southwest

[199] McMahon, J. (2014, June 26). Air pollution spikes in homes near fracking wells. *Forbes*. Retrieved from http://www.forbes.com/sites/jeffmcmahon/2014/06/26/air-pollution-spikes-in-homes-near-fracking-wells/
[200] Finley, B. (2014, May 8). Scientists flying over Colorado oil boom find worse air pollution. *The Denver Post*. Retrieved from http://www.denverpost.com/environment/ci_25719742/scientists-flying-over-colorado-oil-boom-find-worse
[201] Morris, J. (2014, April 26). Texas family plagued with ailments gets $3M in 1st-of-its-kind fracking judgment. *CNN*. Retrieved from http://www.cnn.com/2014/04/25/justice/texas-family-wins-fracking-lawsuit/
[202] Shonkoff, S. B., Hays, J., & Finkel, M. L. (2014). Environmental public health dimensions of shale and tight gas development. *Environmental Health Perspectives*, *122,* 787–795. doi: 10.1289/ehp.1307866
[203] Morris, J., Song, L., & Hasemayer, D. (2014, April 11). Report: Air quality to worsen in Eagle Ford shale. *The Texas Tribune*. Retrieved from http://www.texastribune.org/2014/04/11/report-air-quality-worsen-eagle-ford-shale/

Pennsylvania Environmental Health Project showed that methods do not adequately measure the intensity, frequency, or durations of community exposure to the toxic chemicals routinely released from drilling and fracking activities. They found that exposures may be underestimated by an order of magnitude, mixtures of chemicals are not taken into account, and local weather conditions and vulnerable populations are ignored.[204]

- March 27, 2014 – University of Texas research pointed to "potentially false assurances" in response to community health concerns in shale gas development areas. Dramatic shortcomings in air pollution monitoring to date include no accounting for cumulative toxic emissions or children's exposures during critical developmental stages, and the potential interactive effects of mixtures of chemicals. Chemical mixtures of concern include benzene, toluene, ethylbenzene, and xylenes.[205, 206]

- March 13, 2014 – VOCs emitted in Utah's heavily drilled Uintah Basin led to 39 winter days exceeding the EPA's eight-hour National Ambient Air Quality Standards level for ozone pollutants the previous winter. "Levels above this threshold are considered to be harmful to human health, and high levels of ozone are known to cause respiratory distress and be responsible for an estimated 5,000 premature deaths in the U.S. per year," according to researchers at the University of Colorado. Their observations "reveal a strong causal link between oil and gas emissions, accumulation of air toxics, and significant production of ozone in the atmospheric surface layer."[207] Researchers estimated that total annual VOC emissions at the fracking sites are equivalent to those of about 100 million cars.[208]

- March 3, 2014 – In a report summarizing "the current understanding of local and regional air quality impacts of natural gas extraction, production, and use," a group of researchers from NOAA, Stanford, Duke, and other institutions described what is known and unknown with regard to air emissions including greenhouse gases, ozone precursors (VOCs and nitrogen oxides), air toxics, and particulates. Crystalline silica was also discussed, including as a concern for people living near well pads and production staging areas.[209]

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[204] Brown, D., Weinberger, B., Lewis, C., & Bonaparte, H. (2014). Understanding exposure from natural gas drilling puts current air standards to the test. *Reviews on Environmental Health, 29*(4), 277-92. doi: 10.1515/reveh-2014-0002

[205] Rawlins, R. (2013). Planning for fracking on the Barnett shale: Urban air pollution, improving health based regulation, and the role of local governments. *Virginia Environmental Law Journal, 31*, 226-306. Retrieved from http://www.velj.org/uploads/1/2/7/0/12706894/2._rawlins_-_barnett_shale.pdf

[206] University of Texas at Austin. (2014, March 27). Air pollution and hydraulic fracturing: Better monitoring, planning and tracking of health effects needed in Texas. Retrieved from http://www.utexas.edu/news/2014/03/27/hydraulic-fracturing-texas/

[207] Helmig, D., Thompson, C. R., Evans, J., Boylan, P., Hueber, J., & Park, J. (2014). Highly elevated atmospheric levels of volatile organic compounds in the Uintah Basin, Utah [Abstract]. *Environmental Science & Technology, 48*(9), 4707-4715. doi: 10.1021/es405046r

[208] Lockwood, D. (2014, March 25). Harmful air pollutants build up near oil and gas fields. *Chemical & Engineering News*. Retrieved from http://cen.acs.org/articles/92/web/2014/03/Harmful-Air-Pollutants-Build-Near.html

[209] Moore, C. W., Zielinska, B., Petron, G., & Jackson, R. B. (2014). Air impacts of increased natural gas acquisition, processing, and use: A critical review. *Environmental Science & Technology*. doi: 10.1021/es4053472

- February 18, 2014 – An eight-month investigation by the *Weather Channel*, the *Center for Public Integrity,* and *InsideClimate News* into fracking in the Eagle Ford Shale in Texas revealed that fracking is "releasing a toxic soup of chemicals into the air." They noted very poor monitoring by the state of Texas and reported on hundreds of air complaints filed relating to air pollution associated with fracking.[210]

- December 18, 2013 – An interdisciplinary group of researchers in Texas collected air samples in residential areas near shale gas extraction and production, going beyond previous Barnett Shale studies by including emissions from the whole range of production equipment. They found that most areas had "atmospheric methane concentrations considerably higher than reported urban background concentrations," and many toxic chemicals were "strongly associated" with compressor stations.[211]

- December 10, 2013 – Health department testing at fracking sites in West Virginia revealed dangerous levels of benzene in the air. Wheeling-Ohio County Health Department Administrator Howard Gamble stated, "The levels of benzene really pop out. The amounts they were seeing were at levels of concern. The concerns of the public are validated."[212]

- October 11, 2013 – Air sampling before, during, and after drilling and fracking of a new natural gas well pad in rural western Colorado documented the presence of the toxic solvent methylene chloride, along with several polycyclic aromatic hydrocarbons at "concentrations greater than those at which prenatally exposed children in urban studies had lower developmental and IQ scores."[213]

- September 19, 2013 – In Texas, air monitoring data in the Eagle Ford Shale area revealed potentially dangerous exposures of nearby residents to hazardous air pollutants, including cancer-causing benzene and the neurological toxicant, hydrogen sulfide.[214]

- September 13, 2013 – A study by researchers at the University of California at Irvine found dangerous levels of VOCs in Canada's "Industrial Heartland" where there are more than 40 oil, gas, and chemical facilities. The researchers noted high levels of

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[210] Morris, J., Song, L., & Hasemayer, D. (2014, February 18). Fracking the Eagle Ford Shale. *The Weather Channel*. Retrieved from http://stories.weather.com/fracking
[211] Rich, A., Grover, J. P., & Sattler, M. L. (2014). An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. *Journal of the Air & Waste Management Association, 64*(1), 61-72. doi: 10.1080/10962247.2013.832713
[212] Junkins, C. (2013, December 10). Health dept. concerned about benzene emissions near local gas drilling sites. *The Intelligencer, Wheeling News-Register*. Retrieved from http://www.theintelligencer.net/page/content.detail/id/593209/Health-Dept--Concerned-About-Benzene-Emissions-Near-Local-Gas-Drilling-Sites.html?nav=510
[213] Colborn, T., Schultz, K., Herrick, L., & Kwiatkowski, C. (2014). An exploratory study of air quality near natural gas operations. *Human and Ecological Risk Assessment: An International Journal, 20*(1), 86-105. doi: 10.1080/10807039.2012.749447
[214] Wilson, S., Sumi, L., & Subra, W. (2013, September 19). Reckless endangerment while fracking the Eagle Ford shale. *Earthworks*. Retrieved from http://www.earthworksaction.org/library/detail/reckless_endangerment_in_the_eagle_ford_shale#.UkGi-4Y3uSo.

hematopoietic cancers (leukemia and non-Hodgkin's lymphoma) in men who live closer to the facilities.[215]

- April 29, 2013 – Using American Lung Association data, researchers with the Environmental Defense Fund determined that air quality in rural areas with fracking was worse than air quality in urban areas.[216]

- March 2013 – A review of regional air quality damages in parts of Pennsylvania in 2012 from Marcellus Shale development found that air pollution was a significant concern, with regional damages ranging from $7.2-$32 million in 2011.[217]

- February 27, 2013 – In a letter from Concerned Health Professionals of New York to Governor Andrew Cuomo, a coalition of hundreds of health organizations, scientists, medical experts, elected officials, and environmental organizations noted serious health concerns about the prospects of fracking in New York State, making specific note of air pollution.[218] Signatory organizations included the American Academy of Pediatrics of New York, the American Lung Association of New York, and Physicians for Social Responsibility. The New York State Medical Society, representing 30,000 medical professionals, has issued similar statements.[219]

- January 2, 2013 – A NOAA study identified emissions from oil and gas fields in Utah as a significant source of pollutants that contribute to ozone problems.[220] Exposure to elevated levels of ground-level ozone is known to worsen asthma and has been linked to respiratory illnesses and increased risk of stroke and heart attack.[221]

- December 3, 2012 – A study linked a single well pad in Colorado to more than 50 airborne chemicals, 44 of which have known health effects.[222]

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[215] Simpson, I. J., Marrero, J. E., Batterman, S. & Blake, D. R. (2013) Air quality in the Industrial Heartland of Alberta, Canada and potential impacts on human health. *Atmospheric Environment*, *81,* 702-709. doi: 10.1016/j.atmosenv.2013.09.017

[216] Grossman, D. (2013, April 29). Clean air report card: CO, WY Counties get F's due to oil and gas pollution. *Environmental Defense Fund*. Retrieved from http://blogs.edf.org/energyexchange/2013/04/29/clean-air-report-card-co-wy-counties-get-fs-due-to-oil-and-gas-pollution/#sthash.FXRV6Nxi.dpuf

[217] Litovitz, A., Curtright, A., Abramzon, S., Burger, N., & Samaras, C. (2013). Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania. *Environmental Research Letters, 8*(1). doi: 10.1088/1748-9326/8/1/014017

[218] Concerned Health Professionals of NY. (2013, February 27). Letter to Governor Cuomo. Retrieved from http://concernedhealthny.org/letters-to-governor-cuomo/

[219] Campbell, J. (2013, April 17). Fracking roundup: Gas prices up; Medical society wants moratorium. *Politics on the Hudson*. Retrieved from http://polhudson.lohudblogs.com/2013/04/17/fracking-roundup-gas-prices-up-medical-society-wants-moratorium/

[220] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. *Nature, 493*(7430), 12-12. doi: 10.1038/493012a

[221] American Lung Association. (2013). American Lung Association state of the air 2013 - Ozone pollution. Retrieved from http://www.stateoftheair.org/2013/health-risks/health-risks-ozone.html

[222] Colborn, T., Schultz, K., Herrick, L., & Kwiatkowski, C. (2014). An exploratory study of air quality near natural gas operations. *Human and Ecological Risk Assessment: An International Journal, 20*(1), 86-105. doi: 10.1080/10807039.2012.749447

- July 18, 2012 – A study by the Houston Advanced Research Center modeled ozone formation from a natural gas processing facility using accepted emissions estimates and showed that regular operations could significantly raise levels of ground-level ozone (smog) in the Barnett Shale in Texas and that gas flaring further contributed to ozone levels.[223]

- March 19, 2012 – A Colorado School of Public Health study found air pollutants near fracking sites linked to neurological and respiratory problems and cancer.[224, 225] The study, based on three years of monitoring at Colorado sites, found a number of "potentially toxic petroleum hydrocarbons in the air near gas wells including benzene, ethylbenzene, toluene, and xylene." Lisa McKenzie, PhD, MPH, lead author of the study and research associate at the Colorado School of Public Health, said, "Our data show that it is important to include air pollution in the national dialogue on natural gas development that has focused largely on water exposures to hydraulic fracturing."[226]

- December 12, 2011 – Cancer specialists, cancer advocacy organizations, and health organizations summarized the cancer risks posed by all stages of the shale gas extraction process in a letter to New York Governor Andrew Cuomo.[227]

- October 5, 2011 – More than 250 medical experts and health organizations reviewed the multiple health risks from fracking in a letter sent to New York Governor Andrew Cuomo.[228]

- April 21, 2011 – *Environment & Energy (E&E)* reported that ozone levels exceeding federal health standards in Utah's Uintah Basin, as well as wintertime ozone problems in other parts of the Intermountain West, stem from oil and gas extraction. Levels reached nearly twice the federal standard, potentially dangerous even for healthy adults to breathe. Keith Guille, spokesman for the Wyoming Department of Environmental Quality, said, "We recognize that definitely the main contributor to the emissions that are out there is the oil and gas industry…."[229]

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[223] Olaguer, E. P. (2012). The potential near-source ozone impacts of upstream oil and gas industry emissions. *Journal of the Air & Waste Management Association, 62*(8), 966-977. doi: 10.1080/10962247.2012.688923

[224] Kelly, D. (2012, March 19). Study shows air emissions near fracking sites may pose health risk. *University of Colorado Denver*. Retrieved from http://www.ucdenver.edu/about/newsroom/newsreleases/Pages/health-impacts-of-fracking-emissions.aspx

[225] McKenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L. (2012). Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment, 424*, 79-87. doi: 10.1016/j.scitotenv.2012.02.018

[226] Banerjee, N. (2012, March 20). Study: 'Fracking' may increase air pollution health risks. *Los Angeles Times*. Retrieved from http://articles.latimes.com/2012/mar/20/local/la-me-gs-fracking-increases-air-pollution-health-risks-to-residents-20120320

[227] Physicians, Scientists & Engineers for Healthy Energy. (2011, December 12). Appeal to Gov. Cuomo to consider cancer risks re: High volume hydraulic fracturing for natural gas [Letter to A. Cuomo].

[228] Physicians, Scientists & Engineers for Healthy Energy. (2011, October 5). Letter to Governor Cuomo [Letter to A. Cuomo].

[229] Streater, S. (2011, April 21). Air pollution: Winter ozone problem continues to mystify regulators, industry. *E&E Publishing, LLC*. Retrieved from http://www.eenews.net/stories/1059948108

- March 8, 2011 – The Associated Press reported that gas drilling in some remote areas of Wyoming caused a decline of air quality from pristine mountain air to levels of smog and pollution worse than Los Angeles on its worst days, resulting in residents complaining of watery eyes, shortness of breath, and bloody noses.[230]

- November 18, 2010 – A study of air quality in the Haynesville Shale region of east Texas, northern Louisiana, and southwestern Arkansas found that shale oil and gas extraction activities contributed significantly to ground-level ozone (smog) via high emissions of ozone precursors, including VOCs and nitrogen oxides.[231] Ozone is a key risk factor for asthma and other respiratory and cardiovascular illnesses.[232, 233, 234, 235]

- September 2010 – A health assessment by the Colorado School of Public Health for gas development in Garfield County, Colorado determined that air pollution will likely "be high enough to cause short-term and long-term disease, especially for residents living near gas wells. Health effects may include respiratory disease, neurological problems, birth defects and cancer."[236, 237]

- January 27, 2010 – Of 94 drilling sites tested for benzene in air over the Barnett Shale, the Texas Commission on Environmental Quality discovered two well sites emitting what they determined to be "extremely high levels" and another 19 emitting elevated levels.[238]

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230 Gruver, M. (2011, March 8). Wyoming is beset by a big-city problem: Smog. *USA Today*. Retrieved from http://usatoday30.usatoday.com/money/industries/energy/2011-03-08-natural-gas-ozone-wyoming_N.htm

231 Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., . . . Yarwood, G. (2010). Ozone impacts of natural gas development in the Haynesville Shale. *Environmental Science & Technology, 44*(24), 9357-9363. doi: 10.1021/es1021137

232 U.S. Environmental Protection Agency. (2013). Integrated science assessment for ozone and related photochemical oxidants. Retrieved from http://www.epa.gov/ncea/isa/ozone.htm

233 Shah, A. S., Lee, K. K., McAllister, D. A., Hunter, A., Nair, H., Whiteley, W., . . . Mills, N. L. (2015). Short term exposure to air pollution and stroke: systematic review and meta-analysis. *British Medical Journal, 24*(1295). doi: 10.1136/bmj.h1295

234 Shah, A. S., Langrish, J. P., Nair, H., McAllister, D. A., Hunter, A., L., Donaldson, K., . . . Mills, N. L. (2013). Global association of air pollution and heart failure: a systematic review and meta-analysis. *The Lancet, 382*(9897), 1039-1048. doi: 10.1016/S0140-6736(13)60898-3.

235 Myers, O., Flowers, H., Kang, H., Bedrick, E., Whorton, B., Cui, X., & Stidley, C. A. (2007). The association between ambient air quality ozone levels and medical visits for asthma in San Juan County. New Mexico Department of Health, Environmental Health Epidemiology Bureau Epidemiology and Response Division. Retrieved from http://www.nmenv.state.nm.us/aqb/4C/Documents/SanJuanAsthmaDocBW.pdf

236 Witter, R., McKenzie, L., Towle, M., Stinson, K., Scott, K., Newman, L., & Adgate, J. (2010). Health impact assessment for Battlement Mesa, Garfield County Colorado. *Colorado School of Public Health*. Retrieved from http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf

237 Battlement Mesa HIA/EHMS. (2013, November 30). Retrieved from http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-draft2.aspx

238 The Associated Press. (2010, January 27). Texas agency finds high benzene levels on Barnett Shale. Retrieved from http://www.nola.com/business/index.ssf/2010/01/texas_agency_finds_high_benzen.html

Water contamination

Substantial evidence shows that drilling and fracking activities, and associated wastewater disposal practices, inherently threaten groundwater and have polluted drinking water sources. Repudiating industry claims of risk-free fracking, studies from across the United States present irrefutable evidence that groundwater contamination occurs as a result of fracking activities and is more likely to occur close to well pads. In Pennsylvania alone, the state has determined that 343 private drinking water wells have been contaminated or otherwise impacted as the result of drilling and fracking operations over an eight-year period. As determined by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), the chemical contamination of some private water wells in Dimock, Pennsylvania posed demonstrable health risks, rendering the water unsuitable for drinking.

Evidence of instances and pathways of water contamination exist even though scientific inquiry is impeded by industry secrecy and regulatory exemptions. The 2005 Energy Policy Act exempts hydraulic fracturing from key provisions of the Safe Drinking Water Act. As a result, fracking chemicals have been protected from public scrutiny as "trade secrets." The oil and gas sector is the only U.S. industry permitted to inject known hazardous materials near, or directly into, underground drinking water aquifers. At the same time, in most states where fracking occurs, routine monitoring of groundwater aquifers near drilling and fracking operations is not required, nor are companies compelled to fully disclose the identity of chemicals used in fracking fluid, their quantities, or their fate once injected underground.

Nevertheless, of the more than 1,000 chemicals that are confirmed ingredients in fracking fluid, an estimated 100 are known endocrine disruptors, acting as reproductive and developmental toxicants. Adding to this mix are heavy metals, radioactive elements, brine, and volatile organic compounds (VOCs), which occur naturally in deep geological formations and which can be carried up from the fracking zone with the flowback fluid. As components of the fracking waste stream, these toxic substances also pose threats to surface water and groundwater. A 2017 study found that spills of fracking fluids and fracking wastewater are common, documenting 6,678 significant spills occurring over a period of nine years in four states alone. In these states, between 2 and 16 percent of wells report spills each year. About five percent of all fracking waste is lost to spills, often during transport.

Spills and intentional discharges of fracking waste into surface water have profoundly altered the chemistry and ecology of streams throughout entire watersheds, increasing downstream levels of radioactive elements, heavy metals, endocrine disruptors, toxic disinfection byproducts, and acidity, and decreasing aquatic biodiversity and populations of zooplankton and sensitive fish species, such as brook trout. Recent studies documenting changes in the bacterial flora in groundwater following drilling and fracking operations represent an emerging area of concern.

Demand for water to use in U.S. fracking operations continues to rise and has more than doubled since 2016. Unlike water used for agriculture or other industrial uses, the water used for fracking that remains in the shale bedrock is permanently lost to the hydrologic cycle. A suite of new studies now show that fracking can deplete streams and aquifers in ways that contribute to water stress and water scarcity. A 2018 study found that water use for fracking

operations increased by 770 percent per well between 2011 and 2016 across all U.S. shale basins. At the same time, the volume of fracking wastewater generated during the first year of extraction increased by up to 1440 percent. There is no known solution for the problem of fracking wastewater. It cannot be filtered to create clean, drinkable water, nor is there any safe method of disposal. Recycling is an expensive, limited option that increases radionuclide levels of subsequent wastewater. Underground reservoirs that receive fracking wastewater via injection into disposal wells, a practice that is linked to earthquakes, are reaching capacity in many regions of the United States.

- March 28, 2019 – Chemical surfactants are added to fracking fluid to emulsify, reduce surface tension, and inhibit corrosion. An engineering team looked at the chemical fate of these additives when they come back to the surface as shale gas wastewater. They found that high dissolved solids (salts) in the wastewater inhibit microbes that assist in biodegradation. "The presence of higher total dissolved solids appeared to exert an appreciable, long-standing effect on microbial community composition within one week of exposure to increased salinity, suggesting that an accidental release of recycled produced water may upset naturally occurring microbial communities." These results imply that accidental spills of shale gas wastewater—or deliberate releases (as when fracking wastewater is used for de-icing roads or irrigation)—are likely to result in the environmental persistence of these surfactant chemicals. These findings have implications for treating and recycling fracking wastewater. Its high salt levels mean that it must be filtered through special desalinating membranes, but the persistent presence of surfactant chemicals can clog and damage these membranes.[239]

- March 14, 2019 – Rainbow trout exposed to levels of fracking wastewater that mimic those that would result from a low-level spill, as from a pipeline leak into a small river, did not show significant signs of salinity stress. However, their blood plasma did accumulate strontium and bromide. This study did not examine possible endocrine disrupting effects.[240]

- March 5, 2019 – Water fleas (*Daphnia spp.)* are freshwater zooplankton that feed on phytoplankton and play a crucial role in aquatic food webs. In a Canadian study, water fleas exposed to various concentrations of fracking wastewater displayed altered behaviors that impaired their ability to orient toward light, a response that allows them to avoid predation and find food. This study helps explain the results of earlier research that links fracking fluid exposure to decreased water flea survival. Water fleas are unable to detect and avoid fracking fluid spills.[241] (See also entry for April 28, 2018.)

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[239] Hanson, A. J., Luek J. L., Tummings, S. S., McLaughlin, M. C., Blotevogel, J., & Mouser, P. J. (2019). High total dissolved solids in shale gas wastewater inhibit biodegradation of alkyl and nonlphenol ethoxylate surfactants. *Science of the Total Environment, 668*, 1094-1103. doi: 10.1016/j.scitotenv.2019.03.041

[240] Delompre, P. L. M., Blewett, T. A., Snihur, K. N., Flynn, S. L., Alessi, D. S., Glover, C. N., & Goss, G. G. (2019). The osmotic effect of hyper-saline hydraulic fracturing fluid on rainbow trout, *Oncorhynchus mykiss*. *Aquatic Toxicology, 211*, 1-10. doi: 10.1016/j.aquatox.2019.03.009

[241] Delompre, P. L. M., Blewett, T. A., Goss, G. G., & Glover, C. N. (2019). Shedding light on the effects of hydraulic fracturing flowback and produced water on phototactic behavior in *Daphnia magna*. *Ecotoxicology and Environmental Safety, 174*, 315-323. doi: 10.1016./j.ecoenv.2019.03.006

- February 28, 2019 – An American University team compared water quality parameters in 19 small streams in an intensely fracked area of southwestern Pennsylvania with those of 10 equivalent streams in western Maryland where fracking is banned and has never taken place. Streams in both study areas overlie the Marcellus Shale. Even after accounting for variations in forest cover, urban development, and historical impacts from coal mining, the researchers found significant differences in concentrations of certain salts and heavy metals, including arsenic. The results "imply that water quality has been affected by [shale gas] development in the Marcellus Shale region" and "support the idea that the Pennsylvania streams have received greater pollution inputs than have the Maryland streams."[242]

- February 11, 2019 – The U.S. Justice Department reached a settlement with Antero Resources Corporation over claims that it violated the Clean Water Act at 32 different drilling and fracking-related sites in West Virginia. The violations involved unauthorized dumping of fracking waste into local waterways.[243]

- February 7, 2019 – The Karoo Basin in South Africa is a semi-arid region underlain by gas-containing shale. Its bedrock is also rich in uranium, and, consequently, the basin has a range of different naturally occurring radioactive materials, including radium and radon gas. As part of a baseline study prior to fracking, a South African team monitored the presence of radon in groundwater in 53 aquifers throughout the Karoo Basin. They found that water in seven sites had levels of radon above levels considered safe by the World Health Organization. They also observed lower levels in cool, deep aquifers and higher levels of radon in warm, shallow aquifers, where seasonal and annual fluctuations were common.[244]

- January 22, 2019 – Demand for water to use in fracking operations for oil extraction has more than doubled since 2016, according to data from Rystad Energy, an energy research intelligence company. In the Permian Basin alone, located in west Texas and southeastern New Mexico, water demand for fracking now exceeds the total U.S. demand in 2016.[245]

- January 7, 2019 – From samples of fracking wastewater in Alberta, a Canadian team isolated a previously unidentified class of contaminants, aryl phosphates, which degrade into diphenyl phosphate. Experiments showed that diphenyl phosphate does not bind to clay-rich soils. Therefore, its transportation into groundwater following fracking waste

[242] Knee, K. L., & Masker, A. E. (2019). Association between unconventional oil and gas (UOG) development and water quality in small streams overlying the Marcellus Shale. *Freshwater Science, 38*(1). Advance online publication. doi:10.1086/701675

[243] Reuters. (2019, February 11). U.S. settles with Antero over water pollution from fracking. Retrieved from https://www.reuters.com/article/us-usa-antero/us-settles-with-antero-over-water-pollution-from-fracking-idUSKCN1Q021K

[244] Botha, R., Lindsay, R., Newman, R. T., Makeka, P. P., & Chimba, G. (2019). Radon in groundwater baseline study prior to unconventional shale gas development and hydraulic fracturing in the Karoo Basin (South Africa). *Applied Radiation and Isotopes, 147,* 7-13. doi: 10.1016/j.apradiso.2019.02.006

[245] Rystad Energy (2019, January 22). Frac water demand is sky-rocketing [Press release]. Retrieved from https://www.rystadenergy.com/newsevents/news/press-releases/Frac-water-demand-is-sky-rocketing/

spills would be swift. Further research showed toxic effects of low-level exposure of diphenyl phosphate on fish embryos and embryonic chick tissue. Noting that hundreds of fracking waste spills are reported in Alberta each year, the researchers expressed concern that diphenyl phosphate "may pose an environmental risk to aquatic ecosystems if released into the environment."[246]

- November 28, 2018 – Drilling and fracking operations in the Marcellus Shale region are known to harm biodiversity and reduce the populations of aquatic invertebrate animals that are the basis of the food chain in streams. A research team working in West Virginia investigated whether an observed population decline in a species of bird, the Louisiana Waterthrush, might be related to loss of these aquatic invertebrates, which are its prey. While the results varied from year to year and loss of food resources did not wholly explain the declines in waterthrush populations in areas of active drilling and fracking, "collective evidence suggests there may be a shale gas disturbance threshold at which waterthrush respond negatively to aquatic prey community changes."[247]

- November 19, 2018 – Methane can find its way into groundwater through naturally occurring fractures and fissures in shale deposits or through openings created by nearby drilling and fracking operations. A team led by Pennsylvania State University geochemist Susan Brantley sampled methane in drinking water wells in Pennsylvania with and without fracking, focusing on an area where fracking wells had been cited for contaminating nearby drinking water wells—in some cases with levels of methane high enough to be at risk for explosion. Researchers found that elevated methane levels in water wells near these fracking operations were accompanied by attendant spikes in iron and sulfates. These findings "document a way to distinguish newly migrated methane from pre-existing sources of gas." They also showed that methane and ethane concentrations in local water wells increased after gas drilling compared with predrilling concentrations and that these levels remained elevated seven years after leaks were initially reported.[248, 249] "We've documented that recent methane migration can change water chemistry in a way that can mobilize metals, such as iron, and release other unwanted chemical compounds, such as hydrogen sulfide," said Joshua Woda, a co-author of the study, in a press statement.[250]

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[246] Funk, S. P., Duffin, L., He, Y., McMullen, C., Sun, C., Utting, N., . . . Alessi, D. S. (2019). Assessment of impacts of diphenyl phosphate on groundwater and near-surface environments: Sorption and toxicity. *Journal of Contaminant Hydrology, 221,* 50-57. doi: 10.1016/j.jconhyd.2019.01.002
[247] Frantz, M. W., Wood, P. B., & Merovich, Jr., G. T. (2018). Demographic characteristic of an avian predator, Louisiana Waterthrush (Parkesia motacilla), in response to its aquatic pretty in a Central Appalachian USA watershed impacted by shale gas development. *PLOS One, 13*(11), e0206077. doi: 10.1371/journal.pone.0206077
[248] Woda, J., Wen, T., Oakley, D., Yoxtheimer, D., Engelder, T., Castro, M. C., & Brantley, S. L. (2018). Detecting and explaining why aquifers occasionally become degraded near hydraulically fractured shale gas wells. *Proceedings of the National Academy of Sciences, 115*(49), 12349-12358. doi: 10.1073/pnas.1809013115
[249] Bourzec, K. (2018, November 21). Chemical clues found for methane leaks caused by fracking. *Chemical and Engineering News.* Retrieved from https://cen.acs.org/environment/water/Chemical-clues-found-methane-leaks/96/i47
[250] Carrol, M. (2018, November 19). Ground and stream water clues reveal shale drilling impacts [Press release]. Penn State News. Retrieved from https://news.psu.edu/story/548378/2018/11/19/research/ground-and-stream-water-clues-reveal-shale-drilling-impacts

- November 6, 2018 – As reported by the news outlet, *WyoFile*, contaminated drinking water in Pavillion, Wyoming was likely caused by gas leaking from faulty gas wells as well as by leaks from 40 unlined pits that, for many years, served as dumps for drilling wastewater. This was the conclusion of three researchers, including two former U.S. Environmental Protection Agency (EPA) scientists, who had been investigating the pollution of Pavillion's groundwater, including drinking water wells for at least 30 homes. The scientists presented their findings to the community in advance of publishing a peer-reviewed scientific journal article. Statistical analyses show a correlation between what was disposed in the pits and contaminants appearing in nearby drinking water wells. One of the former EPA scientists told community members that the Wind River Formation drinking water aquifer will likely never be cleaned up. A preliminary report from the EPA in 2011 about groundwater contamination in Pavillion was never finalized.[251]

- October 21, 2018 – Fracking brine, among other factors, is contributing to "freshwater salinization syndrome," according to a study that examined the increasing saltiness of North American inland waters. Freshwater salinization, in turn, alters the behavior of other chemicals in water, mobilizing diverse chemical mixtures that alter drinking water quality.[252]

- October 17, 2018 – An international team of researchers tested fracking wastewater from two different wells in the Fox River area of Alberta, Canada for presence of endocrine-disrupting compounds. Using laboratory assays, they found that organic extracts of the wastewater samples did indeed disrupt hormone signaling pathways in environmentally relevant concentrations, as might occur in an accidental spill, however the wastewater from the two different wells did so in two different ways. "The results suggest that the properties and origins of endocrine-disrupting compounds in [fracking wastewater] from Wells A and B are different, complicating our understanding of potential environmental effects of releases."[253]

- September 4, 2018 – Chemicals from fracking wastewater dumped into the Allegheny River Watershed a decade ago are still accumulating in mussels that live there. Researchers working in Pennsylvania found elevated levels of strontium in the shells of freshwater mussels living downstream of a disposal facility that treated fracking wastewater and released it into streams between 2008 and 2011. (The practice was halted thereafter when heavy metals and radioactivity began rising in drinking water). Mussels living upstream of the treatment plant showed no such elevated levels. Strontium is an elemental metal and a contaminant of fracking waste. It is absorbed by living organisms in a similar manner to calcium. Because mussels excrete their shells in discreet layers that

[251] Thuermer, A. M. (2018, November 6). Pavillion water experts fault leaky gas wells, unlined pits. *WyoFile.* Retrieved from https://www.wyofile.com/pavillion-water-experts-fault-leaky-gas-wells-unlined-pits/
[252] Kaushal, S. S., Likens, G. E., Pace, M. L., Haq, S., Wood, K. L., Galella, J. G., . . . Jaworski, N. (2018). Novel "chemical cocktails" in inland waters are a consequence of the freshwater salinization syndrome. *Philosophical Transactions of the Royal Society B, 374*, 20188017. doi: 10.1098/rstb.2018.0017
[253] He, Y., Zhang, Y., Martin, J. W., Alessi, D. S., Giesy, J. P., & Goss, G. G. (2018). *In vitro* assessment of endocrine disrupting potential of organic fractions extracted from hydraulic fracturing flowback and produced water (HF-FPW). *Environment International, 121*, 824-831. doi: 10.1016/j.envint.2018.10.014

can be aged (like tree rings), researchers were able to show that shell layers created after 2011, when dumping of fracking waste into streams had ceased, did not show a sharp reduction in strontium, suggesting that downstream sediments may act as a reservoir for persistent contaminants years after dumping stops.[254] This is one of the first studies to show bioaccumulation of fracking contaminants in the bodies of living animals, which means that fracking contaminants are entering the food chain. The most endangered of all North American fauna, freshwater mussels are currently suffering a mass extinction event, as a likely result of degraded water quality.[255] Commenting on these findings in a press statement, lead author Nathaniel Warner said, “We know that Marcellus development has impacted sediments downstream for tens of kilometers. And it appears it still could be impacted for a long period of time. The short timeframe that we permitted the discharge of these wastes might leave a long legacy.”[256]

- August 29, 2018 – Using reports created by the oil and gas industry, a Colorado State University team evaluated fracking waste spills in Weld County, Colorado and found that while large-scale operations generated less fracking wastewater per unit of energy generated, the total volume of spilled waste increased as the size of the operation increased. “The results suggest that employing fewer, large-scale operators would help reduce the overall volume of [wastewater] generated but not the overall volume spilled.” This study also found that the probability of groundwater contamination from those spills was not correlated with either the spill area or with the volume spilled. Instead, the depth to groundwater was a more accurate predictor of the probability of contamination, with shallow water tables at highest risk.[257]

- August 17, 2018 – With 548 permitted wells as of 2017, Belmont County is the most intensely fracked county in the state of Ohio. A Yale University team collected drinking water samples from 66 households in Belmont County that were located at varying distances away from well pads and analyzed them for the presence of fracking-related chemical contaminants. They also interviewed residents about their health symptoms. The primary goal of this exploratory study was to determine whether residential proximity to fracked wells was related to detection and concentrations of health-relevant drinking water contaminants. A second objective was to evaluate possible relationships between proximity to wells and health complaints in the community. The team found that all homes had at least one volatile organic compound or other organic compound above detectable levels and that prevalence of contaminants in drinking water, including

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[254] Geeza, T. J., Killikin, D. P., McDevitt, B., Van Sice, K., & Warner, N. R. (2018). Accumulation of Marcellus Formation oil and gas wastewater metals in freshwater mussel shells. *Environmental Science &Technology, 52*(18), 10883-10892. doi: 10.1021/acs.est.8b02727
[255] Marusic, K. (2018, September 5). Fracking chemicals dumped in the Allegheny River a decade ago are still showing up in mussels: study. *Environmental Health News.* Retrieved from https://www.ehn.org/chemicals-from-fracking-in-pennsylvania-polluting-freshwater-mussels-2602333500.html
[256] Matthews, J. (2018, October 22). Fracking wastewater accumulation found in freshwater mussels’ shells. [Press release.] *Penn State News.* Retrieved from https://news.psu.edu/story/543054/2018/10/22/research/fracking-wastewater-accumulation-found-freshwater-mussels-shells
[257] Shores, A., & Laituri, M. (2018) The state of produced water generation and risk for groundwater contamination in Weld County, Colorado. *Environmental Science and Pollution Research, 25*, 30390-30400. doi: 10.1007/s11356-018-2810-8

toluene, bromoform, and dichlorobromomethane, was higher in homes closer to the wells. Further, people who lived closer to multiple wells were more likely to report health problems including wheezing, stress, fatigue, and headache. This is the first study to concurrently collect drinking water samples, health information, and data on proximity to drilling and fracking operations.[258]

- August 15, 2018 – Using well information from the U.S. Energy Information Agency as well as state-based agencies, a Duke University team examined changes in water use intensity in U.S. drilling and fracking operations as horizontal drilling has evolved toward ever-long lateral wellbores. They found that water use for fracking operations increased by 770 percent per well between 2011 and 2016 across all U.S. shale basins. At the same time, the volume of fracking wastewater generated during the first year of extraction increased by up to 1,440 percent. "The steady increase of the water footprint of hydraulic fracturing with time implies that future unconventional oil and gas operations will require larger volumes of water for hydraulic fracturing, which will result in larger produced oil and gas wastewater volumes." Noting that the freshwater used for hydraulic fracturing is either retained within the shale formation or returns as highly saline flowback waste that is often subsequently disposed of via deep well injection, the authors concluded that "the permanent loss of water use for hydraulic fracturing from the hydrosphere could outweigh its relatively lower water intensity" compared to other industrial uses of water, such as agriculture, where water is not lost to the hydrological cycle.[259]

- August 5, 2018 – Using water collected from streams and a reservoir near Middletown, Pennsylvania, a research team investigated how contamination with fracking chemicals, as during a spill event, alters the formation of disinfection byproducts when surface water is chlorinated for use as drinking water. They found a shift toward the creation of more brominated compounds. This finding has significant concerns for public health because brominated chemicals are not easily removed during the water treatment process and because discharge of bromide to surface waters remains largely unregulated.[260]

- July 19, 2018 – By simulating spills and discharge of fracking wastewater into rivers and streams, a Pennsylvania research team investigated the effects of fracking wastewater salinity on the creation of disinfection byproducts during drinking water treatment. They found evidence that the ions in salty fracking waste enhance the creation of these deleterious chemicals in ways that conventional water treatment processes cannot easily remove. "Further studies should focus on salinity removal technologies such as reverse osmosis, nanofiltration, electrodialysis, ion exchange, and lime/soda ash softening."[261]

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[258] Elliott, E. G., Ma, X., Leaderer, B. P., McKay, L. A., Pedersen, C. J., Wang, C., … & Deziel N. C. (2018). A community-based evaluation of proximity to unconventional oil and gas wells, drinking water contaminants, and health symptoms in Ohio. *Environmental Research, 167*, 550-557. doi: 10.1016/j.envres.2018.08.022

[259] Kondash, A. J., Lauer, N. E., & Vengosh, A. (2018). The intensification of the water footprint of hydraulic fracturing. *Science Advances, 4*(8), eaar5982. doi: 10.1126/sciadv.aar5982

[260] Huang, K. Z., Yuefeng, F. X., & Tang, H. L. (2018). Formation of disinfection by-products under influence of shale gas produced water. *Science of the Total Environment, 647*, 744-751. doi: 10.1016/j.scitotenv.2018.08.055

[261] Huang, K. Z., Tang, H. L., & Yuefeng, F. Z. (2018). Impacts of shale gas production wastewater on disinfection byproduct formation: An investigation from a non-bromide perspective. *Water Research, 144*, 656-664. doi: 10.1016/j.watres.2018.07.048

- July 13, 2018 – Chemicals associated with fracking operations have been known to contaminate surface and ground water, and many of them have been identified as endocrine disruptors in mammals, raising questions about possible perturbations of other biological processes, such as immunity. Using tadpoles, an international team investigated how chemicals found in fracking wastewater might affect the developing immune system in amphibians. They found evidence for concern. Even at doses below those found in groundwater near spill sites, many exposed tadpoles died. "A first finding of this study is the startling toxicity of the [fracking chemical] mixture to tadpoles…it seems likely that the lethal effect results from the combined activity of some or all of these chemicals." Lower doses significantly altered genes associated with immune functioning and made the developing frogs less able to fight off viral infections. "These findings suggest that [fracking-associated] water pollutants at low but environmentally relevant doses have the potential to induce acute alterations of immune function and antiviral immunity."[262]

- July 4, 2018 – Wastewater samples from a newly fracked oil well in Colorado were examined over 220 days using assays to assess changing toxicity levels. The results revealed significant toxicity throughout well production and during the first 55 days of flowback, with peak toxicity occurring on the first day of flowback. Researchers also looked at the community of microbes (bacteria and archaea) living in the wastewater. Some of these organisms originated from deep in the shale formation and others from the source water used for fracking. These species rapidly changed in relative abundance to one another as the toxicity of the wastewater evolved over time. "Late stage produced water communities gradually became similar to those in the earliest sample of flowback water, indicating that early conditions have a great impact on the resident microbiota over the life of the well."[263]

- June 21, 2018 – A Duke University-led lab study used mouse tissue cultures to investigate possible impacts of fracking wastewater exposure on the development of fat cells. They found that exposure to mixtures of 23 fracking chemicals, as well as raw stream water believed to be contaminated with fracking waste, promoted the growth of fat cells—even at very low concentrations. Collectively, these results show that fracking wastewater has the potential to impair metabolic health at levels found in the environment.[264] In a statement to the media, co-author Chris Kassotis said, "We saw significant fat cell proliferation and lipid accumulation, even when wastewater samples

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[262] Robert, J., McGuire, C. C., Kim, F., Nagel, S. C., Price, S. J., Lawrence, B. P., & De Jesus Andino, F. (2018). Water contaminants associated with unconventional oil and gas extraction cause immunotoxicity to amphibian tadpoles. *Toxicological Sciences, 166*(1), 39050. doi: 10.1093/toxsci/kfy179

[263] Hull, N. M., Rosenblum, J. S., Robertson, C. E., Harris, J. K., & Linden, K. G. (2018). Succession of toxicity and microbiota in hydraulic fracturing flowback and produced water in the Denver-Julesburg Basin. *Science of the Total Environment, 644*, 183-192. doi: 10.1016/j.scitotenv.2018.06.067

[264] Kassotis, C. D., Nagel, S. C., & Stapleton, H. M. (2018). Unconventional oil and gas chemicals and wastewater-impacted water samples promote adipogenesis via PPARγ-dependent and independent mechanisms in 3T3-L1 cells. *Science of the Total Environment, 640-641*, 1601-1610. doi: 10.1016/j.scitotenv.2018.05.030

were diluted 1,000-fold from their raw state and when wastewater-affected surface water samples were diluted 25-fold."[265]

- April 28, 2018 – A Canadian study found that the water flea (*Daphnia magna*) becomes immobilized when the surface of test waters are contaminated with fracking waste. This effect was persistent and occurred at concentrations significantly lower than is required to kill this common zooplankton outright. Immobilized *Daphnia* did not recover after 48 hours, could not feed, and became unable to shed their carapace, thus impeding reproduction. The evidence suggests that surfactants in fracking fluid together with floating hydrocarbons work together to reduce surface tension in ways that disallow *Daphnia* from re-entering the water column. "The current study shows that an important component of the toxicity of [fracking wastewater] to *Daphnia magna* is physical impairment. Depending on how the endpoint of a toxicity test is defined, this mode of action may not be accounted for in laboratory assessments used to determine risk. However, physical toxicity effects are likely to be important in environmental settings where [fracking wastewater] spills may occur."[266] (See also entry for March 5, 2019.)

- April 11, 2018 – A Drexel University team undertook a risk assessment of residential exposures to drinking water contaminated by fracking wastewater (flowback water). This simulation study found that within just eight hours—a realistic timeline for continual exposure due to a spill event—radioactive substances in the wastewater could produce demonstrable risks to human health, especially through the inhalation route. These radioactive compounds posed a greater threat to human health than other contaminants examined in this assessment, including arsenic, benzene, and vinyl chloride. "Radionuclides, which are known to exist in [fracking wastewater] as a result of occurring naturally within shale formations, pose a significant risk to human health and increase the likelihood of developing cancer in exposed individuals…median values for inhalation risk are at unacceptable levels. These exposures are due to the radionuclides aerosolizing from water primarily during showering.… Exposure to certain compounds of flowback water for only a few hours or days…can still present adverse effects."[267]

- April 9, 2018 – An analysis of the bacterial community in 31 northwestern Pennsylvania trout streams showed that fracking activity altered the composition of species found in the sediment. Confirming the findings of previous studies, streams near drilling and fracking activity had significantly higher numbers of methane-metabolizing and methane-producing microorganisms, which are tolerant to acidic conditions. "Altogether, this study highlighted stable bacterial taxa responding to Marcellus shale activity and further

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[265] Lucas, T. (2018, June 21). Exposure to fracking chemicals and wastewater spurs fat cells. [Press release.] *Duke University Nicholas School for the Environment News.* Retrieved from https://nicholas.duke.edu/about/news/exposure-fracking-chemicals-and-wastewater-spurs-fat-cells
[266] Blewett, T. A., Delompré, P. L. M., Glover, C. N., &. Goss, G. G. (2018). Physical immobility as a sensitive indicator of hydraulic fracturing fluid toxicity toward *Daphnia magna. Science of the Total Environment, 635*, 639-43. doi: 10.1016/j.scitotenv.2018.04.165
[267] Abualfaraj, N., Gurian P. L., & Olson, M. S. (2018). Assessing residential exposure risk from spills of flowback water from Marcellus Shale hydraulic fracturing activity. *International Journal of Environmental Research and Public Health, 15*, 727. doi: 10.3390/ijerph15040727

supplements a longitudinal correlation of increased acidity of stream water and fracking activity adjacent to headwater streams over five years."[268]

- April 8, 2018 – Working in the South Fork Little Red River watershed in northern Arkansas, a research team found that populations of invertebrate animals were reduced downstream of drilling and fracking operations relative to upstream.[269]

- April 6, 2018 – Chemical characterization and toxicological testing of wastewater from fracked and conventionally drilled oil and gas wells in Pennsylvania were compared. Wastewater from both types of wells was equally toxic to animal and human cells growing in culture and was corrosive at high concentrations. This toxicity was not attributable to the presence of salts alone. Hydrocarbon chemicals were found in both well types and are known to be toxic to multiple human organs. "In vitro assays showed that normal cell survival, behavior, and morphology were severely impaired by short-term exposure to either type of sample at up to 1000-fold dilutions. … Taken together, these results suggest that exposure to leaks or spills associated with either conventional or unconventional oil and gas extraction could potentially impact human health."[270]

- April 5, 2018 – Led by researchers from the University of Missouri, a study conducted in Pavillion, Wyoming compared the effects of water pollution linked to fracking to effects from conventional drilling. Endocrine-disrupting chemicals were found in 22 groundwater samples taken near both kinds of wells. However, the results showed that contaminated groundwater collected near fracking sites was more disruptive to hormonal signaling in human cells than contaminated groundwater collected from conventional well pads. These results corroborate those of past studies.[271] In an associated news story in *WyoFile*, Christopher Kassotis, one of the co-authors of the new study, said, "We have now reported similar endocrine bioactivities across numerous unconventional oil/gas sampling regions, and other researchers are beginning to demonstrate similar effects in cell and animal models. These, above all else, lend strong support for our findings."[272]

- March 5, 2018 – An exemption in the Safe Drinking Water Act allows hydraulic fracturing operations to escape federal regulation, leaving it up to individual states to determine how groundwater resources used for drinking are protected during fracking

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[268] Ulrich, N., Kirchner, V., Drucker, R., Wright, J. R., McLimans, J., Hazen, T. C., . . . Lamendella, R. (2018). Response of aquatic bacterial communities to hydraulic fracturing in northwestern Pennsylvania: A five-year study. *Scientific Reports, 8*(1), 5683. doi: 10.1038/s41598-018-23679-7

[269] Austin, B. J., Kelso, J. E., Evans-White, M. A., Entrekin, S. A., & Haggard, B. E. (2018). Can high volume hydraulic fracturing effects be detected in large watersheds? A case study of the South Fork Little Red River. *Current Opinion in Environmental Science & Health, 3*, 40-46. doi: 10.1016/j.coesh.2018.04003

[270] Crosby, L.M., Tatu, C. A., Varonka, M., Charles, K. M., & Orem, W. H. (2018). Toxicological and chemical studies of wastewater from hydraulic fracture and conventional shale gas wells. *Environmental Toxicology, 37*(8), 2098-2111. doi: 10.1002/etc.4146

[271] Kassotis, C. D., Vu, D. C., Vo, P. H., Lin, C.-H., Cornelius-Green, J. N., Patton, S., & Nagel, S. C. (2018). Endocrine-disrupting activities and organic contaminants associated with oil and gas operations in Wyoming groundwater. *Archives of Environmental Contamination and Toxicology, 72*(2), 247-258. doi: 10.1007/s00244-018-0521-2

[272] Thuermer, Jr., A. M. (2018, April 27). Study: Water near fracked Wyo gas field disrupts hormones. *WyoFile*. Retrieved from https://www.wyofile.com/study-water-near-fracked-wyo-gas-field-disrupts-hormones/

operations that take place on lands without federal or tribal mineral rights. A research team from Stanford University, University of California, Berkeley, and Lawrence Berkeley National Laboratory assessed these state-based oil and gas regulations in 17 different states. They found that the definitions of "protected groundwater" are vague, inconsistent and, very often, offer less protection than federal regulations. For example, in Alabama and New Mexico, protection of drinking water appears discretionary. In Colorado and Texas, protection of drinking water depends on the location of the oil and gas fields. In Illinois, protection during fracking only applies to horizontal wells. In California, drinking water must be monitored but not explicitly protected. Concluding from these findings that the nation's drinking water resources are vulnerable to contamination from oil and gas extraction and wastewater disposal, the research team recommended that criteria defined by the EPA for an underground drinking water source be consistently used to define protected groundwater in state-based oil and gas regulations.[273]

- February 15, 2018 – A UK team used reports from the Texas Railroad Commission (1999-2015) and the Colorado Oil and Gas Conservation Commission (2009-2015) to examine spill rates from oil and gas well pads. They found that the spill rate in both Colorado and Texas significantly increased over the recorded time period, with equipment failure cited as the most common cause. In Colorado, 33 percent of the spills were discovered during site remediation and random site inspections. Using these data, the team predicted that a UK fracking industry would likely experience a spill for every 19 well pads developed.[274]

- January 31, 2018 – Researchers in Arkansas found that water withdrawals for fracking operations can dangerously deplete water levels in up to 51 percent of streams in ways that potentially threaten drinking water supplies, damage aquatic life, and disrupt recreation. "There is potential for these withdrawals to cause water stress," the paper concluded.[275] Water stress represents risk of water scarcity for people caused by increases in economic costs or altered stream flow that results in loss of aquatic biodiversity and ecosystem functioning.

- January 27, 2018 – Fracking wastewater is a developmental toxicant to zebra fish embryos, according to results of a laboratory study conducted by a Canadian team of researchers. Exposure to various concentrations of fracking flowback and produced

[273] DiGiulio, D. C., Shonkoff, S. B. C., & Jackson, R. B. (2018). The need to protect fresh and brackish groundwater resources during unconventional oil and gas development. *Current Opinion in Environmental Science and Health, 3,* 1-7. doi: 10.1016/j.coesh.2018.01.002
[274] Clancy, S. A., Worrall, F., Davies, R. J., & Gluyas, J. G. (2018). The potential for spill and leaks of contaminated liquids from shale gas developments. *Science of the Total Environment, 626*, 1463-1473. doi: 10.1016/j.sciotenv.2018.01.177
[275] Entrekin, S., Trainor, A., Saiers, J., Patterson, L., Maloney, K., Fargione, J., . . . Ryan, J. N. (2018). Water stress from high-volume hydraulic fracturing potentially threatens aquatic biodiversity and ecosystem services in Arkansas, United States. *Environmental Science & Technology, 52*(4), 2349-2358. doi: 10.1021/acs.est.7b03304

water, collected from well sites in Alberta, was linked to spinal and heart abnormalities and patterns of altered gene expression consistent with endocrine disruption.[276]

- January 23, 2018 – An Ohio State University team developed and used numerical models to simulate how methane from a leaking well could migrate into different types of drinking water aquifers. Their results showed that rapid, long-distance gas flow was most likely to occur when a pulse of gas under high pressure from a faulty gas well entered into a fractured rock aquifer. In these cases, methane can easily migrate a distance of 1 kilometer within a week and in many different directions, including laterally away from the natural gas well. Current efforts to evaluate natural gas leakage from faulty wells "likely underestimate contributions from small-volume, low-pressure leakage events," which require extended periods of environmental monitoring.[277]

- January 16, 2018 – An editorial in the journal *Groundwater* warned researchers against being too quick to dismiss the presence of methane in groundwater near fracking sites as "always naturally occurring," especially in places where no pre-drill baseline data are available or in studies where average methane levels are being compared. Noting that the geological conditions that facilitate the natural migration of hydrocarbons are often "muddled, obfuscating the presence of hydrocarbon pollution due to gas leaking from production wells," the editorial encouraged study designs that make use of odds-ratio tests and geochemical tracers. Fractured rocks within shallow aquifers, in particular, are concerning "both in terms of their potential for facilitating rapid … gas flow, and their inherent geometric complexity, which impact hydrocarbon gas transport mechanisms."[278]

- January 16, 2018 – The Pennsylvania Department of Environmental Protection determined that fracking wastewater that had leaked from a storage pit contaminated groundwater and rendered a natural spring used for drinking water in Greene County undrinkable.[279]

- January 9, 2018 – A University of Texas team collected groundwater samples from across shale basins in Texas and reported on the discovery of opportunistic, pathogenic bacteria in fracking-impacted water wells in Texas. These results raise questions about fracking's effects on the microbial ecology of aquifers. Commenting on their findings, the researchers noted, "The results were quite surprising. Not only did we find that various opportunistic pathogens could survive in the presence of hydrocarbon gases and chemical additives, they appeared to thrive and exhibited robust resistance profiles to

[276] He, Y., Sun, C., Zhang, Y., Folkerts, E. J., Martine, J. W., & Goss, G. G. (2018). Developmental toxicity of the organic fraction from hydraulic fracturing flowback and produced water to early life stages of zebrafish (*Danio rerio*). *Environmental Science &Technology, 52*, 3820-3830. doi: 10.1021/acs.est.7b06557
[277] Moortgat, J., Schwartz, F. W., & Darrah, T. H. Numerical modeling of methane leakage from a faulty natural gas well into fractured tight formations. *Groundwater, 56*(2), 163-175. doi: 10.1111/gwat.12630
[278] Darrah, T. H. (2018). Time to settle the fracking controversy. *Groundwater*, *65*(2). doi: 10.1111/gwat.12636
[279] Niedbala, B. (2018, January 16). W. Va. company fined $1.7 million for violations at 14 well sites in Greene County. *Observer-Reporter.* Retrieved from https://observer-reporter.com/news/localnews/w-va-company-fined-million-for-violations-at-well-sites/article_cc1ce344-faec-11e7-84ca-076df3832f29.html

multiple antibiotics. We even observed that certain pathogens were resilient to high levels of chlorination."[280]

- December 11, 2017 – A report by the *Texas Observer* investigated groundwater depletion by fracking operations in west Texas at the southern edge of the Ogallala Aquifer. Groundwater conservation districts lack legal financial resources to restrict groundwater pumping or even compel metering on water wells that would monitor exactly how much water is pumped. In Howard County alone, water used for fracking is now believed to constitute about 20 percent of average annual water use.[281]

- November 16, 2017 – The 2005 Energy Policy Act prohibited the EPA from regulating fracking under the Safe Drinking Water Act and from requiring that operators disclose their chemicals. According to an investigation by *InsideClimate News,* the scientific study that justified this provision (which is widely known as the Halliburton loophole) was the subject of a whistleblower complaint. The study was also disavowed by its authors, who said the conclusion of the report—that fracking posed no risk to groundwater—was not supported by the evidence. These authors removed their names from the final document. Interviewed for the story, one of these authors said that the belief that fracking was safe for water was a foregone conclusion at the EPA under George W. Bush. "What we would have said in the conclusion is that there is some form of risk from hydraulic fracturing to groundwater. How you quantify it would require further analyses, but, in general, there is some risk."[282]

- November 9, 2017 – As part of a preliminary study, a Texas team assessed the groundwater microbiome in a rural area of southern Texas where farming and fracking co-exist. Each of the sampled water wells had a unique community of microorganisms living in the water. The dominant bacteria were denitrifying species that transform nitrates into gaseous nitrogen or those that break apart hydrocarbon molecules. Earlier studies have postulated that fracking can alter the chemical composition of groundwater and change the species composition of the microbial communities living within it. The results of this study "do not provide a definitive link between [fracking] or agricultural activities and the groundwater microbiome; however, they do provide a baseline measurement of bacterial diversity and quantity in groundwater located near these anthropogenic activities."[283]

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[280] Hildenbrand, Z. L., Santos, I., & Schug, K. (2018, January 9). Detecting harmful pathogens in water: Characterizing the link between fracking and water safety. *Science Trends.* Retrieved from https://sciencetrends.com/detecting-harmful-pathogens-water-characterizing-link-fracking-water-safety/

[281] Collins, C. (11 December, 2017). Big spring vs. big oil. *Texas Observer.* Retrieved from https://www.texasobserver.org/big-spring-vs-big-oil/

[282] Banerjee, N. (16 November, 2017). Industrial strength: How the U.S. government hid fracking's risks to drinking water. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/16112017/fracking-chemicals-safety-epa-health-risks-water-bush-cheney

[283] Santos, I. C., Martin, M. S., Reyes, M. L., Carlton Jr., D. D., Stigler-Granados, P., Valerio, M. A., … & Schug, K. A. (2017). Exploring the links between groundwater quality and bacterial communities near oil and gas extraction activities. *Science of the Total Environment. 618,* 165-173. doi: 10.1016/j.scitotenv.2017.10.264

- November 1, 2017 – In Oklahoma, horizontal wells can be fracked within 600 feet of older, vertical wells that do not use fracking. Oil companies in Oklahoma that extract oil using conventional, vertical wells alleged that hundreds of their wells have been inundated by fluids from nearby horizontal wells that use high-volume hydraulic fracturing, as documented by *E&E News*. Vertical well operators have raised questions about whether these "frack hits" from nearby horizontal wells that have flooded their own wells have also reached the groundwater. "Logic said it will impact [groundwater]," said one driller. "There was water coming up out of the ground. There was enough pressure to bring it to the surface." Small operators of vertical wells, organized as the Oklahoma Energy Producers Alliance (OEPA), released a study estimating that, in just one county alone, there were 400 cases of frack fluid from horizontal wells flooding nearby vertical wells.[284, 285]

- October 31, 2017 – A study of fracking wastewater disposed of in rivers and streams found that chemical contaminants in the waste were transformed into more toxic substances when they chemically reacted with chlorinated compounds discharged from downstream drinking water treatment plants. The result was dozens of different, brominated and iodinated disinfection byproducts (DBPs). A lab analysis found that all were highly toxic to mammalian cells. Conventional water treatment practices do not remove these chemicals. "It is likely that in oil- and gas-impacted drinking water sources, iodo-phenolic DBPs could form at significant levels, particularly in cases in which chloramination is used."[286]

- October 18, 2017 – Researchers concerned about reports of skin rashes, gastrointestinal distress, and breathing problems among people who live near drilling and fracking operations found increased levels of certain harmful bacteria in private water wells impacted by fracking in the Barnett and Eagle Ford Shale areas in Texas. These results raise questions about whether drilling and fracking activities could alter the communities of microorganisms in groundwater in ways that pose health risks. According to one of the lead authors of the study, interviewed in the *Dallas News*, "the potential contribution of these microbes to these health effects is probably understudied, underappreciated, unknown."[287, 288]

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[284] Soraghan, M. (1 November, 2017). Now it's oilmen who say fracking could harm groundwater. *E&E News.* Retrieved from https://www.eenews.net/stories/1060065209

[285] OEPA. (2017, September 14). Are vertical wells impacted by horizontal drilling? A study of Kingfisher County. *E&E News*. Retrieved from https://www.eenews.net/assets/2017/10/27/document_pm_07.pdf

[286] Liberatore, H. K., Plewa, M. J., Wagner, E. D., VanBriesen, J. M., Burnett, D. B., Cizmas, L. H., & Richardson, S. D. (2017). Identification and comparative mammalian cell cytotoxicity of new iodo-phenolic disinfection byproducts in chloraminated oil and gas wastewaters. *Environmental Science & Technology Letters, 4*(11), 475–480. doi: 10.1021/acs.estlett.7b00468

[287] Martin, M. S., Santos, I. C., Carlton Jr. D. D., Stigler-Granados, P., Hildenbrand, Z. L., & Schug, K. A. (2017). Characterization of bacterial diversity in contaminated groundwater using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry. *Science of the Total Environment.* Advance online publication. doi: 10.1016/j.scitotenv.2017.10.027

[288] Mosier, J. (2017, December 1). UTA research finds dangerous bacteria in groundwater near Texas gas drilling sites. *Dallas News.* Retrieved from https://www.dallasnews.com/business/energy/2017/12/01/uta-study-finds-dangerous-bacteria-groundwater-near-texas-gas-drilling-sites

- August 3, 2017 – Due to permitting errors and a mix-up in records 30 years ago, wastewater from drilling operations in California was mistakenly injected directly into drinking water aquifers. Six years after the discovery of the problem, 175 wastewater wells that were illegally injecting into protected aquifers have been shut down, but hundreds more are still operating. An investigation by KQED Science revealed that California state water regulators know very little about the actual impact of those injections on the state's drinking water reserves. "State water regulators say they hope to figure out what the larger impacts have been in years ahead, but have no set timeline. The risk is that they've allowed oil companies to contaminate drinking water aquifers to such an extent that Californians may have permanently lost those sources of fresh water."[289] An earlier investigation by KQED Science revealed that illegal wastewater wells would still be allowed to operate while the necessary paperwork was filed.[290]

- July 12, 2017 – In western Pennsylvania, a team of researchers looked at sediments in the Conemaugh River watershed downstream of a treatment plant that was specially designed to treat fracking wastewater. The researchers found contamination for many miles downstream with fracking-related chemicals that included radium, barium, strontium, and chloride, as well as endocrine-disrupting and carcinogenic compounds. The peak concentrations were found in sediment layers that had been deposited during the years of peak fracking wastewater discharge. Elevated concentrations of radium were detected as far as 12 miles downstream of the treatment plant and were up to 200 times greater than background. Some stream sediment samples were so radioactive that they approached levels that would, in some U.S. states, classify them as radioactive waste and necessitate special disposal.[291, 292]

- May 31, 2017 – A U.S. Geological Survey (USGS) team sampled drinking water wells near drilling and fracking sites in the Eagle Ford, Fayetteville, and Haynesville Shale basins and found detectable levels of methane and benzene. However, the sources of these contaminants were unclear, and, given the slow travel time of groundwater, "decades or longer may be needed to fully assess the effects of potential subsurface and surface releases of hydrocarbons on the wells."[293]

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[289] Sommer, L. (17 August, 2017). How much drinking water has California lost to oil industry waste? No one knows. *KQED Science.* Retrieved from https://ww2.kqed.org/science/2017/08/03/how-much-drinking-water-has-california-lost-to-oil-industry-waste-no-one-knows/

[290] Sommer, L. (17 January, 2017). California says oil companies can keep dumping wastewater during state review. *KQED Science.* Retrieved from https://ww2.kqed.org/science/2017/01/17/california-says-oil-companies-can-keep-dumping-wastewater-during-state-review/

[291] Burgos, W. D., Castillo-Meza, L., Tasker, T. L., Geeza, T. J., Drohan, P. J., Liu, X., … Warner, N. R. (2017). Watershed-scale impacts from surface water disposal of oil and gas wastewater in Western Pennsylvania. *Environmental Science & Technology, 51*(15), 8851–8860. doi: 10.1021/acs.est.7b01696

[292] Johnston, I., (2017, July 12). Fracking can contaminate rivers and lakes with radioactive material, study finds. *The Independent*. Retrieved from http://www.independent.co.uk/news/science/fracking-dangers-environment-water-damage-radiation-contamination-study-risks-a7837991.html

[293] McMahon, P., Barlow, J. R. B., Engle, M. A., Belitz, K., Ging, P. B., Hunt, A. G., … & Kresse, T. M. (2017). Methane and benzene in drinking-water wells overlying the Eagle Ford, Fayetteville, and Haynesville Shale hydrocarbon production areas. *Environmental Science & Technology, 51*(12), 6727-6734. doi: 10.1021/acs.est.7b00746

- May 1, 2017 – A study examining the impacts of drilling and fracking operations on public drinking water in Pennsylvania found evidence of contamination when drinking water source intakes were located within one kilometer (.62 miles) of a well pad. Noting that many Pennsylvanians living near well pads drink bottled water, the authors concluded, "our results suggest that these perceived risks may in fact be justified."[294] (See also entry below for October 13, 2016.)

- April 19, 2017 – Using data from the South Coast Air Quality Monitoring District, a team of researchers in California compared chemicals used in fracking operations with those used in the routine maintenance of conventional oil and gas wells where chemicals are used to aid in drilling, for corrosion control, to clean the wellbore, and to enhance oil recovery. They found significant overlap in both the types and amounts of chemicals used. "The results of this study indicate regulations and risk assessments focused exclusively on chemicals used in well-stimulation activities may underestimate potential hazard or risk from overall field chemical-use. . . . Our analysis shows that hydraulic fracturing is just one of many applications of hazardous chemicals on oil and gas fields."[295]

- April 5, 2017 – A three-year study in West Virginia led by scientists at Duke University assessed surface water and groundwater drawn from drinking water wells both before and after drilling and fracking began in the region. Using geochemical techniques, including a suite of tracers that help distinguish naturally occurring methane and salts from those contained in fracking fluid, the researchers found no evidence of groundwater contamination. They did, however, document threats to surface water from fracking wastewater spills.[296] In an accompanying statement, the researchers noted, "What we found in the study area in West Virginia after three years may be different from what we see after 10 years because the impact on groundwater isn't necessarily immediate."[297]

- Feb 21, 2017 – Between 2005 and 2014, researchers surveyed spill record data from drilling and fracking operations in four states (Colorado, New Mexico, North Dakota, and Pennsylvania). During these nine years, they documented 6,678 total spills, or about five spills each year for every 100 wells. Between 2 and 16 percent of wells reported a spill each year. Half of all spills were related to storage and transport of fluids through flow lines. The authors also found that the chances of spills are highest during the first three

[294] Hill, E., & Ma, L. (2017). Shale gas development and drinking water quality. *American Economic Review: Papers & Proceedings, 107*(5), 522–525. doi: 10.1257/aer.p20171133
[295] Stringfellow, W. T., Camarillo, M. K., Domen, J. K., & Shonkoff, S. B. C. (2017) Comparison of chemical-use between hydraulic fracturing, acidizing, and routine oil and gas development. *PLoS ONE, 12*(4), e0175344. doi: 10.1371/journal.pone.0175344
[296] Harkness, J. S., Darrah, T. H., Warner, N. R., Whyte, C. J., Moore, M. T., Millot, R., … Vengosh, A. (2017). The geochemistry of naturally occurring methane and saline groundwater in an area of unconventional shale gas development. *Geochimica et Cosmochimica Acta, 208,* 302–334. doi: 10.1016/j.gca.2017.03.039
[297] Lucas, T. (2017, April 24). West Virginia groundwater not affected by fracking, but surface water is [Press release]. Retrieved from https://nicholas.duke.edu/about/news/west-virginia-groundwater-not-affected-fracking-surface-water

years of a well's life and that spill reporting requirements differ markedly from state to state, making impossible the task of comparing states or creating a national picture.[298, 299]

- January 31, 2017 – California is the only state that allows fracking waste to be held in unlined, open pits, creating risks for groundwater contamination. A California Water Boards investigation found that, as of January 2017, 1,000 such pits were operational, with 400 lacking required state permits. The vast majority is located in Kern County.[300]

- December 14, 2016 – To better understand the impact of fracking fluid spills on aquatic animals, scientists at the University of Alberta exposed rainbow trout in laboratory tanks to various dilutions of fracking fluids. Even at very low exposures, the fish experienced adverse effects, including alterations in liver functioning and disruption of hormonal pathways. [This study was partially funded by industry.][301]

- December 13, 2016 – The final version of the EPA's six-year, $29 million study on the impacts of hydraulic fracturing on the nation's drinking water confirmed that fracking activities have caused contamination of water resources in the United States, and it traced the various routes by which drinking water can be impacted by fracking. Documented cases of drinking water contamination have resulted from spills of fracking fluid and fracking wastewater; discharge of fracking waste into rivers and streams; and underground migration of fracking chemicals, including gas, into drinking water wells. Depletion of aquifers caused by water withdrawals has created other impacts.[302, 303, 304, 305] The final EPA report detailed the problem of fracking-related drinking water contamination in three communities—Pavillion, Wyoming; Dimock, Pennsylvania; and

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298 Patterson, L., Konschnik, K., Wiseman, H., Fargione, J., Maloney, K. O., Kiesecker, J., … Saiers, J. E. (2017). Unconventional oil and gas spills: Risks, mitigation priorities and states reporting requirements. *Environmental Science & Technology, 51*(5), 2563–2573. doi: 10.1021/acs.est.05749

299 Kusnetz, N. (2017, February 21). Fracking well spills poorly reported in most top-producing states, study finds. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/21022017/fracking-spills-north-dakota-colorado

300 California Water Boards. (2017, January 31). *Produced water pond status report.* Retrieved from https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/pond_rpt_0117_fnl.pdf

301 He, Y., Folkerts, E. J., Zhang, Y., Martin, J. W. Alessi, D. S., & Goss, G. G. (2017). Effects on biotransformation, oxidative stress, and endocrine disruption in rainbow trout (*Oncorhynchus mykiss*) exposed to hydraulic fracturing flowback and produced water. *Environmental Science & Technology, 51*(2), 940-947. doi: 10.1021/acs.est.6b04695

302 U.S. EPA. (2016). *Hydraulic fracturing for oil and gas: Impacts from the hydraulic fracturing water cycle on drinking water resources in the United States.* U.S. Environmental Protection Agency, Washington, DC, EPA-600-R-16-236Fa. Retrieved from https://www.epa.gov/hfstudy

303 U.S. EPA. (2016). *Hydraulic fracturing for oil and gas: Impacts from the hydraulic fracturing water cycle on drinking water resources in the United States* (Appendices). U.S. Environmental Protection Agency, Washington, DC, EPA-600-R-16-236Fb. Retrieved from https://www.epa.gov/hfstudy

304 U.S. EPA. (2016). *Hydraulic fracturing for oil and gas: Impacts from the hydraulic fracturing water cycle on drinking water resources in the United States* (Executive Summary). U.S. Environmental Protection Agency, Washington, DC, EPA-600-R-16-236ES. Retrieved from https://www.epa.gov/hfstudy

305 Tong, S., & Scheck, T. (30 November, 2016). EPA's late changes to fracking study downplay risk of drinking water pollution. *Marketplace.org.* Retrieved from https://www.marketplace.org/2016/11/29/world/epa-s-late-changes-fracking-study-portray-lower-pollution-risk

Parker County, Texas.[306] Summing up the report, then-EPA Deputy Administrator Tom Burke said in a statement to *American Public Media*, "We found scientific evidence of impacts to drinking water resources at each stage of the hydraulic fracturing cycle."[307] (See also the entry for June 5, 2015, which describes the contents of the 2015 draft report.)

- December 1, 2016 – According to a review paper that examines the potential environmental impacts of oil and gas wastewater, about 5 percent of fracking waste is accidentally or illegally spilled. Almost all of the rest is transported off site and injected into disposal wells that are drilled into porous geological formations. In North Dakota's Bakken Shale, disposal wells are located within miles of the well pad, and the wastewater can travel there via pipeline. In Pennsylvania's Marcellus Shale, drilling activity exceeds the capacity for disposal of waste in local wells and must be trucked out of state.[308]

- November 4, 2016 – A critical review of potential routes of water contamination from drilling and fracking operations in the Bakken Shale noted that the high salinity of fracking wastewater minimizes its recycling options and thus contributes to the need for disposal wells. Transportation of large volumes of waste to these wells, via truck or pipeline, presents opportunities for large spills that can threaten groundwater.[309]

- October 16, 2016 – A team of scientists led by researchers at the Lawrence Berkeley National Laboratory evaluated chemicals used for fracking in California oil fields. Chemical additives included a wide variety of solvents in large amounts, as well as other toxic substances, including biocides and corrosion inhibitors.[310]

- October 14, 2016 – One of the first studies to investigate the impacts of fracking on the ecology of streams found that fracking "has the potential to alter aquatic biodiversity and methyl mercury concentrations at the base of food webs." The researchers sampled 27 remote streams in the Marcellus Shale basin of Pennsylvania where drilling and fracking is taking place. They showed that methyl mercury levels in stream sites where fracking occurs were driven upwards by higher acidity and lower numbers of macroinvertebrates. In streams with the highest numbers of fracking fluid spills, "fish diversity was nil," and

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306 U.S. Environmental Protection Agency Science Advisory Board. (2016, August 11). *SAB review of the EPA's draft assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources.* EPA-SAB-16-005. Retrieved from https://yosemite.epa.gov/sab/sabproduct.nsf/LookupWebReportsLastMonthBOARD/BB6910FEC10C01A18525800C00647104/$File/EPA-SAB-16-005+Unsigned.pdf

307 Scheck, T. & Tong, S. (2016, December 13). EPA reverses course, highlights fracking contamination of drinking water. *APM Reports.* Retrieved from https://www.apmreports.org/story/2016/12/13/epa-fracking-contamination-drinking-water

308 Konkel, L. (2016). Salting the earth: The environmental impact of oil and gas wastewater spills. *Environmental Health Perspectives, 124*(12), A230-A235. doi: 10.1289/ehp.124-A230

309 Shrestha, N., Chilkoor, G., Wilder, J., Gadhamshetty, V., & Stone, J. J. (2016). Potential water resource impacts of hydraulic fracturing from unconventional oil production in the Bakken shale. *Water Research, 108,* 1-24. doi: 10.1016/j.watres.2016.11.006

310 Stringfellow, W. T., Camarillo, M. K., Domen, J. K., Sandelin, W. L., Varadharajan, C., Jordan, P. D., & … Birkholzer, J. T. (2017). Identifying chemicals of concern in hydraulic fracturing fluids used for oil production *Environmental Pollution, 220,* Part A, 413-420. doi: 10.1016/j.envpol.2016.09.082

in some cases, there were no fish at all, including in streams previously classified as high-quality brook trout habitat. "Fracking and flowback fluids can contain various highly acidic agents, organic and inorganic compounds, and even Hg [mercury]. The flowback fluids can reach nearby streams through leaking wastewater hoses, impoundments, and lateral seepage and blowouts, as well as by backflow into the wellhead. Flowback water reaching streams can . . . decrease aquatic biodiversity. . . . Lowered stream pH increases Hg solubility, leading to increased bioaccumulation in food webs."[311]

- October 13, 2016 – Researchers at Pennsylvania State University and Ohio State University combined GIS data on drilling and fracking activities in Pennsylvania and Ohio with household data on bottled water purchases. They found that yearly household purchases of bottled water increased as local drilling and fracking intensity increased. This "averting behavior" is a measure of perceived risk. In 2010, averting-behavior expenditures in the form of bottle water purchases by people living in Pennsylvania's shale counties totaled $19 million.[312] (A subsequent study suggests that those engaged in tapwater averting behaviors in Pennsylvania have evidence-based reasons to be concerned. See entry above, for May 1, 2017.)

- September 22, 2016 – Using the agency's list of 1076 chemicals that have reported use as ingredients in hydraulic fracturing fluid, EPA scientists developed a framework to analyze and rank subsets of chemicals in order to better understand which fracking-related chemicals pose the greatest risk to drinking water. Their model collates multiple lines of evidence. For example, data on inherent toxicity are combined with data on occurrence and propensity for environmental transport. In the absence of local data on actual human exposures, this model can serve as a qualitative metric to "identify chemicals that may be more likely than others to impact drinking water resources."[313]

- September 16, 2016 – A reconnaissance analysis of groundwater in the Eagle Ford Shale region in southern Texas found sporadic detections of multiple VOCs and dissolved gas, providing evidence that "groundwater quality is potentially being affected by neighboring [drilling and fracking] activity, or other anthropogenic activities, in an episodic fashion." The authors called for a more extensive investigation of possible groundwater contamination in the Eagle Ford basin.[314, 315]

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[311] Grant, C. J., Lutz, A. K., Kulig, A. D., & Stanton, M. R. (2016). Fracked ecology: Response of aquatic trophic structure and mercury biomagnification dynamics in the Marcellus Shale Formation. *Ecotoxicology, 25,* 1739–1750. doi: 10.1007/s10646-016-1717-8

[312] Wrenn, D. H., Klaiber, H. A., & Jaenicke, E. C. (2016). Unconventional shale gas development, risk perceptions, and averting behavior: evidence from bottled water purchases. *Journal of the Association of Environmental and Resource Economists, 3*(4), 770-817. doi: 10.1086/688487

[313] Yost, E. E., Stanek, J., & Burgoon, L. D. (2016). A decision analysis framework for estimating the potential hazards for drinking water resources of chemicals used in hydraulic fracturing fluids. *Science of the Total Environment, 574,* 1544–1558. doi: 10.1016/j.scitotenv.2016.08.167

[314] Hildenbrand, Z. L., Carlton Jr., D. D., Meik, J. M., Taylor, J. T., Fontenot, B. E., Walton, J. L., … Schug, K. A. (2016). A reconnaissance analysis of groundwater quality in the Eagle Ford shale region reveals two distinct bromide/chloride populations. *Science of the Total Environment, 575,* 672–680. doi: 10.1016/j.scitotenv.2016.09.070

[315] Hildenbrand, Z. L., Carlton Jr., D. D., Meik, J. M., Taylor, J. T., Fontenot, B. E., Walton, J. L., … Schug, K. A. (2017). Corrigendum to "A reconnaissance analysis of groundwater quality in the Eagle Ford shale region reveals

- July 11, 2016 – An interdisciplinary team led by University of Colorado researchers found methane in 42 water wells in the intensely drilled Denver-Julesburg Basin where high volume, horizontal fracking operations began in 2010. By examining isotopes and gas molecular ratios, the researchers determined that the gas contaminating these wells was thermogenic in origin, rather than microbial, and therefore had migrated up into the groundwater from underlying oil- and gas-containing shale. The steady rate of well contamination over time—two cases per year from 2001 to 2014—suggests that well failures, rather than the process of hydraulic fracturing itself, was the mechanism that created migration pathways for the stray gas to reach drinking water sources. Of the 42 affected wells, 11 had already been identified by state regulators as suffering from "barrier failures."[316] Duke University geochemist Avner Vengosh, who was not an author of the paper, commented on the study in an accompanying article in *InsideClimate News*: "The bottom line here is that industry has denied any stray gas contamination: that whenever we have methane in a well, it is always preexisting. The merit of this is that it's a different oil and gas basin, a different approach, and it's saying that stray gas could happen." In this same article, *InsideClimate News* reported that national standards for well construction do not exist, nor are there laws governing the type of cement that is used to seal the wellbore and prevent leaks.[317]

- May 24, 2016 – ATSDR conducted a public health evaluation using groundwater data gathered in 2012 by the EPA from 64 private drinking water wells in Dimock, Pennsylvania where natural gas drilling and fracking activities began in 2008 and where residents began reporting problems with their water shortly thereafter. The agency found that water samples collected from 27 Dimock wells contained contaminants "at levels high enough to affect human health." These included methane, salts, organic chemicals, and arsenic. In 17 wells, levels of methane were high enough to create risk of fire or explosion.[318] Methane levels were not assessed in wells prior to the start of fracking activities in the area. Hence, the study is limited by lack of pre-drilling baseline data, and investigators did not attempt to determine the source of the contaminants. However, in its focus on identifying health impacts, ATSDR's evaluation is a more comprehensive study than that conducted four years earlier by the EPA and calls into question its earlier, more reassuring conclusions.[319, 320]

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two distinct bromide/chloride populations." *Science of the Total Environment, 603–604,* 834-835. doi: 10.1016/j.scitotenv.2017.05.200

[316] Sherwood, O. A., Rogers, J. D., Lackey, G., Burke, T. L., Osborn, S. G. & Ryan, J. N. (2016). Groundwater methane in relation to oil and gas development and shallow coal seams in the Denver-Julesburg Basin of Colorado. *Proceedings of the National Academy of Sciences 113*(30). doi: 10.1073/pnas.1523267113

[317] Banerjee, N. (2016, July 11). Colorado fracking study blames faulty wells for contamination. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/11072016/water-contamination-near-colorado-fracking-tied-well-failures

[318] U.S. Agency for Toxic Substances and Disease Registry (2016, May 24). *Health Consultation: Dimock Groundwater Site*. Retrieved from http://www.atsdr.cdc.gov/hac/pha/DimockGroundwaterSite/Dimock_Groundwater_Site_HC_05-24-2016_508.pdf

[319] Lustgarten, A. (2016, June 9). Federal report appears to undercut EPA assurances on water safety in Pennsylvania. *ProPublica.* Retrieved from https://www.propublica.org/article/federal-report-appears-to-undercut-epa-assurances-water-safety-pennsylvania

- May 9, 2016 – Sampling downstream of a fracking wastewater disposal facility in West Virginia, a USGS team documented changes in microbial communities and found evidence indicating the presence of fracking waste in water and sediment samples collected from Wolf Creek in West Virginia. Specifically, the researchers documented increased concentrations of barium, bromide, calcium, sodium, lithium, strontium, iron, and radium downstream of the disposal well.[321] In a *Washington Post* story about this study, lead author Denise Akob said that the key take-away message "is really that we're demonstrating that facilities like this can have an environmental impact."[322] (This study was done in collaboration with Susan Nagel's team, which studied endocrine-disrupting activity in this same stream. See entry below for April 6, 2016.)

- April 30, 2016 – As part of an investigation based on aerial photographs taken by emergency responders during spring 2016 flooding, the *El Paso Times* documented plumes and sheens of chemicals from tipped-over storage tanks and inundated oil wells and fracking sites entering rivers and streams. "Many of the photos shot during Texas' recent floods show swamped wastewater ponds at fracking sites, presumably allowing wastewater to escape into the environment—and potentially into drinking-water supplies."[323]

- April 27, 2016 – Using geochemical and isotopic tracers to identify the unique chemical fingerprint of Bakken region brines, a Duke University study found that accidental spills of fracking wastewater have contaminated surface water and soils throughout North Dakota where more than 9,700 wells have been drilled in the past decade. Contaminants included salts as well as lead, selenium, and vanadium. In the polluted streams, levels of contaminants often exceeded federal drinking water guidelines. Soils at spill sites showed elevated levels of radium.[324] The study concluded that "inorganic contamination associated with brine spills in North Dakota is remarkably persistent, with elevated levels of contaminants observed in spill sites up to 4 years following the spill events." In a comment about this study, lead author and Duke University geochemist Avner Vengosh said, "Until now, research in many regions of the nation has shown that contamination from fracking has been fairly sporadic and inconsistent. In North Dakota, however, we

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320 U.S. Environmental Protection Agency. (2012, July 25). *EPA completes drinking water sampling in Dimock, Pa.* [Press release]. Retrieved from https://yosemite.epa.gov/opa/admpress.nsf/0/1A6E49D193E1007585257A46005B61AD

321 Akob, D. M., Mumford, A. C., Orem, W. H., Engle, M. A., Klinges, J. G., Kent, D. B., & Cozzarelli, I. M. (2016). Wastewater disposal from unconventional oil and gas development degrades stream quality at a West Virginia injection facility. *Environmental Science and Technology, 50*(11). doi: 10.1021/acs.est.6b00428

322 Fears, D. (2016, May 11). This mystery was solved: scientists say chemicals from fracking wastewater can taint fresh water nearby. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2016/05/11/this-mystery-was-solved-scientists-say-chemicals-from-fracking-wastewater-can-taint-fresh-water-nearby/?utm_term=.c27045b60338

323 Schladen, M. (2016, April 30). Flooding sweeps oil, chemicals into rivers. *El Paso Times.* Retrieved from http://www.elpasotimes.com/story/news/2016/04/30/flooding-sweeps-oil-chemicals-into-rivers/83671348/

324 Lauer, N. E., Harkness, J. S., & Vengosh A. (2016). Brine spills associated with unconventional oil development in North Dakota. *Environmental Science & Technology, 50*(10). doi: 10.1021/acs.est.5b06349

find it is widespread and persistent, with clear evidence of direct water contamination from fracking."[325]

- April 6, 2016 – A research team led by Susan Nagel at the University of Missouri traced a spike in endocrine-disrupting activity in a West Virginia stream, Wolf Creek, to an upstream facility that stores fracking wastewater. Levels detected downstream of the waste facility were above levels known to create adverse health effects and alter the development of fish, amphibians, and other aquatic organisms. Endocrine-disrupting compounds were not elevated in upstream sections of the creek.[326, 327] (See also entry for May 9, 2016 above.)

- March 29, 2016 – A study by Stanford University scientists determined that fracking and related oil and gas operations have indeed contaminated drinking water in the town of Pavillion, Wyoming where residents have long complained about foul-tasting water. The researchers found substances in the water that match those used in local fracking operations or found in nearby pits used for the disposal of drilling waste. Chemical contaminants included benzene, a known carcinogen, and toluene, a neurotoxicant. Possible mechanisms for contamination include defective cement well casings; spills and leaks from disposal pits; and underground migration of chemicals into aquifers from the fracked zone, which, in this area, is quite shallow. Also, in the Pavillion area, operators sometimes fracked directly into underground sources of water.[328] One of the authors of this study, Dominic DiGuilio, was also a lead scientist on the EPA's earlier aborted investigation of Pavillion's drinking water. (See entry for December 6, 2015 below.) In an interview about his new research, DiGiulio said that his findings raise concerns about similar water pollution in other heavily fracked regions. "Pavillion isn't geologically unique in the West, and I'm concerned about the Rocky Mountain region of the U.S. The impact on [underground drinking water sources] could be fairly extensive. Pavillion is like a canary in a coal mine and we need to look at other fields."[329] Co-author Rob Jackson noted, "There are no rules that would stop a company from doing this anywhere else."[330]

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325 Nicholas School of the Environment, Duke University. (2016, April 27). *Contamination in North Dakota linked to fracking spills* [Press release]. Retrieved from https://nicholas.duke.edu/about/news/ContaminationinNDLinkedtoFrackingSpills

326 Kassotis, C. D., Iwanowicz, L. R., Akob, D. M., Cozzarelli, I. M., Mumford, A. C., Orem, W. H., & Nagel, S. C. (2016). Endocrine disrupting activities of surface water associated with West Virginia oil and gas industry wastewater disposal site. *Science of the Total Environment, 557-558.* doi: 10.1016/j.sci.tenv.2016.03.113

327 Bienkowski, B. (2016, April 6). In W. Virginia, frack wastewater may be messing with hormones. *Environmental Health News*. Retrieved from http://www.environmentalhealthnews.org/ehs/news/2016/april/in-w.-virginia-frack-wastewater-may-be-messing-with-hormones

328 DiGiulio, D. C. & Jackson, R. B. (2016). Impact to underground sources of drinking water and domestic wells from production well stimulation and completion practices in the Pavillion, Wyoming, Field. *Environmental Science & Technology, 50*(8). doi: 10.1021/acs.est.5b04970

329 Banerjee, N. (2016, March 29). Fracking study finds toxins in Wyoming town's groundwater and raises broader concerns. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/29032016/fracking-study-pavillion-wyoming-drinking-water-contamination-epa

330 Jordan, R. (2016, March 29). Stanford researchers show fracking's impact to drinking water sources. Stanford News. Retrieved from http://news.stanford.edu/2016/03/29/pavillion-fracking-water-032916/

- February 22, 2016 – Relying on voluntary disclosures reported to the FracFocus registry and a list compiled by the U.S. Congress, a German team surveyed the physiochemical properties of chemicals used in hydraulic fracturing fluid to evaluate their environmental fate and potential toxicity. Common ingredients included those known to contaminant groundwater, such as solvents, as well as those known to react strongly with other chemicals, such as biocides and strong oxidants, indicating that almost certainly, new chemical products are formed during the process of fracking and its aftermath. Hence, non-toxic additives could potentially react with other substances to create harmful byproducts. The authors conclude that a comprehensive assessment of risks would require an unabridged list of the chemical additives used for fracking, and they call for full disclosure.[331, 332]

- February 9, 2016 – An investigation of water contamination in the Barnett Shale by ABC-affiliate station WFAA in Dallas found numerous violations by operators who ignored regulations that require sealing vertical well pipes with a cement sheath to protect groundwater from stray gas and other vapors that might escape and migrate upwards into overlying aquifers. The WFAA report said that the Texas Railroad Commission, which oversees drilling and fracking operations in Texas, has failed to respond to alleged violations of a rule that requires cement seals around steel well casings in geological zones where drilling has penetrated layers of rock containing oil and gas deposits.[333]

- February 8, 2016 – An investigation by the *Columbus Dispatch* revealed that the amount of water that operators use for hydraulic fracturing in Ohio gas wells increased steadily from 2011 to 2015. The total amount of water increased, as did the volume of water used per well—from an average of 5.6 million gallons per well in 2011 to 7.6 million in 2014. The reason is that the horizontally drilled holes beneath each well have become longer, and these require more water during the fracking process.[334]

- February 2016 – In a lengthy account to Congress on the status of the underground waste injection well program that is overseen by the EPA, the U.S. Government Accountability Office (GAO) reported that the agency "has not consistently conducted oversight activities necessary to assess whether state and EPA-managed programs are protecting underground sources of drinking water" from contamination by fracking waste. Specifically, the GAO took the EPA to task for failure to require well-specific inspections, collect data on enforcement actions, review permitting requirements by state regulatory agencies, or analyze the resources the agency would need to do all the above to adequately oversee the Underground Injection Control program. The GAO noted that it

[331] Elsner, M., & Hoelzer, K. (2016). Quantitative survey and structural classification of hydraulic fracturing chemicals reported in unconventional gas production. *Environmental Science & Technology, 50*(7). doi:10.1021/acs.est.5b02818
[332] Phys.Org. (9 March 2016). How to get a handle on potential risks posed by fracking fluids. Retrieved from http://phys.org/news/2016-03-potential-posed-fracking-fluids.html
[333] Shipp, B. (2016, February 9). Drilling records suggest lax state enforcement. WFAA, Dallas. Retrieved from http://www.wfaa.com/mb/news/local/investigates/rules-ignored-water-fouled-in-barnett-shale/38337835
[334] Arenschield, L. (2016, February 8). Drillers using more water to frack Ohio shale. *The Columbus Dispatch*. Retrieved from http://www.dispatch.com/content/stories/local/2016/02/07/drillers-using-more-water-to-frack-ohio-shale.html

had once before, in 2014, previously found the EPA negligent in its responsibilities to monitor drinking water sources for possible contamination with fracking waste.[335] (See entry below for September 23, 2014.)

- January 6, 2016 – Yale School of Public Health researchers analyzed more than 1,021 chemicals either used in fracking fluid or created during the process of hydraulic fracturing. They found that 781 of these chemicals lacked basic toxicity data. Of the 240 that remained, 157 were reproductive or developmental toxicants. These included arsenic, benzene, cadmium, formaldehyde, lead, and mercury.[336] Commenting on this study, lead author Nicole Deziel said, "This evaluation is a first step to prioritize the vast array of potential environmental contaminants from hydraulic fracturing for future exposure and health studies. Quantification of the potential exposure to these chemicals, such as by monitoring drinking water in people's homes, is vital for understanding the public health impact of hydraulic fracturing."[337]

- December 15, 2015 – A research team led by geologist Mukul Sharma from Dartmouth College discovered that chemical reactions between fracking fluid and rock can contribute to the toxicity of fracking wastewater. Specifically, the researchers found that fracking fluid can chemically react with the fractured shale in ways that cause barium, a toxic metal, to leach from clay minerals in the Marcellus Shale.[338, 339]

- December 6, 2015 – The *Caspar Star Tribune* investigated the EPA's decision to transfer its study of possible fracking-related drinking water contamination in Pavillion, Wyoming to a state agency in 2013. Preliminary data from the EPA suggested that drilling and fracking operations had contaminated drinking water supplies. To date, the state study has found no definitive link between drilling and water contamination. Interviews with officials and documents obtained under the Freedom of Information Act revealed that the EPA had bowed to political pressure from state officials and industry representatives and that Wyoming regulators narrowed the scope of the study considerably and conducted little fieldwork.[340] (See also entry above for March 29, 2016.)

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[335] U.S. Government Accountability Office. (2016, February). *Drinking Water: EPA Needs to Collect Information and Consistently Conduct Activities to Protect Underground Sources of Drinking Water.* GAO-16-281. Retrieved from http://gao.gov/assets/680/675439.pdf
[336] Elliot, E. G., Ettinger, A. S., Leaderer, B. P., Bracken, M. B., & Deziel, N. (2016). A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. Advance online publication. *Journal of Exposure Science & Environmental Epidemiology.* doi: 10.1038/jes.2015.81
[337] Greenwood, M. (2016, January 6). Toxins found in fracturing fluid and wastewater, study shows. *Yale News*. Retrieved from: http://news.yale.edu/2016/01/06/toxins-found-fracking-fluids-and-wastewater-study-shows
[338] Renock, D., Landis, J. D., & Sharma, M. (2016). Reductive weathering of black shale and release of barium during hydraulic fracturing. *Applied Geochemistry, 65.* doi: 10.1016/j.apgeochem.2015.11.001
[339] Dartmouth College. (15 December 2015). Fracking plays active role in generating toxic metal wastewater, study finds. *Science Daily*. Retrieved from https://www.sciencedaily.com/releases/2015/12/151215134653.htm
[340] Storrow, B. (2015, December 6). Pavillion today an EPA in retreat, a narrow state inquiry and no answers. *Caspar Star Tribune*. Retrieved from http://trib.com/business/energy/pavillion-today-an-epa-in-retreat-a-narrow-state-inquiry/article_403f84de-830c-5558-9f3f-ea48fd48d7ca.html?utm_medium=social&utm_source=facebook&utm_campaign=user-share

- November 19, 2015 – The Science Advisory Board (SAB) for the EPA reviewed the EPA's June 2015 draft assessment of fracking's impacts on drinking water, and challenged some of the summary statements that accompanied it, saying that they were over-generalized and not always aligned with the data in the report itself. Specifically, the SAB said, in a draft review, that the data cited by the report were too limited to support the headlined claim in the executive summary that drinking water impacts were neither "widespread" nor "systemic." The SAB also critiqued the study for downplaying local impacts in its conclusions, noting that these impacts can sometimes be severe.[341]

- October 19, 2015 – A six-month investigation by *Penn Live* found long-standing "systemic failures" on the part of the Pennsylvania Department of Environmental Protection (PA DEP) to enforce regulations governing drilling and fracking operations. Lack of oversight and reliance on industry self-policing have been the hallmarks of Marcellus Shale development for the past ten years, in violation of Pennsylvanians' constitutional right to clean air and water. Among the findings of this investigation: chronically leaking wastewater impoundments for which no fines or notices were issued to the operator; laboratory coding systems designed to obscure possible detections of certain chemical contaminants in residents' drinking water; and lack of inspections at well sites.[342]

- October 13, 2015 – An international team of researchers found detectable levels of multiple organic chemical contaminants in private drinking water wells in northeastern Pennsylvania where fracking is practiced. One of the compounds was a known additive of fracking fluid. Chemical fingerprinting and noble gas isotopes were used to determine if the contaminants most likely originated from surface spills at the well site or via upward transport from the shale itself. The organic pollutants found in the water did not contain chemical markers—certain elements and salts—that would indicate migration from deep geological strata. The authors concluded that "the data support a transport mechanism…to groundwater via accidental release of fracturing fluid chemicals derived from the surface rather than subsurface flow of these fluids from the underlying shale formation."[343, 344]

- September 23, 2015 – A team of researchers, examining how natural gas drilling and fracking operations across the nation affect creeks, streams and rivers, developed a predictive model and vulnerability index for surface water. They found that "all shale plays, regardless of location, had a suite of catchments that spanned highly degraded to

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[341] Banerjee, N. (2015, November 19). EPA finding on fracking's water pollution disputed by its own scientists. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/19112015/fracking-water-pollution-epa-study-natural-gas-drilling
[342] Woodwell, C. (2016, October 19). Pa. regulators fail to protect environment during Marcellus Shale boom. *Penn Live*. Retrieved from http://www.pennlive.com/midstate/index.ssf/2015/10/state_regulators_fail_to_prote.html
[343] Drollette, B. D., Hoelzer, K., Warner, N. R., Darrah, T. H., Karatum, O., O'Connor, M. P. . . . Plata, D. L. (2015). Elevated levels of diesel range organic compounds in groundwater near Marcellus gas operations are derived from surface activities. *Proceedings of the National Academy of Sciences, 112*(43). doi: 10.1073/pnas.1511474112
[344] Drollette B. D. & Plata, D. A. (2015, October 13). Hydraulic fracturing components in Marcellus groundwater likely from surface operations, not wells. *Phys.Org*. Retrieved from http://phys.org/news/2015-10-hydraulic-fracturing-components-marcellus-groundwater.html

those that are less altered and naturally sensitive to alteration." Surface water in Pennsylvania's Marcellus Shale region is classified by this model as vulnerable to fracking-related impacts because of steep slopes and loose, erodible soils within the watersheds.[345]

- July 30, 2015 – As reported by the *Los Angeles Times*, unlined waste pits and hillside spraying of oil-field wastewater have contaminated groundwater in Kern County, California. Five of six monitoring wells in the 94-acre waste site showed high levels of salt, boron, and chloride, but it is not known how far and fast the contaminated plume has traveled.[346]

- July 21, 2015 – By surveying records for 44,000 wells fracked between 2010 and 2013, researchers from Stanford University, Duke University, and Ohio State University attempted a first-ever assessment of the range of depths at which fracking occurs across the United States. They found that many wells are shallower than widely presumed.[347] As the authors noted, vertical fractures are able to propagate 2,000 feet upward, and hence, "shallow hydraulic fracturing often has greater potential risks of contamination than deeper hydraulic fracturing does." This study showed that drinking water sources may be more vulnerable from upward migration of fracking contaminants than previously presumed. Surprisingly, the researchers found no strong relationship between depth and the volume of water and chemicals used for fracking. Many wells were both shallow and water-intensive, with significant variation in water use from state to state.[348]

- July 9, 2015 – A multi-volume report from the California Council of Science and Technology (CCST) found threats to groundwater in California from several parts of the fracking lifecycle, most notably from toxic wastewater. First, wastewater from California fracking operations is sometimes used for crop irrigation, in which case contaminants may seep from the surface of agricultural areas into groundwater. Second, nearly 60 percent of fracking wastewater in California is disposed of in unlined, open-air pits, a practice that is banned in almost all other states. There are 900 such waste disposal pits in the state, most of which are located in Kern County. Third, for many years, fracking wastewater in California has been mistakenly sent, via injection wells, directly into protected aquifers containing clean freshwater.[349] California's Division of Oil, Gas and Geothermal Resources allowed fracking wastes to be injected into aquifers that it

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[345] Entrekin, S. A., Maloney, K. O., Kapo, K. E., Walters, A. W., Evan-White, M. A., & Klemow, K. M. (2015). Stream vulnerability to widespread and emergent stressors: a focus on unconventional oil and gas. *PLoS One, 10*(9). doi:10.1371/journal.pone.0137416

[346] Cart, J. (2015, July 30). Central valley wastewater disposal to continue despite contamination. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-oil-waste-pits-20150731-story.html

[347] Jordon, R. (2015, July 21). *Shallow fracking raises questions for water, new Stanford research shows.* [Press release]. Retrieved from http://news.stanford.edu/news/2015/july/fracking_water-jackson-072115.html

[348] Jackson, R. B., Lowry, E. R., Pickle, A., Kang, M., DiGiullo, D., & Zhao, K. (2015). The depths of hydraulic fracturing and accompanying water use across the United States. *Environmental Science & Technology*, *49*(15). 8969–8976. doi: 10.1021/acs.est.5b01228

[349] Shonkoff, S. B. C., Jordan, P., Hays, J., Stringfellow, W. T., Wettstein, Z. S., Harrison, R., Sandelin, W., & McKone, T. E. (2015, July 9). Volume II, Chapter 6: Potential impacts of well stimulation on human health in California. In: *An Independent Scientific Assessment of Well Stimulation in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from http://ccst.us/publications/2015/vol-II-chapter-6.pdf

believed were exempt from the U.S. Safe Drinking Water Act. Conceding this mistake, the agency has shut down 23 injection wells for fracking waste disposal and established a two-year timetable for phasing out other wells injecting waste into aquifers that should have been protected.[350] Fracking also threatens California's groundwater resources through water consumption, according to the CCST study. While this volume of water represents a small percentage of overall annual water consumption in California, fracking-related water use is, the study noted, disproportionately concentrated in areas of the state already suffering from water shortages. Further drawdowns of these aquifers may interfere with agricultural and municipal water needs.[351] In addition, because the oil-containing rock layers in California are located closer to the surface than in other states, the state's groundwater is potentially vulnerable to chemical contamination through vertical faults and fissures and via old and abandoned wells. The absence of evidence for direct contamination of groundwater by fracking, the study concluded, reflects absence of investigation rather than evidence of safety.[352]

- June 30, 2015 – The USGS released the first nationwide map of water usage for hydraulic fracturing. It shows wide geographic and temporal variation in the amount of water used to frack a single well. In general, gas wells consume more water per well (5.1 million gallons on average) than oil wells (4 million gallons). Median annual water volumes needed to frack a single horizontal oil or gas well increased dramatically—by a factor of 25 or more—between 2000 and 2014. A typical gas or oil well that is horizontally fracked now requires between six and eight Olympic-sized swimming pools of water. In 2014, the majority (58 percent) of new hydraulically fracked oil and gas wells were horizontally drilled. The watersheds where the most water was consumed for hydraulic fracturing are mostly located in southern or southwestern states and correspond to the following shale formations: the Eagle Ford and Barnett Shales in Texas; the Haynesville-Bossier Shale in Texas and Louisiana; the Fayetteville Shale in Arkansas; the Tuscaloosa Shale in Louisiana and Mississippi; and the Woodford Shale in Oklahoma. The Marcellus and Utica Shales—which underlie watersheds in parts of Ohio, Pennsylvania, West Virginia, and New York—were also in the top seven water-consuming shale plays in the United States.[353]

- June 26, 2015 – A decade-long USGS study of 11,000 public drinking water wells in California—nearly all the groundwater used for public supply—found high levels of potentially toxic contaminants in about 20 percent of the wells, affecting about 18 percent

[350] Baker, D. R. (2015, July 16). U.S. likely to bar oil-waste dumping into 10 California aquifers. *San Francisco Chronicle.* Retrieved from http://www.sfchronicle.com/business/article/U-S-likely-to-bar-oil-waste-dumping-into-10-6389677.php
[351] Stringfellow, W. T., Cooley H., Varadharajan, C., Heberger, M., Reagan, M. T., Domen, J.K., . . . Houseworth, J. E. (2015, July 9). Volume II, Chapter 2: Impacts of well stimulation on water resources. In: *An Independent Scientific Assessment of Well Stimulation in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from http://ccst.us/publications/2015/vol-II-chapter-2.pdf
[352] Long, J. C. S, Birkholzer, J. T., & Feinstein, L. C. (2015, July 9). Summary report. In: *An Independent Scientific Assessment of Well Stimulation in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from: http://ccst.us/publications/2015/2015SB4summary.pdf
[353] Gallegos, T. J., Varela, B. A., Haines, S. S., & Engle, M. A. (2015). Hydraulic fracturing water use variability in the United States and potential environmental implications. *Water Resources Research*. Accepted author manuscript. doi: 10.1002/2015WR017278

of the state's population.[354] Although the study did not specifically investigate contaminants from oil and gas extraction, it does provide evidence for farm irrigation draining into groundwater, raising questions about the possible contamination of drinking water aquifers from the reuse of fracking wastewater for crop irrigation.[355]

- June 16, 2015 – A University of Texas research team documented widespread drinking water contamination throughout the heavily drilled Barnett Shale region in northern Texas. The study, which analyzed 550 water samples from public and private water wells, found elevated levels of 19 different hydrocarbon compounds associated with fracking (including the carcinogen benzene and the reproductive toxicant, toluene), detections of methanol and ethanol, and strikingly high levels of 10 different metals.[356] "In the abstract, we can't state that unconventional oil and gas techniques are responsible," the lead author, Zachariah Hildenbrand, said in a media interview. "But when you get into areas where drilling is happening, you find more instances of contamination. It's not coincidental. There are causes for concern."[357]

- June 5, 2015 – The EPA's long-awaited 600-page draft report on the potential impacts of fracking for drinking water resources confirmed specific instances of drinking water contamination linked to drilling and fracking activities. The report also identified potential mechanisms, both above and below ground, by which drinking water resources can be contaminated by fracking. In some cases, drinking water was contaminated by spills of fracking fluid and wastewater. In other cases, "[b]elow ground movement of fluids, including gas . . . have contaminated drinking water resources." The EPA investigators documented 457 fracking-related spills over six years but acknowledged that they do not know how many more may have occurred. Of the total known spills, 300 reached an environmental receptor such as surface water or groundwater. The EPA also conceded that insufficient baseline drinking water data and a lack of long-term systematic studies limited the power of its findings. The EPA investigation confirmed a number of specific instances where these potential mechanisms did indeed lead to drinking water contamination. An assertion in the EPA's accompanying press release that it had not found "widespread, systemic impacts to drinking water resources" was quoted out of context by many media sources as proof that fracking poses little threat to drinking water. To the contrary, this report confirmed that drilling and fracking activities have contaminated drinking water in some cases and acknowledged that it cannot ascertain

[354] Belitz, K., Fram, M. S., & Johnson, T. D. (2015). Metrics for assessing the quality of groundwater used for public supply, CA, USA: equivalent-population and area. *Environmental Science & Technology*, *9*(14), 8330–8338. doi: 10.1021/acs.est.5b00265
[355] Knickmeyer E., & Smith, S. (2015, July 15). Study finds contaminants in California public-water supplies. *Associated Press.* Retrieved from http://abcnews.go.com/Health/wireStory/study-finds-contaminants-california-public-water-supplies-32476456
[356] Hildenbrand, Z. L., Carlton, D. D., Fontenot, B. E., Meik, J. M., Walton, J.L., Taylor, J. T., . . . Schug, K.A. (2015). A comprehensive analysis of groundwater quality in the Barnett Shale region. *Environmental Science & Technology, 49*(13), 8254-8262. doi: 10.1021/acs.est.5b01526
[357] McPhate, C. (2015, June 18). New study reveals potential contamination. *Denton Record-Chronicle*. Retrieved from http://www.dentonrc.com/local-news/local-news-headlines/20150618-new-study-reveals-potential-contamination.ece

how widespread the problem was due to insufficient data.[358] EPA Science Advisor Thomas A. Burke later clarified that the report does not show that fracking is safe. Burke said, "That is not the message of this report. The message of this report is that we have identified vulnerabilities in the water system that are really important to know about and address to keep risks as low as possible."[359]

- May 19, 2015 – A Pennsylvania State University research team documented the presence of a fracking-related solvent, 2-n-Butoxyethanol, in the drinking water from three homes in Bradford County, Pennsylvania, as part of an investigation of private drinking water wells near drilling and fracking operations that contained methane and foam. This finding represents the first fully documented case of a commonly used fracking chemical entering a drinking water source. "The most likely explanation of the incident is that stray natural gas and drilling or [hydrofracking] compounds were driven ~1-3 km along shallow to intermediate depth fractures to the aquifer used as a potable water source."[360] In an accompanying *New York Times* story, lead author Susan Brantley described the geology in northern Pennsylvania "as being similar to a layer cake with numerous layers that extend down thousands of feet to the Marcellus Shale. The vertical fractures are like knife cuts through the layers. They can extend deep underground, and can act like superhighways for escaped gas and liquids from drill wells to travel along, for distances greater than a mile away."[361]

- May 15, 2015 – A research team from the University of Colorado Boulder and California State Polytechnic Institute developed a model for identifying which fracking fluid chemicals are most likely to contaminate drinking water. Of 996 fracking fluid compounds known to be in use, researchers screened 659 of them for their ability to persist, migrate, and reach groundwater aquifers over a short time scale. Of the fifteen compounds so identified, two were commonly used in fracking operations: naphthalene and 2-butoxyethanol. Both are ingredients in surfactants and corrosion inhibitors. The authors noted that 2-butoxyethanol has been detected in drinking water in a heavily fracked area of Pennsylvania. Exposure to 2-butoxyethanol has been linked to birth defects in animals. Naphthalene is a possible human carcinogen that is toxic to red blood cells and contributes to kidney and liver damage. Researchers did not consider the impact of mixtures, interactions between contaminants, or chemical transformations during the fracking or flowback process and noted, "the need for data on the degradation of many

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358 U.S. EPA. (2015). *Assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources* (External review draft). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/047, 2015. Retrieved from http://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=244651

359 Ward Jr., K. (2015, June 7). EPA says new study doesn't show fracking is safe. *Charleston Gazette*. Retrieved from http://www.wvgazettemail.com/article/20150607/GZ01/150609432

360 Llewellyn, G. T., Dorman, F., Westland, J. L., Yoxtheimer, D., Grieve, P. Sowers, T., . . . Brantley, S. L. (2015). Evaluating a groundwater supply contamination incident attributed to Marcellus Shale gas development. *Proceedings of the National Academies of Science, 112,* 6325-30. doi: 10.1073/pnas.1420279112/-/DCSupplemental

361 St. Fleur, N. (2015, May 4). Fracking chemicals detected in Pennsylvania drinking water. *The New York Times*. Retrieved from http://www.nytimes.com/2015/05/05/science/earth/fracking-chemicals-detected-in-pennsylvania-drinking-water.html?_r=0#addendums

compounds used in fracturing fluids under conditions relevant for groundwater transport."[362]

- May 7, 2015 – A survey of streams in Arkansas, led by the University of Central Arkansas, found alterations in macroinvertebrate communities to be related to drilling and fracking operations in the Fayetteville Shale. Fracking activity near streams was associated with greater sediment and more chlorophyll. "This study suggests that land disturbance from gas development affected stream communities."[363]

- April 20, 2015 – A USGS team analyzed water brought to the surface during natural gas extraction at 13 fracked wells in northern Pennsylvania. They found large variability in the VOCs and microorganisms in the water samples from different wells. Organic chemical contaminants included benzene, toluene, and perchloroethylene, chloroform, and methylene chloride. The presence of microbes was associated with concentrations of benzene and acetate. Despite the addition of biocides during the fracking process, hydrogen sulfide-producing bacteria were present at culturable levels, along with methogenic and fermenting bacteria. The source of these microorganisms was not determined. "Therefore, we cannot exclude the possibility that these microorganisms are native to the shale formation and reactivated by [hydrofracking] activities, as their physiology does not indicate a terrestrial surficial source."[364]

- April 8, 2015 – A University of Colorado Boulder research team's analysis of the organic chemicals found in liquid waste that flowed out of gas wells in Colorado after they had been fracked revealed the presence of many fracking fluid additives, including biocides, which are potentially harmful if they leak into groundwater. According to the authors, treatment of fracking wastewater must include aeration, precipitation, disinfection, a biological treatment to remove dissolved organic matter, and reverse osmosis desalination in order for it to be appropriate for non-fracking uses, such as crop irrigation.[365]

- March 18, 2015 – Using a new stream-based monitoring method, a team of scientists with USGS, Pennsylvania State University, and University of Utah found elevated levels of methane in groundwater discharging into a stream near drilling and fracking operations in Pennsylvania. In this same area, several private water wells contained high levels of methane as a result of gas migration near a gas well with a defective casing. The

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[362] Rogers, J. D., Burke, T. L., Osborn, S. G., & Ryan, J. N. (2015). A framework for identifying organic compounds of concern in hydraulic fracturing fluids based on their mobility and persistence in groundwater. *Environmental Science & Technology Letters, 2,* 158-64.
[363] Johnson, E., Austin, B. J., Inlander, E., Gallipeau, C., Evans-White, M. A., & Entrekin, S. (2015). Stream macroinvertebrate communities across a gradient of natural gas development in the Fayetteville Shale. *Science of the Total Environment*, *530-531,* 323-32. doi: 10.1016/j.scitotenv.2015.05.027
[364] Akob, D. M., Cozzarelli, I. M., Dunlap, D. S., Rowan, E. L., & Lorah, M. M. (2015). Organic and inorganic composition and microbiology of produced waters from Pennsylvania shale gas wells. *Applied Geochemistry,* in press, corrected proofs online April 20. doi: 10.1016/j.apgeochem.2015.04.011
[365] Lester, Y., Ferrer, I., Thurman, E. M., Sitterley, K. A., Korak, J. A., Aiken, G., & Linden, K. G. (2015). Characterization of hydraulic fracturing flowback water in Colorado: Implications for water treatment. *Science of the Total Environment, 512-513,* 637-644. doi: 10.1016/j.scitotenv.2015.01.043

monitoring technique used by the scientists allowed them to demonstrate that the source of the methane was shale gas from the Middle Devonian period, which is the kind of gas found in the Marcellus Shale.[366] Researcher Susan Brantley said, "I found it compelling that using this new method for a reconnaissance of just 15 streams in Pennsylvania, we discovered one instance of natural gas entering the stream, perhaps from a nearby leaking shale gas well."[367]

- March 12, 2015 – A team led by geologist Donald Siegel of Syracuse University found no relationship between methane levels in drinking water wells and proximity to oil or gas wells in a heavily fracked area of northeastern Pennsylvania.[368] However, Siegel failed to reveal in his paper — as is required by the journal — that he had received industry funding from the Chesapeake Energy Corporation. Subsequently, the journal published a lengthy correction that revealed that Chesapeake had not only privately funded the lead author but had provided the baseline groundwater data set. A second author was revealed to be a former employee of Chesapeake, and another had worked as a consultant in the energy sector.[369]

- March 3, 2015 – A Duquesne University study of private drinking water wells in an intensely drilled southwestern Pennsylvania community compared pre-drill and post-drill data on water quality and found changes in water chemistry that coincided with the advent of drilling and fracking activities. Levels of chloride, iron, barium, strontium, and manganese were elevated. In some cases, concentrations exceeded health-based maximum contaminant levels. Methane was detected in most houses tested. Surveys of residents revealed widespread complaints about changes in water quality that began after drilling and fracking operations commenced. Violation records from the PA DEP uncovered possible pathways for water contamination. The researchers concluded that alterations of local hydrology caused by the injection of large volumes of hydraulic fracturing fluids may have mobilized contaminants left over from legacy oil, gas, and mining operations as well as opened pathways for the migration of fracking fluids themselves.[370]

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[366] Heilweil, V. M., Grieve, P. L., Hynek, S. A., Brantley, S. L., Solomon, D. K., & Risser, D. W. (2015). Stream measurements locate thermogenic methane fluxes in groundwater discharge in an area of shale-gas development. *Environmental Science & Technology, 49,* 4057-4065. doi: 10.1021/es503882b

[367] U.S. Geological Survey. (2015, April 1). New stream monitoring method locates elevated groundwater methane in shale-gas development area. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=4176&from=rss&utm_source=dlvr.it&utm_medium=facebookhttp://www.readcube.com/articles/10.1002%2F2014WR016382?r3_referer=wol&tracking_action=preview_click&show_checkout=1&purchase_site_license=LICENSE_DENIED_NO_CUSTOMER#.VaPKNYsqdyA

[368] Siegel, D. I., Azzolina, N. A., Smith, B. J., Perry, A. E., & Bothun, R. L. (2015). Methane concentrations in water wells unrelated to proximity to existing oil and gas wells in northeastern Pennsylvania. *Environmental Science & Technology, 49,* 4106-12. doi: 10.1021/es505775c

[369] Siegel, D. I., Azzolina, N. A., Smith, B. J., Perry, A. E., & Bothun, R. L. (2015). Correction to Methane concentrations in water wells unrelated to proximity to existing oil and gas wells in northeastern Pennsylvania. *Environmental Science & Technology, 49,* 4106-12. doi: 10.1021/es505775c

[370] Alawattegama, S. K., Kondratyuk, T., Krynock, R., Bricker, M., Rutter, J. K., Bain, D. J., & Stolz, J. F. (2015). Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering, 50,* 516-528. doi: 10.1080/10934529.2015.992684

- March 3, 2015 – A research team from Duquesne University reviewed the evidence for environmental impacts to air and water from activities related to shale gas extraction in Pennsylvania and explored potential mechanisms for contamination of air and water related to the drilling and fracking process itself. Among them: deformations of the shale bedrock caused by the injection of large volumes of fluid result in "pressure bulbs" that are translated through rock layers and can impact faults and fissures, so affecting groundwater.[371]

- February 23, 2015 – The arrival of drilling and fracking activities coincided with an increase in salinity in a creek that drains public land in a semi-arid region of Wyoming, determined a USGS study. The dissolved minerals associated with the rise in salinity matched those found in native soil salts, suggesting that disturbance of naturally salt-rich soils by ongoing oil and gas activities, including pipeline, road, and well pad construction, was the culprit. "As [shale gas and oil] development continues to expand in semiarid lands worldwide, the potential for soil disturbance to increase stream salinity should be considered, particularly where soils host substantial quantities of native salts."[372]

- February 14, 2015 – A review by a *Dickinson Press* news reporter of disposal well files and more than 2,090 mechanical integrity tests revealed that North Dakota frack waste injection wells were often leaky and that state regulators continued to allow fluid injection into wells with documented structural problems even though the wells did not meet EPA guidelines for wellbore integrity. Officials with the North Dakota Division of Oil and Gas said they had primary enforcement responsibilities and that EPA guidance did not apply to these wells. The investigation noted, "… a review of state and federal documents, as well as interviews with geologists, engineers, environmental policy experts and lawyers who have litigated under the Safe Drinking Water Act, suggests the agency is loosely interpreting guidance and protocols that are meant to maintain the multiple layers of protection that separate aquifers from the toxic saltwater." *The Dickinson Press* is the daily newspaper for Stark County in southwest North Dakota.[373]

- February 11, 2015 – The *Los Angeles Times* analyzed self-reported testing results on fracking wastewater that California drillers were required to submit to the state. Samples of wastewater collected from 329 fracked oil wells found that virtually all—98 percent—contained benzene at levels that exceeded standards for permissible concentrations in drinking water. This finding likely underrepresents the extent of the problem, according

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371 Lampe, D. J., & Stolz, J. F. (2015). Current perspectives on unconventional shale gas extraction in the Appalachian Basin. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, *50*(5), 434-446. doi: 10.1080/10934529.2015.992653

372 Bern, C. R., Clark, M. L., Schmidt, T. S., Nolloway, J. M., & McDougal, R. R. (2015). Soil disturbance as a driver of increased stream salinity in a semiarid watershed undergoing energy development. *Journal of Hydrology, 524,* 123-136. doi: doi.org/10.1016/j.jhydrol.2015.02.020

373 Brown, A. (2015, February 14). Lacking integrity? State regulatory officials don't follow EPA guidance on saltwater disposal wells. *The Dickinson Press.* Retrieved from http://www.thedickinsonpress.com/energy/bakken/3679507-lacking-integrity-state-regulatory-officials-dont-follow-epa-guidance

to the newspaper investigation, because many operators failed to comply with reporting requirements. The discovery that fracking wastewater is high in benzene is particularly alarming in light of the admission by the state of California that it had inadvertently allowed frack waste disposal directly into aquifers containing clean water that could potentially be used for drinking. Those wells are now the subject of federal and state review.[374]

- February 1, 2015 – An investigation of the chemical make-up of fracking fluid found that the compositions of these mixtures vary widely according to region and company, making the process of identifying individual compounds difficult. Classes of hydrocarbon-based chemicals include solvents, gels, biocides, scale inhibitors, friction reducers, and surfactants. Chemical analysis identified around 25 percent of the organic compounds that are believed to be present in fracking fluid and that are necessary to test for in identifying groundwater and drinking water contamination.[375] Dr. Imma Ferrer, lead author, explained in a *Science Daily* article about her research that "[b]efore we can assess the environmental impact of the fluid, we have to know what to look for."[376]

- January 30, 2015 – A USGS review of national water quality databases found that insufficient data exist to understand the impact of fracking on drinking water.[377] In a media interview, lead author Zack Bowen said, "There are not enough data available to be able to assess the potential effects of oil and gas development over larger geographic areas."[378]

- January 21, 2015 – A team of researchers from the USGS and Virginia Tech University established that petroleum-based hydocarbons can break down underground in ways that promote the leaching of naturally occurring arsenic into groundwater. Arsenic is a known human carcinogen that causes bladder, lung, and skin cancer. Elevated levels of arsenic in drinking water represent a public health threat.[379] Researchers found that arsenic concentrations in a hydrocarbon plume can reach 23 times the current drinking water

[374] Cart. J. (2015, February 11). High levels of benzene found in fracking waste water. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-fracking-20150211-story.html#page=1
[375] Ferrer, I., & Thurman, E.M. (2015), Chemical constituents and analytical approaches for hydraulic fracturing waters. *Trends in Environmental Analytical Chemistry*, *5,* 18-25, doi: 10.1016/j.teac.2015.01.003
[376] Elsevier. (2015 April 8). Fracking fluids contain potentially harmful compounds if leaked into groundwater. *ScienceDaily*. Retrieved from http://www.sciencedaily.com/releases/2015/04/150408090323.htm?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+sciencedaily%2Fearth_climate%2Frecycling_and_waste+%28Recycling+and+Waste+News+--
[377] Bowen, Z. H., Oeisner, G. P., Cade, B., Gallegos, T. J., Farag, A. M., Mott, D. N., . . . Varela, B. A. (2015). Assessment of surface water chloride and conductivity trends in areas of unconventional oil and gas development—why existing national data sets cannot tell us what we would like to know. *Water Resources Research, 51,* 704-15. doi: 10.1002/2014WR016382
[378] Phillips, S. (2015, March 3). USGS: fracking water quality data "scarce." *StateImpact Pennsylvania.* Retrieved from https://stateimpact.npr.org/pennsylvania/2015/03/03/usgs-fracking-water-quality-data-scarce/
[379] U.S. Geological Survey (2015, January. 26). Natural breakdown of petroleum underground can lace arsenic into groundwater. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=4110&from=rss&utm_source=dlvr.it&utm_medium=facebook#.VavGXIsqdyA

standard of 10 micrograms per liter. The authors of the study said that the metabolism of carbon-rich petroleum products by subterranean microbes is involved in a complex geochemical process that leads to mobilization of arsenic into aquifers.[380]

- January 14, 2015 – Researchers from Duke University, Dartmouth College, and Stanford University found high levels of iodide, bromide, and ammonium in samples of wastewater from fracking operations in both the Marcellus and Fayetteville Shales. These same chemicals were present when fracking wastewater was discharged into rivers and streams at three treatment sites in Pennsylvania and during an accidental spill in West Virginia. Iodide and bromide are known to create toxic disinfection byproducts when downstream water is subsequently chlorinated for drinking water. In water, ammonium can convert to ammonia, which is toxic to aquatic life. The authors noted that this is the first study to identify ammonium and iodide as widespread in fracking waste discharges.[381] In an interview with the *Pittsburgh Post-Gazette*, lead author Avner Vengosh said that the findings raise new concerns about the environmental and health impacts of wastewater from drilling and fracking operations.[382]

- November 27, 2014 – An interdisciplinary team of researchers found methane contamination in drinking water wells located in eight areas above the Marcellus Shale in Pennsylvania and the Barnett Shale in Texas, with evidence of declining water quality in the Barnett Shale area. By analyzing noble gases and their isotopes (helium, neon, argon), the investigators were able to isolate the origin of the fugitive methane in drinking water. The results implicate leaks through cement well casings as well as via naturally occurring cracks and fissures in the surrounding rock.[383] In a related editorial, one of the study's authors, Robert Jackson, called on the EPA to reopen its aborted investigation into drinking water contamination in heavily fracked areas of Texas. Jackson also emphasized that methane migration through unseen cracks in the rock surrounding the wellbore "raises the interesting possibility that a drilling company could follow procedures — cementing and casing below the local aquifer — and still create a potential pathway for gas to migrate into drinking water."[384]

- November 26, 2014 – A critical review of biocides in fracking fluid by a Colorado State team found that the fate of these chemicals underground is not known and their toxicity not well understood. While many biocides are short-lived, some may transform into more

[380] Cozzarelli, I. M. Schreiber, M. D., Erickson, M. L., & Ziegler, B. A. (2015). Arsenic cycling in hydrocarbon plumes: secondary effects of natural attenuation. *Groundwater*. doi: 10.1111/gwat.12316
[381] Harkness, J. S., Dwyer, G. S., Warner, N. R., Parker, K. M., Mitch, W. A., & Vengosh, A. (2015). Iodide, bromide, and ammonium in hydraulic fracturing and oil and gas wastewaters: environmental implications. *Environmental Science & Technology*, *49,* 1955-63. doi: 10.1021/es504654n
[382] Hopey, D. (2015, January 15). Study: high levels of pollutants from drilling waste found in Pa. rivers. *Pittsburgh Post-Gazette*. Retrieved from http://powersource.post-gazette.com/powersource/latest-oil-and-gas/2015/01/14/Study-High-levels-of-pollutants-from-drilling-waste-found-in-Pennsylvania-rivers-shale/stories/201501140143
[383] Darrah, T. H., Vengosh, A., Jackson, R. B., Warner, N. R., & Poreda, R. J. (2014). Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales. *Proceedings of the National Academy of Sciences, 111* (39), 14076-14081. doi: 10.1073/pnas.1322107111
[384] Jackson, R. (2014, December 1). Reopen Barnett Shale water probe. *The Texas Tribune.* Retrieved from http://tribtalk.org/2014/12/01/reopen-barnett-shale-water-probe/

toxic or persistent compounds. Among the most common chemical components of fracking fluid, biocides are used to inhibit the growth of deep-life microorganisms, including sulfate-reducing bacteria that contribute to corrosion of well casings and can form biofilms that prevent the upward flow of natural gas. Oxidizing biocides that are chlorine- or bromine-based can react with other fracking chemicals and may produce toxic halogenated byproducts. The authors noted biocides pose a unique risk for drinking water when fracking liquid waste is treated for discharge to surface water via sewage treatment plants. Sub-lethal concentrations may contribute to adaptation of surviving microorganisms and, hence, antibiotic resistance of pathogens. They cited particular concern over surface spills and well integrity issues associated with casing or cement failure.[385]

- November 3, 2014 – The West Virginia Department of Environmental Protection confirmed that three private drinking water wells were contaminated when Antero Resources mistakenly drilled into one of its own gas wells. Benzene, a human carcinogen, and toluene, a reproductive toxicant, were detected in the drinking water at concentrations four times the legal maximum limit. Additionally, a nearby abandoned gas well, a drinking water well, and an actively producing gas well were all pressurized as a result of the mishap and began exhibiting "artesian flow."[386]

- October 22, 2014 – A follow-up to the August 2014 Environmental Integrity Project report describes an even greater potential public health threat from a loophole in the Safe Drinking Water Act, wherein companies are allowed to inject other petroleum products (beyond diesel) without a permit, and many of these non-diesel drilling fluids contain even higher concentrations of the same toxins found in diesel. The authors recommend that "EPA should revisit its guidance and broaden the categories of diesel products that require Safe Drinking Water Act permits before they can be injected into oil and gas wells."[387]

- October 20, 2014 – While developing a technique to fingerprint and trace accidental releases of hydraulic fracturing fluids, researchers showed that liquid waste from shale gas fracking operations is chemically different than waste flowing out of conventional wells. The researchers hypothesized that the hydraulic fracturing process itself liberates elements from clay minerals in the shale formations, including boron and lithium, which then enter the liquid waste.[388]

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[385] Kahrilas, G. A. Blotevogel, J., Stewart, P. S., & Borch, T. (2015). Biocides in hydraulic fracturing fluids: a critical review of their usage, mobility, degradation, and toxicity. *Environmental Science & Technology, 49,*16-32. doi: 10.1021/es503724k

[386] Board, G. (2014, November 3). September drilling accident contaminated water in Doddridge County. *West Virginia Public Broadcasting*. Retrieved from http://wvpublic.org/post/dep-september-drilling-accident-contaminated-water-doddridge-county

[387] Schaeffer, E., & Bernhardt, C. (2014, October 22). Fracking's toxic loophole. The Environmental Integrity Project. Retrieved from http://environmentalintegrity.org/wp-content/uploads/FRACKINGS-TOXIC-LOOPHOLE.pdf

[388] Warner, N. R., Darrah, T. H., Jackson, R. B., Millot, R., Kloppmann, W., & Vengosh, A. (2014). New tracers identify hydraulic fracturing fluids and accidental releases from oil and gas operations. *Environ. Sci. Technol.*, *48*(21), 12552–12560. doi: 10.1021/es5032135

- October 15, 2014 – Four thousand gallons of liquid fracking waste dumped into Waynesburg sewer system was discovered by sewage treatment plant workers in Greene County, Pennsylvania. The Department of Environmental Protection surmised that "someone removed a manhole cover in a remote location and dumped the fluid." The treatment plant discharges into a creek that feeds the Monongahela River, which provides drinking water to more than 800,000 people.[389]

- October 6, 2014 – A state investigation that found no fracking-related water contamination in a drinking water well in Pennsylvania's Washington County was invalidated by testimony presented to the state Environmental Hearing Board. Not all contaminants that were present in the water were reported, and the investigation relied on obsolete testing methods. More sophisticated testing revealed the presence of several chemical contaminants in the well water. The well is located 2,800 feet down gradient from a drilling site and fracking waste pit where multiple spills and leaks more than four years earlier had contaminated two springs.[390]

- September 23, 2014 – In a two-part audit of records, the GAO found that the EPA is failing to protect U.S. drinking water sources from fracking-related activities such as waste disposal via injection wells. Nationwide, 172,000 injection wells accept fracking waste; some are known to have contaminated drinking water. And yet, both short-term and long-term monitoring is lax, and record-keeping varies widely from state to state. The EPA neither mandates nor recommends a fixed list of chemicals for monitoring on the grounds that "injection fluids can vary widely in composition and contain different naturally occurring chemicals and fluids used in oil and gas production depending on the source of the injection fluid."[391] Disposal of oil and gas waste via injection wells is, in fact, subject to regulation under the Safe Drinking Water Act, but, in practice, no one knows exactly what the waste contains, and regulations are deficient. In the United States, at least two billion gallons of fluids are injected into the ground *each day* to enable oil and gas extraction via fracking or to dispose of liquid waste from fracking operations.[392, 393]

- September 18, 2014 – Range Resources was fined a record $4.5 million by the Pennsylvania Department of Environmental Protection for contaminating groundwater.

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389 Hopey, D. (2014, October 15). Waynesburg officials investigate dumping of fracking wastewater. *Pittsburgh Post-Gazette*. Retrieved from http://powersource.post-gazette.com/news/environment/2014/10/15/Waynesburg-investigates-dumping-of-fracking-wastewater/stories/201410150056

390 Hopey, D. (2014, October 6). Testimony: obsolete tests tainted shale analysis. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/companies-powersource/2014/10/06/Testimony-Obsolete-tests-tainted-shale-analysis/stories/201410060075

391 U.S. Government Accountability Office. (2014, September 23). Drinking water: characterization of injected fluids associated with oil and gas production. GAO-14-657R. Retrieved from http://www.gao.gov/products/GAO-14-857R.

392 Sadasivam N. (2014, July 29). Report criticizes EPA oversight of injection wells, *ProPublica.* Retrieved from http://www.propublica.org/article/report-criticizes-epa-oversight-of-injection-wells

393 U.S. Government Accountability Office. (June 27, 2014). EPA program to protect underground sources from injection of fluids associated with oil and gas production needs improvement. GAO-14-555. Retrieved from http://www.gao.gov/products/GAO-14-555

The culprits were six leaking pits in Washington County that each held millions of gallons of fracking wastewater.[394]

- September 12, 2014 – A Pennsylvania State ecosystems scientist, together with USGS scientists, reviewed the current knowledge of the effects of fracking and its associated operations on terrestrial and aquatic ecosystems in 20 shale plays in the U.S. Findings of species and habitats at highest risk include (in addition to land-based examples) vernal pond inhabitants and stream biota. The research builds on previous reviews identifying "three main potential stressors to surface waters: changes in water quantity (hydrology), sedimentation, and water quality." Researchers determined that there are no published data specifically on the effects of fracking on forest-dwelling amphibians, but "many species breed in vernal ponds which are negatively affected by changes in water quantity and quality and direct disturbance. Many amphibians are also highly sensitive to road salts." Given that the U.S. EPA recently found 55 percent of all rivers and streams to be in poor condition, these researchers warned, "Large-scale development of shale resources might increase these percentages." They expressed concern for the native range of brook trout by the cumulative effects of shale development, especially in Pennsylvania.[395]

- September 9, 2014 – A research team from Stanford and Duke Universities discovered that fracking wastewater processed by sewage treatment plants contributes to the formation of carcinogenic chemical byproducts. These raise public health risks when downstream surface water is used for drinking. Even when fracking wastewater was diluted by a factor of 10,000, the bromides and iodides in the waste reacted with organic matter to create highly toxic halogenated compounds—at troublingly high concentrations. These toxic compounds are not filterable by municipal wastewater treatment plants. Halogenated disinfection byproducts in drinking water are linked to both colon and bladder cancers.[396]

- August 29, 2014 – A review of Pennsylvania Department of Environmental Protection files on fracking-related damage to drinking water—which are kept on paper and stored in regional offices—revealed that 243 private water supplies in 22 counties had been contaminated or had lost flow and dried up as a result of nearby drilling and fracking operations in the past seven years. Pollutants included methane, metals, and salts as well as carbon-based compounds (ethylene glycol and 2-butoxyethanol) that are known to be constituents of fracking fluid. As reported by the *Pittsburgh Post-Gazette*, this tally—which came as a response to multiple lawsuits and open-records requests by media

[394] Hopey, D. (2014, September 18). Range resources to pay $4.15M penalty. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/local/2014/09/18/DEP-orders-Range-Resources-to-pay-4-million-fine/stories/201409180293

[395] Brittingham, M. C., Maloney, K. O., Farag, A. M., Harper, D. D., & Bowen, Z. H. (2014). Ecological risks of shale oil and gas development to wildlife, aquatic resources and their habitats. *Environmental Science & Technology*, *48*(19), 11034–11047. doi: dx.doi.org/10.1021/es5020482

[396] Parker, K. M., Zeng, T., Harkness, J., Vengosh, A., & Mitch, W. A. 2014. Enhanced formation of disinfection byproducts in shale gas wastewater-impacted drinking water supplies. *Environmental Science & Technology*, *48*(19), 11161–11169. doi: 10.1021/es5028184

sources—was the first time the agency "explicitly linked a drilling operation to the presence of industrial chemicals in drinking water."[397, 398]

- August 13, 2014 – Over the last decade, drilling companies have repeatedly claimed they are no longer using diesel fuel in fracking, although a 2011 investigation by U.S. House Democrats concluded otherwise. The Environmental Integrity Project examined disclosure data submitted to FracFocus and identified at least 351 wells in 12 states that have been fracked over the last four years with one or more of the five prohibited products identified as diesel. EIP researchers also discovered numerous fracking fluids with high diesel content for sale online, including over a dozen products sold by Halliburton and advertised as additives, friction reducers, emulsifiers, etc.[399]

- August 13, 2014 – An international team of researchers found high levels of carbon-based compounds in liquid fracking waste. These impurities can react with chlorine and bromine to create toxic byproducts. This study suggests that chemical treatment of liquid fracking waste will magnify its toxic potency, as will reusing and recycling it.[400] The European Commission subsequently published a summary of these findings.[401]

- August 13, 2014 – A team from Lawrence Berkeley National Laboratory reported that scientific efforts to understand the hazards of fracking continue to be hampered by industry secrecy. A comprehensive examination of the chemical formulations of fracking fluid—whose precise ingredients are protected as proprietary business information—revealed that no publicly available toxicity or physical chemical information was available for one-third of all the fracking chemicals surveyed. Another ten percent of chemicals, including biocides and corrosion inhibitors, were known to be toxic to mammals.[402, 403]

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397 Pennsylvania Department of Environmental Protection. (2014 August 29). Water supply determination letters. Retrieved from http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/Determination_Letters/Regional_Determination_Letters.pdf

398 Legere, L. (2014, September 9). DEP releases updated details on water contamination near drilling sites: some 240 private supplies damaged by drilling in the past 7 years. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/policy-powersource/2014/09/09/DEP-releases-details-on-water-contamination/stories/201409090010

399 Greene, M. (2014, August 13). Fracking beyond the law: Despite industry denials, investigation reveals continued use of diesel in hydraulic fracturing. The Environmental Integrity Project. Retrieved from http://environmentalintegrity.org/wp-content/uploads/Fracking-Beyond-the-Law.pdf

400 Maguire-Boyle, S. J., & Barron, A. R. (2014). Organic compounds in produced waters from shale gas wells. *Environmental Science: Processes & Impacts*, *16,* 2237-2248. doi: 10.1039/C4EM00376D

401 European Commission. (2015, February 19). Chemical composition of fracking wastewater. *Science for Environment Policy, 404.* Retrieved from http://ec.europa.eu/environment/integration/research/newsalert/pdf/chemical_composition_of_fracking_wastewater_404na4_en.pdf

402 Stringfellow, W. T., Domen, J. K., Carmarillo, M. K., Sandelin, W. L., Tinnacher, R., Jordan, P., . . . Birkholzer, J. (August 13, 2014). Characterizing compounds used in hydraulic fracturing: a necessary step for understanding environmental impacts. Presentation before the American Chemical Society conference, San Francisco. Abstract retrieved from http://abstracts.acs.org/chem/248nm/program/view.php?obj_id=262051&terms=

403 Robinson, P. (2014, August 19). Fracking fluid survey shows missing information. *Scientific American.* Retrieved from http://www.scientificamerican.com/article/fracking-fluid-survey-shows-missing-information/

- August 12, 2014 – A Stanford University research team working in the Pavillion gas basin in Wyoming documented that fracking in shallow layers of bedrock, including those that serve as drinking water aquifers, is not uncommon. This finding overturns the industry claim that oil and gas deposits targeted by fracking operations are located at much greater depths than underground drinking water sources and are isolated from them by hundreds of feet of impermeable rock. Because it is exempt from provisions of the Safe Drinking Water Act, fracking in drinking water aquifers is not prohibited by law.[404]

- August 3, 2014 – An investigation by the *Pittsburgh Post-Gazette* found that half of all fracking-related spills that resulted in violations and fines were not discovered by the gas companies themselves, even though Pennsylvania state law requires them to pro-actively seek and report such incidents. The newspaper's analysis of hundreds of thousands of state and company documents showed that self-regulation in the gas fields is a failure. One-third of all spills were discovered by state inspectors, while one-sixth were found by residents. Likely, much contamination is entirely undetected and unreported.[405]

- July 21, 2014 – An investigation by the *Columbus Dispatch* showed that Halliburton delayed disclosure to federal and state EPA agencies of the full list of chemicals that spilled into a creek following a fire on one of its well pad in Monroe County, Ohio. Although the creek is an important supply of drinking water for downstream communities and the spill precipitated a mass die-off of fish and other aquatic wildlife, five full days passed before EPA officials were provided a full inventory of chemicals used at Halliburton's operation. As a result, the public was denied knowledge of potential chemical exposures.[406]

- July 17, 2014 – A team of environmental scientists, biologists, and engineers, from institutions including the University of Michigan and McGill University, assessed the current state of understanding of the impact fracking and its associated activities have on the ecological health of surface waters. Though various approaches such as geographic information systems and site monitoring provide insights into potential risks to aquatic ecosystems, the authors concluded that inadequate data currently exist. They identified possible outcomes such as, "erosion and sedimentation, increased risk to aquatic ecosystems from chemical spills or runoff, habitat fragmentation, loss of stream riparian

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[404] Banerjee, N. (2014, August 12). Oil companies fracking into drinking water sources, new research finds. *Los Angeles Times.* Retrieved from http://www.latimes.com/nation/la-na-fracking-groundwater-pavillion-20140811-story.html#page=1

[405] Hamill, S. D. (2014, August 3). Drillers did not report half of spills that led to fines. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/news/state/2014/08/03/Drillers-did-not-report-half-of-spills-that-led-to-fines/stories/201408020142

[406] Arenschield, L. (2014, July 21). Halliburton delayed releasing details on fracking chemicals after Monroe County spill. *The Columbus Dispatch*. Retrieved from http://www.dispatch.com/content/stories/local/2014/07/21/details-on-chemicals-trickle-in-after-spill.html

zones, altered biogeochemical cycling, and reduction of available surface and hyporheic water volumes because of withdrawal-induced lowering of local groundwater levels."[407]

- July 7, 2014 – California Department of Gas, Oil, and Geothermal Resources ordered seven energy companies to stop injecting liquid fracking waste into aquifers. The ongoing drought that has compelled farmers to supplement irrigation with water drawn from groundwater sources prompted state officials to look at the status of aquifers previously considered too deep for use or too poor in quality. They discovered that at least seven injection wells were very likely pumping liquid fracking waste into protected groundwater supplies rather than aquifers that had been sacrificed for the purpose of waste disposal. Across the United States, more than 1000 aquifers are exempt from any type of pollution protection at all, and many of these are in California, according to a related *ProPublica* investigation.[408]

- June 25, 2014 – A study by Cornell University researchers found that fracking fluid and fracking wastewater mobilized previously deposited chemical contaminants in soil particles in ways that could potentially exacerbate the impacts of fracking fluid spills or leaks. The research team concluded that, by interfering with the ability of soil to bond to and sequester pollutants such as heavy metals, fracking fluids may release from soils an additional repository of contaminants that could migrate into groundwater.[409]

- June 23, 2014 – Building on earlier findings that water samples collected from sites with confirmed fracking spills in Garfield County, Colorado exhibited moderate to high levels of estrogen and androgen-disrupting activity, a University of Missouri team extended their investigation to other types of hormonal effects. As reported at a joint meeting of the International Society of Endocrinology and the Endocrine Society, their research documented that commonly used fracking chemicals can also block the receptors for thyroid hormone, progesterone, and glucocorticoids (a family of hormones involved in both fertility and immune functioning). Of 24 fracking chemicals tested, all 24 interfered with the activity of one or more important hormone receptors. There is no known safe level of exposure to hormone-disrupting chemicals.[410]

- May 11, 2014 – According to the GAO, the federal government is failing to inspect thousands of oil and gas wells located on public land, including those that pose special

[407] Burton Jr., G. A., Basu, N., Ellis, B. R., Kapo, K. E., Entrekin, S. & Nadelhoffer, K. (2014). Hydraulic "fracking": are surface water impacts an ecological concern? *Environmental Toxicology and Chemistry*, *33*(8), 1679-1689.
[408] Lustgarten, A. (2014, July 18). California halts injects of fracking waste, warning it may be contaminating aquifers. *ProPublica.* Retrieved from http://www.propublica.org/article/ca-halts-injection-fracking-waste-warning-may-be-contaminating-aquifers
[409] Sang, W., Stoof, C., Zhang, W., Morales, V., Gao, B., Kay, R., . . . Steenhuis, T. (2014). Effect of hydrofracking fluid on colloid transport in the unsaturated zone. *Environmental Science & Technology*, *48*(14), 8266–8274. Retrieved from http://pubs.acs.org/doi/abs/10.1021/es501441e
[410] The Endocrine Society (2014, June 23). Hormone-disrupting activity of fracking chemicals worse than initially found. *Science Daily.* Retrieved from http://www.sciencedaily.com/releases/2014/06/140623103939.htm?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+sciencedaily%2Ftop_news%2Ftop_health+%28ScienceDaily%3A+Top+Health+News%29

risks of water contamination or other environmental damage. An investigation by the Associated Press found that the Bureau of Land Management "had failed to conduct inspections on more than 2,100 of the 3,702 wells that it had specified as 'high priority' and drilled from 2009 through 2012. The agency considers a well 'high priority' based on a greater need to protect against possible water contamination and other environmental safety issues."[411]

- March 25, 2014 – An industry-funded study of oil and gas well integrity found that more than six percent of wells in a major shale exploration region in Pennsylvania showed evidence of leaking and conceded that this number is likely an underestimate. Researchers concluded that the percentage of wells with some form of well barrier or integrity failure is highly variable and could be as high as 75 percent. A separate analysis in the same study found 85 examples of cement or casing failures in Pennsylvania wells monitored between 2008 and 2011.[412]

- March 7, 2014 – In a comprehensive evaluation, Duke University scientists and colleagues reviewed the state of knowledge on possible effects of shale gas and hydraulic fracturing on water resources in the United States and concluded, "Analysis of published data (through January 2014) reveals evidence for stray gas contamination, surface water impacts in areas of intensive shale gas development, and the accumulation of radium isotopes in some disposal and spill sites."[413]

- February 19, 2014 – A Pennsylvania court found a gas corporation guilty of contaminating a woman's drinking water well in Bradford County. Methane levels after fracking were 1,300-2,000 times higher than baseline, according to the court brief. Iron levels and turbidity had also increased. The brief stated, "In short, Jacqueline Place lived for ten months deprived totally of the use of her well, and even after its 'restoration,' has been burdened with a water supply with chronic contamination, requiring constant vigilance and ongoing monitoring."[414]

- January 16, 2014 – Data from the Colorado Oil and Gas Conservation Commission showed that fracking-related chemical spills in Colorado exceed an average rate of one spill per day. Of the 495 chemical spills that occurred in that state over a one-year period of time, nearly a quarter impacted ground or surface water. Sixty-three of the spills spread within 1,500 feet of pigs, sheep, and cows; 225 spread within 1,500 feet of

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[411] Yen, H. (2014, May 11). Fed govt failed to inspect higher risk oil wells. *Associated Press*. Retrieved from http://bigstory.ap.org/article/fed-govt-failed-inspect-higher-risk-oil-wells

[412] Davies, R. J., Almond, S., Ward, R. S., Jackson, R. B., Adams, C., Worrall, F., . . . Whitehead, M. A. (2014). Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. *Marine and Petroleum Geology, 56*, 239-254. doi: 10.1016/j.marpetgeo.2014.03.001

[413] Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es405118y

[414] Gibbons, B. (2014, February 19). Woman wins case against Chesapeake Jaqueline Place of Terry Township to receive compensation for well contamination. *Thedailyreview.com*. Retrieved from http://thedailyreview.com/news/woman-wins-case-against-chesapeake-jaqueline-place-of-terry-township-to-receive-compensation-for-well-contamination-1.1636832

buildings.[415]

- January 10, 2014 – Duke University water tests revealed ongoing water contamination in Parker County, Texas, providing evidence that the EPA had prematurely ended its prior investigation into the water contamination.[416] A letter sent to the EPA from more than 200 environmental organizations called on the agency to re-open its investigation.[417]

- January 5, 2014 – An Associated Press investigation into drinking water contamination from fracking in four states—Pennsylvania, Ohio, West Virginia, and Texas—found many cases of confirmed water contamination and hundreds more complaints. The Associated Press noted that their analysis "casts doubt on industry view that it rarely happens."[418]

- December 24, 2013 – A report from the EPA Inspector General concluded that evidence of fracking-related water contamination in Parker County, Texas was sound and faulted the EPA for prematurely ending its investigation there, relying on faulty water testing data from the gas industry in doing so, and failure to intervene when affected residents' drinking water remained unsafe.[419] As reported by *Business Insider*, "The EPA Screwed Up When It Dropped This Fracking Investigation."[420]

- December 16, 2013 – Lead by Susan Nagel of the University of Missouri School of Medicine, researchers documented endocrine-disrupting properties in chemicals commonly used as ingredients of fracking fluid and found similar endocrine-disrupting activity in groundwater and surface water samples collected near drilling and fracking sites in Garfield County, Colorado. Endocrine disruptors are chemicals that interfere with the activity of hormones in the body and, at very low concentrations, can raise the risk of reproductive, metabolic, and neurological disorders, especially when exposures occur in early life. [421, 422, 423]

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415 Tomasic, J. (2014, January 16). Colorado drilling data: More than a spill a day. *The Colorado Independent*. Retrieved from http://www.coloradoindependent.com/145629/colorado-drilling-data-more-than-a-spill-a-day
416 Drajem, M. (2014, January 9). Duke fracking tests reveal dangers driller's data missed. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2014-01-10/epa-s-reliance-on-driller-data-for-water-irks-homeowners.html
417 Drajem, M. (2014, January 27). EPA needs fracking review: 'Gasland' maker, environmentalists. *Bloomberg*. Retrieved from http://go.bloomberg.com/political-capital/2014-01-27/epa-needs-fracking-review-gasland-producer-environmentalists-say/.
418 Begos, K. (2014, January 05). 4 states confirm water pollution from drilling. *USA Today*. Retrieved from http://www.usatoday.com/story/money/business/2014/01/05/some-states-confirm-water-pollution-from-drilling/4328859/
419 Banjeree, N. (2013, December 24). EPA report on fracking in Texas raises new concerns. *Los Angeles Times*. Retrieved from http://www.latimes.com/nation/la-na-epa-fracking-20131225,0,6042944.story#ixzz2oVB9FXVY
420 Miedema, D. (2013, December 25). The EPA screwed up when it dropped this fracking investigation. *Business Insider*. Retrieved from http://www.businessinsider.com/epa-criticized-for-dropping-fracking-investigation-2013-12
421 Kassotis, C. D., Tillitt, D. E., Davis, J. W., Hormann, A. M., & Nagel, S. C. (2013). Estrogen and androgen receptor activities of hydraulic fracturing chemicals and surface and ground water in a drilling-dense region. *Endocrinology*. doi: 10.1210/en.2013-1697
422 Banerjee, N. (2013, December 16). Hormone-disrupting chemicals found in water at fracking sites. *Los Angeles Times*. Retrieved from http://articles.latimes.com/2013/dec/16/science/la-sci-fracking-health-20131217
423 Endocrine Society. (2013, December 16). Fracking chemicals disrupt hormone function. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2013/12/131216140428.htm

- December 7, 2013 – Reporting on the second gas leak at a single gas well in one month, the Fort Worth *Star-Telegram* uncovered another inherent risk of fracking for groundwater contamination: Silica sand, which is used as an ingredient in fracking fluid for its ability to prop open the shale fractures, can damage steel pipes as it flows back up the well along with the gas. According to Dan Hill, head of the petroleum engineering department at Texas A&M University, new wells are the most susceptible to sand erosion because "the amount of sand and gas rushing through valves and flow lines is at its greatest when a well first goes into production."[424]

- November 28, 2013 – An Associated Press investigation uncovered nearly 300 oil pipeline spills in North Dakota in the previous ten months, all with no public notification. These were among some 750 "oil field incidents" that had occurred in the state over the same time period, also without public notification. Until the AP inquiry, industry and state officials had kept quiet about one particular "massive spill" that had been accidentally discovered by a wheat farmer. Even small spills can contaminate water sources permanently and take cropland out of production.[425]

- November 26, 2013 – A USGS report found serious impacts of fracking on watersheds and water quality throughout the Appalachian Basin, as well as issues with radiation and seismic events. As noted in the report, the knowledge of how extraction affects water resources has not kept pace with the technology.[426, 427] Meanwhile, clean fresh water is becoming an increasingly scant resource. A report prepared for the U.S. State Department forecasts a serious freshwater shortage by 2030, with global demand exceeding supply by 40 percent.[428]

- November 22, 2013 – A USGS study of pollution from oil production in North Dakota, where horizontal drilling and hydraulic fracturing are heavily used, identified two potential plumes of groundwater contamination covering 12 square miles. The cause was traced to a casing failure in a wastewater disposal well. Drilling companies had incorrectly assumed that, once injected underground, the wastewater would remain contained. According to *EnergyWire*, the development of the Bakken oil formation is

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[424] Hirst, C., & Fuquay, J. (2013, December 7). Second leak reported at east Fort Worth gas well site. *Star-Telegram*. Retrieved from http://www.star-telegram.com/2013/12/07/5399740/second-leak-reported-at-east-fort.html?rh=1

[425] MacPherson, J. (2013, October 28). Nearly 300 pipeline spills in North Dakota have gone unreported to the public since January 2012. *Huffington Post*. Retrieved from http://www.huffingtonpost.com/2013/10/28/pipeline-spills-north-dakota_n_4170133.html?ncid=edlinkusaolp00000003

[426] Kappel, W. M., Williams, J. H., & Szabo, Z. (2013). Water resources and shale gas/oil production in the Appalachian Basin - Critical issues and evolving developments. *U.S. Geological Survey*. Retrieved from http://pubs.usgs.gov/of/2013/1137/pdf/ofr2013-1137.pdf

[427] Mall, A. (2013, November 26). New USGS analysis: Threats to water, wildlife, and health from oil and gas development in the Appalachian basin [Web log post]. Retrieved from http://switchboard.nrdc.org/blogs/amall/new_usgs_analysis.html

[428] National Intelligence Council. (2012, February 2). *Global Water Security: Intelligence Community Assessment,* (ICA 2012-08). Retrieved from http://www.dni.gov/files/documents/Special%20Report_ICA%20Global%20Water%20Security.pdf

"leaving behind an imprint on the land as distinct as the ones left by the receding ice sheets of the ice age."[429]

- September 10, 2013 – Pennsylvania Attorney General Kathleen Kane filed criminal charges against Exxon Mobil Corporation's subsidiary, XTO Energy Corporation, for a spill of 50,000 gallons of toxic drilling wastewater in 2010 that contaminated a spring and a tributary of the Susquehanna River. In July, XTO settled civil charges for the incident without admitting liability by agreeing to pay a $100,000 fine and improve its wastewater management.[430]

- September 10, 2013 – Out of concern for risks posed to drinking water in the nation's capital, George Hawkins, General Manager of DC Water, Washington, DC's local water provider, called for a prohibition on horizontal drilling and hydraulic fracturing in the George Washington National Forest until the process can be proven safe.[431] The Potomac River is the source of the District's water supply and has its headwaters in the George Washington National Forest, which sits atop the Marcellus Shale. The general managers of Fairfax Water, provider of drinking water for Fairfax County, Virginia, and the U.S. Army Corps of Engineers have called for a similar prohibition.[432]

- September 3, 2013 – The North Dakota Department of Mineral Resources voiced concern about an increasing number of fracking well blowouts (23 incidents in the past year) that result in spills and public safety threats.[433]

- August 28, 2013 – A joint USGS and U.S. Fish and Wildlife Service study documented a causal link between a fracking wastewater spill and the widespread death of fish in the Acorn Fork, a creek in Kentucky.[434]

- July 25, 2013 – A University of Texas at Arlington study of drinking water found elevated levels of arsenic and other heavy metals in some samples from private drinking

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429 Vaidyanathan, G. (2013, November 22). Bakken shale: As oil production sets in, pollution starts to migrate -- scientists. *E&E Publishing, LLC*. Retrieved from http://www.eenews.net/stories/1059990892

430 Maykuth, A. (2013, September 13). Shale criminal charges stun drilling industry. *Philly.com*. Retrieved from http://articles.philly.com/2013-09-13/news/42012429_1_xto-energy-inc-criminal-charges-attorney-general

431 Letter from George Hawkins, General Manager, DC Water, to U.S. Secretary of Agriculture, Thomas Vilsack, (Sept. 10, 2013), http://www.washingtoncitypaper.com/blogs/housingcomplex/2013/09/20/dc-water-chief-urges-agriculture-secretary-not-to-allow-fracking-near-d-c/

432 Wiener, A. (2013, September 20). DC Water Chief urges Agriculture Secretary not to allow fracking near D.C. *Washington City Paper*. Retrieved from http://www.washingtoncitypaper.com/blogs/housingcomplex/2013/09/20/dc-water-chief-urges-agriculture-secretary-not-to-allow-fracking-near-d-c/

433 Sun Staff. (2013, September 3). More blowouts a concern for N.D. *The Jamestown Sun*. Retrieved from http://www.jamestownsun.com/content/more-blowouts-concern-nd

434 Papoulias, D., & MacKenzie, T. (2013, August 28). Hydraulic fracturing fluids likely harmed threatened Kentucky fish species. *USGS Newsroom*. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=3677

water wells located within five kilometers of active natural gas wells in the Barnett Shale.[435]

- July 3, 2013 – *ProPublica* reported that the EPA was wrong to have halted its investigation of water contamination in Wyoming, Texas and Pennsylvania—where high levels of benzene, methane, arsenic, oil, methane, copper, vanadium, and other chemicals associated with fracking operations have been documented.[436] Although numerous organizations and health professionals around the country have since called on the agency to resume its investigation, no action has been taken.

- June 6, 2013 – Reviewing hundreds of regulatory and legal filings, *Bloomberg News* reported that drillers have offered out-of-court cash settlements and property buyouts to homeowners who claim that fracking ruined their water. These agreements typically come with gag orders and sealed records. This strategy, the investigation noted, allows the industry to continue claiming that no cases of water contamination due to fracking have ever been confirmed, impedes public health research, and shields data from regulators, policy makers, and the new media.[437] The EPA also long ago noted how non-disclosure agreements between oil and gas operators and landowners challenge scientific progress and keep examples of drilling harm secret from the public. In a 1987 report, the EPA wrote, "In some cases, even the records of well-publicized damage incidents are almost entirely unavailable for review. In addition to concealing the nature and size of any settlement entered into between the parties, impoundment curtails access to scientific and administrative documentation of the incident."[438]

- June 3, 2013 – A study by Duke University researchers linked fracking with elevated levels of methane, ethane, and propane in nearby groundwater.[439] Published in *Proceedings of the National Academy of Sciences*, the study included results from 141 northeastern Pennsylvania water wells. Methane levels were, on average, six times higher in drinking water wells closer to drilling sites when compared with those farther away, while ethane was 23 times higher.[440]

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[435] Fontenot, B. E., Hunt, L. R., Hildenbrand, Z. L., Carlton Jr., D. D., Oka, H., Walton, J. L., . . . Schug, K. A. (2013). An evaluation of water quality in private drinking water wells near natural gas extraction sites in the Barnett Shale formation. *Environmental Science & Technology, 47*(17), 10032-10040. doi: 10.1021/es4011724

[436] Lustgarten, A. (2013, July 3). EPA's abandoned Wyoming fracking study one retreat of many. *ProPublica*. Retrieved from http://www.propublica.org/article/epas-abandoned-wyoming-fracking-study-one-retreat-of-many

[437] Efstathiou, J., Jr., & Drajem, M. (2013, June 5). Drillers silence fracking claims with sealed settlements. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2013-06-06/drillers-silence-fracking-claims-with-sealed-settlements.html

[438] Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). 137-138. Washington, D.C.: U.S. Environmental Protection Agency.

[439] Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poreda, R. J., . . . Karr, J. D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the National Academy of Sciences*, *110*(28), 11250-11255. doi: 10.1073/pnas.1221635110

[440] CBS/AP. (2013, June 25). Methane found in Pa. drinking water near fracked wells. *CBS News*. Retrieved from http://www.cbsnews.com/news/methane-found-in-pa-drinking-water-near-fracked-wells/

- May 19, 2013 – In Pennsylvania, the *Scranton Times-Tribune* released details of an investigation that revealed at least 161 cases of water contamination from fracking between 2008 and the fall of 2012, according to state Department of Environmental Protection records.[441]

- April 2013 – Researchers analyzing publicly available Colorado data found 77 surface spills impacting groundwater in Weld County alone. Samples of these spills often exceeded drinking water maximum contaminant levels (MCLs) for benzene, toluene, ethylbenzene and xylene; for benzene, a known carcinogen, 90 percent of the samples exceeded the legal limit.[442]

- March 4, 2013 – Researchers at the University of Pittsburgh Graduate School of Public Health analyzed samples of gas drilling wastewater discharged to surface water through wastewater treatment plants. Barium, strontium, bromides, chlorides, and benzene all exceeded levels known to cause human health impacts.[443]

- December 9, 2012 – State data in Colorado showed more than 350 instances of groundwater contamination resulting from more than 2,000 spills from oil and gas operations over the past five years. Further, as the *Denver Post* reported, "Contamination of groundwater—along with air emissions, truck traffic and changed landscapes—has spurred public concerns about drilling along Colorado's Front Range."[444]

- May 4, 2012 – A report for the Canadian Government, released under the Access to Information Act, reviewed the process, the regulatory framework globally, and the potential health hazards related to shale gas extraction. Additionally, the report evaluated mechanisms for potential impacts and summarized the data knowledge and data gaps. Regarding water contamination, the report determined, "Although quantitative data are lacking, the qualitative data available indicate that potential contamination of water related to the shale gas industry may present hazard to the public health, especially for local population." Regarding air contamination: "air emissions related to the shale gas industry present health hazards since the air pollutants originating from the vehicles and engines fuelled by diesel are toxic to the respiratory and cardiovascular systems and can cause premature mortality, volatile organic compounds have been associated to neurotoxicity and some of these compounds (e.g. benzene) as well as NORMs are known or possible human carcinogens." The report concluded, "Any step of shale gas

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[441] Legere, L. (2013, May 19). Sunday Times review of DEP drilling records reveals water damage, murky testing methods. *The Times-Tribune*. Retrieved from http://thetimes-tribune.com/news/sunday-times-review-of-dep-drilling-records-reveals-water-damage-murky-testing-methods-1.1491547

[442] Gross, S. A., Avens, H. J., Banducci, A. M., Sahmel, J., Panko, J. M., & Tvermoes, B. E. (2013). Analysis of BTEX groundwater concentrations from surface spills associated with hydraulic fracturing operations. *Journal of the Air & Waste Management Association, 63*(4), 424-432. doi: 10.1080/10962247.2012.759166

[443] Ferrar, K. J., Michanowicz, D. R., Christen, C. L., Mulcahy, N., Malone, S. L., & Sharma, R. K. (2013). Assessment of effluent contaminants from three facilities discharging Marcellus shale wastewater to surface waters in Pennsylvania. *Environmental Science & Technology, 47*(7), 3472-3481. doi: 10.1021/es301411q

[444] Finley, B. (2012, December 9). Drilling spills reaching Colorado groundwater; state mulls test rules. *The Denver Post*. Retrieved from http://www.denverpost.com/environment/ci_22154751/drilling-spills-reaching-colorado-groundwater-state-mulls-test#ixzz2EihHU2fg

exploration/exploitation may represent a potential source of drinking water and air contamination; Hydraulic fracturing and wastewater disposal were identified as the main potential sources of risk."[445]

- May 2012 – A report by researchers at Natural Resources Defense Council and Carnegie Mellon University found that the options available for dealing with fracking wastewater are inadequate to protect public health and the environment, resulting in increasing quantities of toxic wastewater as an ongoing problem without a good solution.[446]

- January 11, 2012 – The USGS reported that the Marcellus Shale is already highly fractured and that numerous fissures naturally occurring within the formation could potentially provide pathways for contaminants to migrate vertically into water supplies.[447]

- October 25, 2011 – After receiving new information from two companies, members of Congress updated their findings to show that "between 2005 and 2009, oil and gas service companies injected 32.7 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 20 states."[448]

- October 17, 2011 – Thomas P. Jacobus, General Manager of the U.S. Army Corps of Engineers' Washington Aqueduct, called for a prohibition on horizontal hydraulic fracturing in the George Washington National Forest because of concern that fracking poses risks to drinking water. The Washington Aqueduct—which provides drinking water to Washington, DC, Arlington County, Virginia, and Falls Church, Virginia—is supplied by the Potomac River, which has its headwaters in the George Washington National Forest that sits atop the Marcellus Shale. Jacobus said, "Enough study on the technique [hydraulic fracturing] has been published to give us great cause for concern about the potential for degradation of the quality of our raw water supply…."[449]

- October 11, 2011 – Charles M. Murray, General Manager of Fairfax Water, called for a prohibition on horizontal hydraulic fracturing in the George Washington National Forest. "Natural gas development activities have the potential to impact the quantity and quality

[445] Louis, S. (2012, May 4). Potential health hazards from shale gas exploration and exploitation–Drinking water and ambient air. Presented to Health Canada by SANEXEN Environmental Services; 0/Ref.: RA11-410. Document released under the (Canadian) Access to Information Act.
[446] Hammer, R., & VanBriesen, J. (2012, May). *In fracking's wake: New rules are needed to protect our health and environment from contaminated wastewater* (Rep.). Natural Resources Defense Council. Retrieved from http://www.nrdc.org/energy/files/fracking-wastewater-fullreport.pdf
[447] U.S. Geological Survey, New York Water Science Center. (2012, January 11). *Comments on the revised draft supplemental generic environmental impact statement*. (Rep.). Retrieved from http://www.ewg.org/sites/default/files/report/ReviseddraftSGEIS_USGScomments_Version3_0.pdf
[448] Waxman, H. A., Markey, E. J., & DeGette, D. (2011, October 25). *Committee on Energy & Commerce* (U.S.A., Congress, Committee on Energy & Commerce). Retrieved from http://democrats.energycommerce.house.gov/index.php?q=news/reps-waxman-markey-and-degette-report-updated-hydraulic-fracturing-statistics-to-epa
[449] Jacobus, T. P. (2012, April 25). Draft environmental impact statement for the George Washington National Forest [Letter written October 17, 2011 to K. Landgraf]. Retrieved, from http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5366331.pdf

of Fairfax Water's source water," Murray wrote. "Downstream water users and consumers will bear the economic burden if drinking water sources are contaminated or the quality of our source water supply is degraded."[450] Fairfax Water provides drinking water for Fairfax County in Virginia.

- September 7, 2011 – In its draft Supplemental Generic Environmental Impact Statement (SGEIS), the New York State Department of Environmental Conservation (NYS DEC) acknowledged that "there is questionable available capacity"[451] for New York's public sewage treatment plants to accept drilling wastewater, yet the agency said that it would allow those facilities to accept such waste if the plants meet permitting conditions.[452] The NYS DEC proposed underground injection as one alternative to sewage treatment procession of fracking waste. Although it is a common method of disposal for fracking wastewater,[453] the last significant government study of pollution risks from oil and gas wastewater injection wells occurred in 1989 and found multiple cases of costly groundwater contamination.[454] In subsequent years, studies have continued to link underground injection of drilling wastewater to pollution as well as earthquakes.[455]

- September 2011 – A team led by Theo Colburn of the Endocrine Disruptor Exchange found that 25 percent of chemicals known to be used in fracking fluids are implicated in cancer, 37 percent could disrupt the endocrine system, and 40-50 percent could cause nervous, immune and cardiovascular system problems. The research team also found that more than 75 percent could affect the skin, eyes, and respiratory system, resulting in various problems such as skin and eye irritation or flu-like symptoms.[456]

- August 4, 2011 – As reported by the *New York Times,* the EPA had alerted Congress in 1987 about a case of water contamination caused by fracking. Its report documented that

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[450] Murray, C. M. (n.d.). Draft environmental impact statement for the George Washington National Forest [Letter written October 11, 2013 to K. Landgraf]. Retrieved from http://www.svnva.org/wp-content/uploads/fairfax-wash-aquaduct-gwnf-comments.pdf

[451] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-62, Rep.).

[452] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-57 through 6-63, Rep.).

[453] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-64, Rep.).

[454] United States Government Accountability Office. (1989, July 5). Drinking water: Safeguards are not preventing contamination from injected oil and gas wastes. Retrieved from http://www.gao.gov/products/RCED-89-97

[455] Fountain, H. (2012, January 1). Disposal halted at well after new quake in Ohio. *The New York Times*. Retrieved from http://www.nytimes.com/2012/01/02/science/earth/youngstown-injection-well-stays-shut-after-earthquake.html

[456] Colborn, T., Kwiatkowski, C., Schultz, K., & Bachran, M. (2011). Natural gas operations from a public health perspective. *Human and Ecological Risk Assessment: An International Journal, 17*(5), 1039-1056. doi: 10.1080/10807039.2011.605662

a shale gas well hydraulically fractured at a depth of more than 4,200 feet contaminated a water supply only 400 feet from the surface.[457, 458, 459]

- May 17, 2011 – The state of Pennsylvania fined Chesapeake Energy Corporation $900,000 for an incident in which improper cementing and casing in one of the company's gas wells allowed methane to migrate underground and contaminate 16 private drinking water wells in Bradford County.[460]

- May 17, 2011 – A Duke University study documented "systematic evidence for methane contamination of drinking water associated with shale gas extraction."[461] The study showed that methane levels were 17 times higher in water wells near drilling sites than in water wells in areas without active drilling.[462]

- April 22, 2011 – Describing one of many blowouts, the Associated Press reported on a shale gas well in Canton, Pennsylvania that spewed thousands of gallons of chemical-laced water on farmland and into a stream for two consecutive days before being brought under control.[463]

- April 18, 2011 – As part of a year-long investigation into hydraulic fracturing and its potential impact on water quality, U.S. Representatives Henry Waxman (D-Calif.), Edward Markey (D-Mass.) and Diana DeGette (D-Colo.) released the second of two reports issued in 2011. Their analysis of hydraulic fracturing fluids used by the 14 leading oil and natural gas service companies between 2005 and 2009 found, among other things, that the companies used more than 650 different products that contained chemicals that are known or possible human carcinogens, regulated under the Safe Drinking Water Act, or listed as hazardous air pollutants under the Clean Air Act. The report also showed that "between 2005 and 2009, the companies used 94 million gallons of 279 products that contained at least one chemical or component that the manufacturers deemed proprietary or a trade secret … in most cases the companies stated that they did not have access to proprietary information about products they purchased 'off the shelf' from chemical suppliers. In these cases, the companies are injecting fluids containing

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457 Urbina, I. (2011, August 4). A tainted water well, and concern there may be more. Retrieved from http://www.nytimes.com/2011/08/04/us/04natgas.html
458 U.S. Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). 4-22, 4-23. Retrieved from http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20012D4P.PDF
459 Horwitt, D. (2011, August 3). Cracks in the facade. *Environmental Working Group*. Retrieved from http://www.ewg.org/research/cracks-façade
460 Levy, M. (2011, May 18). DEP fines Chesapeake $1 million. *Pressconnects.com*. Retrieved from http://www.pressconnects.com/viewart/20110517/NEWS01/105170345/DEP-fines-Chesapeake-1-million
461 Osborn, S. G., Vengosh, A., Warner, N. R., & Jackson, R. B. (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proceedings of the National Academy of Sciences*, *108,* 8172-8176. doi: 10.1073/pnas.1100682108
462 Duke University. (2011). Methane levels 17 times higher in water wells near hydrofracking sites, study finds. *ScienceDaily*. Retrieved from http://www.sciencedaily.com/releases/2011/05/110509151234.htm
463 The Associated Press. (2011, April 22). Crews stop flow of drilling fluid from Pennsylvania well. *Syracuse.com*. Retrieved from http://www.syracuse.com/news/index.ssf/2011/04/crews_stop_flow_of_drilling_fl.html

chemicals that they themselves cannot identify."[464] These findings were reported in the *New York Times*.[465]

- January 2011 – A team of scientists led by a University of Central Arkansas researcher called attention to the threat posed to surface waters by rapidly expanding shale gas development, noting a lack of data collection accompanying the rush to drill. "Gas wells are often close to surface waters that could be impacted by elevated sediment runoff from pipelines and roads, alteration of stream flow as a result of water extraction, and contamination from introduced chemicals or the resulting wastewater."[466]

- January 31, 2011 – As part of a year-long investigation into hydraulic fracturing and its potential impact on water quality, U.S. Representatives Henry Waxman (D-Calif.), Edward Markey (D-Mass.) and Diana DeGette (D-Colo.) reported that "between 2005 and 2009, oil and gas service companies injected 32.2 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 19 states." Furthermore, revealing apparent widespread violation of the Safe Drinking Water Act, the investigation found that no oil and gas service companies had sought—and no state or federal regulators had issued—permits for the use of diesel fuel in hydraulic fracturing.[467]

- April 29, 2010 – In 2010, the Colorado Oil and Gas Conservation Commission fined Occidental Petroleum Corporation (OXY) USA a record $390,000 for an incident of pollution, discovered in 2008, when its drilling wastes leaked through an unlined pit, contaminated two springs with benzene, and polluted other nearby water sources. In addition, the regulators separately fined OXY USA $257,400 for a nearby case of pollution, also discovered in 2008, in which a torn liner in a pit caused drilling waste fluids to leak out and contaminate two springs with benzene.[468]

- June 5, 2009 – A leaking pipe carrying fracking waste in Washington County, Pennsylvania, polluted a tributary of Cross Creek Lake, killing fish, salamanders, crayfish, and aquatic insect life in approximately three-quarters of a mile of the stream.[469]

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[464] Waxman, H. A., Markey, E. J., & DeGette, D. (2011, April 18). Committee on Energy & Commerce (U.S.A., Congress, Committee on Energy & Commerce). Retrieved from http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic-Fracturing-Chemicals-2011-4-18.pdf

[465] Urbina, I. (2011, April 17). Chemicals were injected into wells, report says. *The New York Times*. Retrieved from http://www.nytimes.com/2011/04/17/science/earth/17gas.html

[466] Entrekin, S., Evans-White, M., Johnson, B., & Hagenbuch, E. (2011). Rapid expansion of natural gas development poses a threat to surface waters. *Frontiers in Ecology and the Environment, 9*(9), 503-511. doi: 10.1890/110053

[467] Waxman, H. A., Markey, E. J., & DeGette, D. (2011, January 31). *Committee on Energy & Commerce* (U.S.A., Congress, Committee on Energy & Commerce). Retrieved from http://democrats.energycommerce.house.gov/index.php?q=news/waxman-markey-and-degette-investigation-finds-continued-use-of-diesel-in-hydraulic-fracturing-f

[468] Webb, D. (2010, April 29). Record fine, second one against Oxy approved. *Grand Junction Sentinel*. Retrieved from http://www.gjsentinel.com/news/articles/record-fine-second-one-against-oxy-approved

[469] Pittsburgh Post-Gazette. (2009, June 5). Waste from Marcellus shale drilling in Cross Creek Park kills fish. *Pittsburgh Post-Gazette*. Retrieved, from http://www.post-gazette.com/washington/2009/06/05/Waste-from-Marcellus-shale-drilling-in-Cross-Creek-Park-kills-fish/stories/200906050136

- April 26, 2009 – Officials in three states linked water contamination and methane leaks to gas drilling. Incidents included a case in Ohio where a house exploded after gas seeped into its water well and multiple cases of exploding drinking water wells in Dimock, Pennsylvania.[470]

- November 13, 2008 – *ProPublica* reported more than 1,000 cases of drilling-related contamination documented by courts and state and local governments in Colorado, New Mexico, Alabama, Ohio, and Pennsylvania.[471]

- December 15, 2007 – In Bainbridge, Ohio, a gas well that was improperly cemented and subsequently fractured by Ohio Valley Energy Systems Corporation allowed natural gas to migrate outside of the well, causing a home to explode. In addition, 23 nearby water wells were contaminated, two of which were located more than 2,300 feet from the drilling site.[472, 473, 474]

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[470] Lustgarten, A. (2009, April 26). Officials in three states pin water woes on gas drilling. *ProPublica*. Retrieved from http://www.propublica.org/article/officials-in-three-states-pin-water-woes-on-gas-drilling-426
[471] Lustgarten, A. (2008, November 13). Buried secrets: Is natural gas drilling endangering U.S. water supplies? *ProPublica*. Retrieved from http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113
[472] Ohio Department of Natural Resources Division of Mineral Resources Management. (2008, September 1). *Report on the investigation of the natural gas invasion of aquifers in Bainbridge Township of Geauga County, Ohio*. (Rep.). Retrieved from http://www.ohiodnr.com/mineral/bainbridge/tabid/20484/default.aspx
[473] Bair, E. S., Freeman, D. C., & Senko, J. M. (2010, June). *Expert panel technical report, subsurface gas invasion Bainbridge Township, Geauga County, Ohio* (Rep.). Retrieved from http://oilandgas.ohiodnr.gov/portals/oilgas/pdf/bainbridge/DMRM%200%20Title%20Page,%20Preface,%20Acknowledgements.pdf
[474] Ohio Department of Natural Resources, Order Number 2009-17 (Apr. 14, 2009) (see attachments A, B).

Inherent engineering problems that worsen with time

Studies show that many oil and gas wells leak, allowing for the migration of natural gas and potentially other substances into groundwater and/or the atmosphere. About five percent of wells leak immediately, 50 percent leak after 15 years, and 60 percent leak after 30 years. The act of fracking itself can redistribute stress and create underground pathways for fluid migration, which, in turn, can communicate with pathways caused by deterioration of cement in aging well casings, leading to both groundwater contamination and atmospheric emissions.

The problem of leaking wells, first identified by industry, has no known solution. Data from Pennsylvania's Department of Environmental Protection (DEP) agree, showing over nine percent of shale gas wells drilled in the state's northeastern counties leaking within the first five years. Leaks pose serious risks, including potential loss of life or property from explosions and migration of gas and other harmful chemicals into drinking water supplies. Methane leaking into aquifers can, under some conditions, be transformed by bacteria into hydrogen sulfide and other poisonous byproducts. Microbes from deep shale formations can likewise generate sulfides contributing, over time, to corrosion of pipes and casings.

There is no evidence to suggest that the problem of cement and well casing impairment is abating. Industry has no solution for rectifying the chronic problem of well casing/cement failures and resulting leakage. Plugging old, inactive wells is an imperfect solution because, as research shows, the cement plugs themselves degrade over time and because many wells leak from outside the well casing.

- April 19, 2018 – As part of a major review, a University of Aberdeen team of researchers assessed the various underground pathways by which fracking creates methane leaks and concluded that aging well casings are a leading cause of methane leaks from drilling and fracking operations. While the intersection of fracture propagation with naturally present geological faults in the subsurface is another potential route for methane leakage, the more important route is the intersection of fracture propagation with other wells with old cement. "The major sources of methane leakage related to shale gas activities are the intersections of hydraulic fractures with abandoned oil and gas wells which have a reduced mechanical well integrity due to cement degradation. As a result, the stress redistributions caused by hydraulic fracturing and the deterioration of cement in abandoned wells with age allow migration pathways to be created easily, leading to both groundwater contamination and atmospheric emissions." Plugging wells is an imperfect solution because the cement commonly used for this process itself degrades with time, especially in the presence of carbon dioxide. "No concrete method [has been] established for the methane leakage mitigation from shale gas wells."[475]

[475] Yudhowijoyo, A., Rafati, R., Haddad, A. S., Raja, M. S., & Hamidi, H. (2018). Subsurface methane leakage in unconventional shale gas reservoirs: A review of leakage pathways and current sealing techniques. *Journal of Natural Gas Science and Engineering, 54*, 309-319. doi: 10.1016/j.jngse.2018.04.013

- November 23, 2017 – An investigative journalist from *The Tyee* in Vancouver obtained a copy of a 2013 report from British Columbia's Oil and Gas Commission warning about hundreds of uncontrolled methane leaks from shale gas wells located in the northern Rocky Mountain range near Fort Nelson. The commission's report, never shared with the public or with elected officials, remained an internal document until it was uncovered by the newspaper. Cornell University engineer Anthony Ingraffea, quoted in the story, said the report's findings served as another confirmation that wells leak badly and inevitably over time. "What do they expect from underground operations such as these, total obedience to design intent? Why are operators and regulators around the world seemingly surprised when things go wrong underground, and in so many ways, and so often?" Ingraffea said.[476, 477]

- July 5, 2017 – A team of researchers led by microbiologists from Ohio State University investigated bacteria from hydraulically fractured shale by sampling fracking wastewater from a well drilled in the Utica shale. The dominant microrganism was a bacterium that generates sulfides, which can contribute to corrosion of well casings. "The impact of microbial metabolism within these environments is poorly understood. . . . These findings emphasize the potential detrimental effects that could arise from thiosulfate-reducing microorganisms in hydraulically fractured shales, which are undetected by current industry-wide corrosion diagnostics."[478]

- April 1, 2017 – The rapid depletion of fracked wells requires drilling ever more wells to keep up with production. As time goes by, wells become more densely packed into a drilling section. Decreasing distances between wells increases the risk of inter-well communication, which occurs when the pumping of fracking fluid into one well affects a nearby well. According to an analysis in the *Journal of Petroleum Technology*, these so called "frack hits" are unpredictable, uncontrolled, and can be violent, damaging tubing, casings, and well integrity. In some cases, frack hits involve blowouts of fracking fluid. The industry has no solution for this increasingly common problem.[479] Indeed, as a sequel report describes, operators use frack hits as a tool for revealing how tightly wells can be spaced in a drilling section to maximize extraction—even while acknowledging inherent safety risks. A drilling section with no frack hits at all is presumed to lack sufficient well density for optimal "economic recovery."[480]

- July 9, 2015 – As part of a larger examination of the potential health and environmental impacts of fracking in California, the California Council on Science and Technology

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[476] Nikiforuk, A. (2017, November 23). Despite what politicians say, hundreds of BC gas wells leak methane. *The Tyee.* Retrieved from https://thetyee.ca/News/2017/11/23/Hundreds-of-BC-Gas-Wells-Leak-Meth/

[477] BC Oil and Gas Commission. (2013, December). *Gas migration preliminary investigation report.* Retrieved from https://www.bcogc.ca/node/14620/download

[478] Booker, A. E., Borton, M. A., Daly, R. A., Welch, S. A., Nicora C. D., Hoyt, D. W., . . . Wilkins, M. J. (2017). Sulfide generation by dominant Halanaerobium microorganisms in hydraulically fractured shales. *mSphere, 2*(4), e00257-17. doi: 10.1128/mSphereDirect.00257-17

[479] Jacobs, T. (2017, April 1). Oil and gas producers find frac hits in shale wells a major challenge. *Journal of Petroleum Technology*. Retrieved from https://www.spe.org/en/jpt/jpt-article-detail/?art=2819

[480] Jacobs, T. (2017, November 1). Frac hits reveal well spacing may be too tight, completion volumes too large. *Journal of Petroleum Technology*. Retrieved from https://www.spe.org/en/jpt/jpt-article-detail/?art=3510

(CCST) documented cases of well failures triggered by underground movements that caused well casings to shear. Sheared well casings can allow gas and fluids from the fracking zone to migrate to overlying aquifers. The CCST team identified several mechanisms by which casing shears can occur in California as oil wells age: surface subsidence, heaving, reservoir compaction, and earthquakes. Prolonged drought can also damage the integrity of well casings: as groundwater levels fall, landforms can sink and contribute to casing shear.[481]

- June 30, 2015 – According to the New York State Department of Environmental Conservation (NYS DEC) Findings Statement, "there is a risk that well integrity can fail, especially over time, and questions have arisen about whether high-volume hydraulic fracturing can cause seismic changes which could potentially result in fracturing fluid migration through abandoned wells or existing fissures and faults. Thus, high-volume hydraulic fracturing could result in significant adverse impacts to water resources from well construction and fracturing fluid migration."[482]

- June 4, 2015 – As part of a draft assessment of fracking's impact on drinking water, the U.S. Environmental Protection Agency (EPA) examined cases of water contamination across the United States and concluded that "construction issues, sustained casing pressure, and the presence of natural faults and fractures can work together to create pathways for fluids to migrate toward drinking water resources." Fracking older wells poses additional risks, the draft study notes, because aging itself "can contribute to casing degradation, which can be accelerated by exposure to corrosive chemicals, such as hydrogen sulfide, carbonic acid, and brines" and because many older wells were never designed to withstand the high pressures and stress of fracking operations. The EPA estimates that 6 percent of the 23,000 U.S. oil and gas wells (= 1,380 wells) first fracked in 2009 or 2010 were drilled more than ten years earlier.[483]

- December 2, 2014 – Problems with structural integrity have been documented in a well at the only hydraulically fractured site in the United Kingdom. Email messages obtained under freedom of information laws reveal that problems with wellbore integrity emerged in April of 2014 and attempts were made to remediate the problem, although nothing was reported at that time to regulators. The drilling company, Cuadrilla Resources, continues to deny that any problems exist with the well, emphasizing that "no leak of fluids" occurred and that "the issue" was resolved during the abandonment process. Cuadrilla

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[481] Stringfellow, W. T., Cooley H., Varadharajan, C., Heberger, M., Reagan, M. T., Domen, J.K., Sandelin, W. … Houseworth, J. E. (2015, July 9). Volume II, Chapter 2: Impacts of well stimulation on water resources. In: *An Independent Scientific Assessment of Well Stimulation in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from http://ccst.us/publications/2015/vol-II-chapter-2.pdf

[482] New York State Department of Environmental Conservation. (2015, June 30). *Final supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program: Regulatory program for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permeability gas reservoirs, findings statement.* Retrieved from http://www.dec.ny.gov/docs/materials_minerals_pdf/findingstatehvhf62015.pdf

[483] U.S. Environmental Protection Agency (2015, June 30). *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources*, executive summary (draft). Retrieved from http://www2.epa.gov/sites/production/files/2015-06/documents/hf_es_erd_jun2015.pdf

had previously been reprimanded for failing to disclose a more minor deformation in the well casing. The well was abandoned at the end of last year, following two earthquakes in 2011, which scientists determined to have been caused by fracking at the site.[484]

- August 11, 2014 – Researchers affiliated with multiple universities and with the Los Alamos National Laboratory summarized recent field observations of wellbore-integrity failure, concluding that, because at least some well failures are not identified, reported barrier failure rates of 1-10 percent of wells and reported rates of groundwater contamination of 0.01-0.1 percent of wells constitute a "lower bound" for possible environmental problems. Citing hydraulic fracturing, as well as temperature and pressure changes, as operations that can induce pathways for leaks, the authors point out that few studies have considered the very-long-term fate (">50 years") of wellbore systems. They include "whether unconventional resource development alters the frequency of well integrity failures" as a critical topic for future research.[485]

- July 30, 2014 – Based on records obtained from Pennsylvania's DEP, Scranton's *Times-Tribune* reported that five natural gas wells in Bradford County have leaked methane for years because of persistent casing and cement problems. In the most recent violation, a PA-DEP inspector found combustible gas flowing through vents connected to the cement between layers of pipe. The agency issued a notice of violation for each well, saying combustible gas outside the well's surface casing violates state regulations. Each of the wells has four layers of steel casing, but nothing prevents leaking (stray) methane from flowing into the atmosphere. No evidence of water contamination has yet been seen. None of the wells have produced any gas for sale.[486]

- June 30, 2014 – A study published in *Proceedings of the National Academy of Sciences* by a Cornell University research team projected that over 40 percent of shale gas wells in Northeastern Pennsylvania will leak methane into groundwater or the atmosphere over time. Analyzing more than 75,000 state inspections of more than 41,000 oil and gas wells in Pennsylvania since 2000, the researchers identified high occurrences of casing and cement impairments inside and outside the wells. A comparative analysis showed that newer, unconventional (horizontally fracked) shale gas wells were leaking at six times the rate of conventional (vertical) wells drilled over the same time period. The leak rate for unconventional wells drilled after 2009 was at least six percent, and rising with time. In the state's northeastern counties between 2000 and 2012, over nine percent of shale gas wells drilled leaked within the first five years.[487] The study also discovered that over

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[484] Bryant, B. (2014, December 2). The only fracked site in the United Kingdom suffered structural failure. *Vice News*. Retrieved from https://news.vice.com/article/the-only-fracking-site-in-the-united-kingdom-suffered-structural-failure

[485] Jackson R. B., Vengosh, A., Carey, J. W., Davies, R. J., Darrah, T. H., O'Sullivan, F., & Pétron, G. (2014). The environmental costs and benefits of fracking. *Annual Review of Environment and Resources, 39,* 327–62. doi: 10.1146/annurev-environ-031113-144051

[486] Gibbons, B. (2014, July 30). Five gas wells leaked methane for years. *Times-Tribune*. Retrieved from http://thetimes-tribune.com/news/five-gas-wells-leaked-methane-for-years-1.1727537

[487] Ingraffea, A., Wells, M., Santoro, R., & Shonkoff, S. (2014). Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000–2012. *Proceedings of the National Academy of Sciences*. Retrieved from http://www.pnas.org/content/early/2014/06/25/1323422111.abstract

8,000 oil and gas wells drilled since 2000 had not received a facility-level inspection. This study helps explain the results of earlier studies that documented elevated levels of methane in drinking water aquifers located near drilling and fracking operations in Pennsylvania and points to compromised structural integrity of well casings and cement as a possible mechanism.

- May 22, 2014 – In a 69-page report, University of Waterloo researchers warned that natural gas seeping from 500,000 wellbores in Canada represents "a threat to environment and public safety" due to groundwater contamination, greenhouse gas emissions, and explosion risks wherever methane collects in unvented buildings and spaces. The report found that 10 percent of all active and suspended gas wells in British Columbia now leak methane. Additionally, the report found that some hydraulically fractured shale gas wells in that province have become "super methane emitters" that spew as much as 2,000 kilograms of methane a year.[488, 489]

- May 1, 2014 – Following a comprehensive review of evidence, the Council of Canadian Academies identified inherent problems with well integrity as one of its top concerns about unconventional drilling and fracking. According to one expert panel, "the greatest threat to groundwater is gas leakage from wells from which even existing best practices cannot assure long-term prevention."[490] Regarding their concerns related to well integrity and cement issues, the panel wrote:

  > Two issues of particular concern to panel members are water resources, especially groundwater, and GHG emissions. Both related to well integrity…. Natural gas leakage from improperly formed, damaged, or deteriorated cement seals is a long-recognized yet unresolved problem …. Leaky wells due to improperly placed cement seals, damage from repeated fracturing treatments, or cement deterioration over time, have the potential to create pathways for contamination of groundwater resources and to increase GHG emissions.

  They further explain:

  > Cement may crack, shrink, or become deformed over time, thereby reducing the tightness of the seal around the well and allowing the fluids and gases … to escape into the annulus between casing and rock and thus to the surface…. The challenge of ensuring a tight cement seal [will] be greater for shale gas wells that are subjected to repeated pulses of high pressure during the hydraulic fracturing process than for conventional gas wells. This pressure stresses the casing and therefore the cement that isolates the well from surrounding formations

488 Dusseault, M. B., Jackson, R. E., & MacDonald, D. (2014, May 22). Towards a road map for mitigating the rates and occurrences of long-term wellbore leakage. Geofirma Engineering, Ltd. Retrieved from http://geofirma.com/wp-content/uploads/2015/05/lwp-final-report_compressed.pdf
489 Nikiforuk, A. (2014, June 5). Canada's 500,000 leaky energy wells: 'Threat to public' *The Tyee*. Retrieved from http://www.thetyee.ca/News/2014/06/05/Canada-Leaky-Energy-Wells/
490 Council of Canadian Academies. (2014, May 1). *Environmental Impacts of Shale Gas Extraction in Canada: the Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction.* Retrieved from http://bit.ly/1nNicuf

repeatedly.

- January 8, 2013 – According to state inspections of all 6,000 wells drilled in Pennsylvania's Marcellus Shale before 2013, six to ten percent of them leaked natural gas, with the rate of leakage increasing over time. The rate was six percent in 2010 (97 well failures out of 1,609 wells drilled); 7.1 percent in 2011 (140 well failures out of 1,972 wells drilled); and 8.9 percent in 2012 (120 well failures out of 1,346 wells drilled).[491] These data include wells that were cited for leakage violations, and wells that were noted to be leaking by inspectors but which had not been given violations. The NYS DEC forecasts that 50,000 wells could be drilled over the life of the Marcellus Shale play. If they fail at the same rate as wells in Pennsylvania, 4,000 wells would fail and leak in New York almost immediately.[492]

- March 2009 – A study published by the Society of Petroleum Engineers of more than 315,000 oil, gas, and injection wells in Alberta, Canada, found that 4.5 percent of the wells had unintended gas flow to the surface. In one designated area, officials required testing for gas migration outside the well casings in addition to routine testing for gas leaks within the rings of steel casings (annuli). Within this special testing zone, 15.5 percent of wells (3,205 of 20,725) leaked gas, and the incidence of gas leaks was four times percent higher in horizontal or deviated wells than in vertical wells.[493]

- Autumn 2003 – Schlumberger, one of the world's largest companies specializing in hydraulic fracturing and other oilfield services, reported in its in-house publication, *Oilfield Review*, that more than 40 percent of approximately 15,500 wells in the outer continental shelf area in the Gulf of Mexico were leaking gas. These included actively producing wells, in addition to shut-in and temporarily abandoned wells. In many cases, the gas leaked through the spaces (annuli) between layers of steel casing that drilling companies had injected with cement precisely to prevent such gas leaks. Leakage rates increased dramatically with age: about five percent of the wells leaked immediately; 50 percent were leaking after 15 years; and 60 percent were leaking after about 30 years.[494] Gas leaks pose serious risks including loss of life from explosions and migration of gas and associated contaminants into drinking water supplies. Leaks also allow the venting of raw methane into the atmosphere where it acts as a powerful greenhouse gas.

- November 2000 – Maurice Dusseault, a specialist in rock mechanics at the University of

[491] Ingraffea, A. R. (2013). Some scientific failings within high volume hydraulic fracturing proposed regulations. Retrieved from http://www.psehealthyenergy.org/data/NYS_DEC_Proposed_REGS_comments_Ingraffea_Jan_2013.pdf

[492] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (2-1, Rep.).

[493] Watson, T. L., & Bachu, S. (2009). Evaluation of the potential for gas and CO2 leakage along wellbores, Society of Petroleum Engineers. *SPE Drilling & Completion*, *24,* 115-126. doi: 10.21.18/106817-PA

[494] Brufatto, C. (2003). From mud to cement - Building gas wells. *Oilfield Review, 15*(3). Retrieved from http://www.slb.com/resources/publications/industry_articles/oilfield_review/2003/or2003aut06_building_gas_wells.aspx

Waterloo in Ontario, and two co-authors presented a paper published by the Society of Petroleum Engineers, in which they reported that oil and natural gas wells routinely leak gas through cracks in their cement casings, likely caused by cement shrinkage over time and exacerbated by upward pressure from natural gas. According to their paper, in Alberta, it is common for wells to leak natural gas into aquifers. "Because of the nature of the mechanism, the problem is unlikely to attenuate," they wrote, "and the concentration of the gases in the shallow aquifers will increase with time."[495]

[495] Dusseault, M. B., Gray, M. N., & Nawrocki, P. A. (2000). Why oil wells leak: Cement behavior and long-term consequences. *Society of Petroleum Engineers*. Retrieved from http://www.hydrorelief.org/frackdata/references/65704543-Casing-Leaks.pdf

Radioactive releases

Exemptions from federal hazardous waste laws mean that no national regulatory framework exists for handling the radioactive materials in solid and liquid fracking waste. Instead, regulation is the responsibility of individual states, which vary widely in their approaches. High levels of radiation documented in fracking wastewater from many shale formations raise special concerns in terms of impacts to groundwater and surface water. Measurements of radium in fracking wastewater in New York and Pennsylvania, from the particularly radioactive Marcellus Shale, have been as high as 3,600 times the regulatory limit for drinking water, as established by the U.S. Environmental Protection Agency (EPA). Studies have found toxic levels of radiation in Pennsylvania waterways even after fracking wastewater was disposed of through an industrial wastewater treatment plant.

A study found high levels of radon in buildings located in heavily drilled areas of Pennsylvania, with levels of radon rising since the start of the fracking boom. Unsafe levels of radon and its decay products in natural gas produced from the Marcellus Shale may also contaminate pipelines and compressor stations, as well as pose risks to end-users when allowed to travel into homes. Increasing evidence documents illegal, haphazard dumping of radioactive fracking waste, along with its disposal in municipal landfills not engineered to contain radioactivity. Drill cuttings—the pulverized rock pulled up during the drilling process—are a special concern as this form of solid waste, generated in prodigious amounts, is typically disposed of in municipal landfills lacking special protections for hazardous waste. Radioactivity in drill cuttings has been shown to exceed, in some cases, the regulatory limits for landfills that accept fracking waste. New research suggests that the chemical composition of fracking fluid itself helps to mobilize radioactive materials in the shale.

- March 15, 2019 – Due to a 1980 hazardous waste exemption from the Resource Conservation and Recovery Act (RCRA), drill cuttings from oil and gas fields became exempt from federal oversight, leaving it to states to regulate the disposal of this solid waste stream. A team of researchers measured radioactivity in drill cuttings extracted from Pennsylvania wells and found levels of radium-226 and radium-228 that exceeded the regulatory limits for landfills in Ohio and New York, two states where there are regulatory limits and that accept fracking waste from other states, including from Pennsylvania. The authors recommended rescinding the RCRA exemption for hazardous fracking waste to better protect public health.[496]
- August 3, 2018 – A two-part study by Dartmouth College researchers investigated the source of radium in fracking wastewater from Marcellus Shale wells. By comparing the isotopic ratios, they showed that the high salinity of the wastewater is responsible for extracting radium from the shale. "Experimental results and wastewater data together provide a coherent picture, that the distinctive Ra isotopic signature of Marcellus wastewaters results from contemporaneous water-rock interactions that promote

[496] Swiedler, E. W., Muehlenbachs, L. A., Chu, Z., Shih, J.-S., & Krupnick, A. (2019). Should solid waste from shale gas development be regulated as hazardous waste? *Energy Policy, 129*, 1020-1033. doi: 10.1016/j.enpol.2019.02.016

desorption of ^{226}Ra from organics during hydraulic fracturing."[497] In the second part of the study, the researchers used mass balance and isotope mixing models to attribute both the extreme salinity and the presence of radium in liquid fracking waste to the progressive, hydrologic enrichment of injected fluids during hydraulic fracturing.[498] In sum, the chemical composition of fracking fluid itself and its interactions with black shale during the fracking process combine to make fracking waste radioactive. Explaining these findings in a news article, co-author Makul Sharam said, "Radium is sitting on mineral and organic surfaces within the fracking site waiting to be dislodged. When water with the right salinity comes by, it takes it on the radioactivity and transports it."[499]

- February 19, 2018 – A study conducted in the Bakken Shale region of North Dakota used a multivariate regression model to predict radium-226 levels in fracking wastewater based on levels of other elements (barium, strontium, calcium). Their simulation model gave results that align with the extremely limited actual data based on direct measurements of radionuclides in Bakken Shale wastewater. The research team then used their model to predict potential harm to human health based on spills into surface water that is issued as a source of drinking water, irrigation, and recreational fishing. Even in the best-case scenario, using simulated concentrations on the low end, the results indicated that "there is potential risk to human health" in North Dakota due to radium-226 in fracking wastewater spills. This model can be used for any area where oil and gas waste is produced. "Overall, the results presented in this study can be treated as a warning and a reference to conduct further investigations."[500]

- February 6, 2018 – A research team from City University of New York School of Public Health and Health Policy surveyed the various state-based regulations and state licensing requirements governing the disposal of radioactive waste from oil and gas waste streams. They found that 17 states had drafted express regulations to reduce exposure to radiation from oil and gas waste. States with active oil and gas drilling that lack such regulations "may leave the public and workers susceptible to adverse health effects from radiation." Among the authors' policy recommendations: due to accumulation of radioactivity on equipment, future studies should explore impacts on workers; exposed workers should wear badges to monitor exposures; worker exposures should be limited by shift changes; regulations across states should be harmonized to prevent cross-state dumping of large

[497] Landis, J. D., Sharma, M., Renock, D., & Niu, D. (2018). Rapid desorption of radium isotopes from black shale during hydraulic fracturing. 1. Source phases that control the release of Ra from Marcellus Shale. *Chemical Geology, 496*, 1-13. doi: 10.1016/j.chemgeo.2018.06.013
[498] Landis, J. D., Sharma, M., & Renock, D. (2018). Rapid desorption of radium isotopes from black shale during hydraulic fracturing. 2. A model reconciling radium extraction with Marcellus wastewater production. *Chemical Geology, 500*, 194-206. doi: 10.1016/j.chemgeo.2018.08.001
[499] Dartmouth College. (2018, September 18). How slick water and black shale in fracking combine to produce radioactive waste. *Science Daily.* Retrieved from https://www.sciencedaily.com/releases/2018/09/180918154831.htm
[500] Torres, L., Yadav, O. P., & Khan, E. (2018). Risk assessment of human exposure to Ra-226 in oil produced water from the Bakken Shale. *Science of the Total Environment, 626,* 867-874. doi: 10.1016/j.scitotenv.2018.01.171

amounts of radioactive solid waste and assure protection of the public from the risk of radiation from exposure to oil and gas drilling wastes.[501]

- January 4, 2018 – A research team from Duke and Pennsylvania State universities collected stream sediments upstream and downstream from three disposal sites in Pennsylvania that receive oil and gas wastewater, treat it, and release it into surface water. While the practice of treating and dumping liquid waste from fracking operations into Pennsylvania streams largely ended in 2011, these three facilities continue to treat and release waste from conventional drilling operations. The researchers consistently detected elevated radioactivity in stream sediments in the vicinity of the outfall compared to upstream areas. The ratios of radium isotopes to their decay products showed that some of the radium had accumulated in the sediments in recent years—after discharges of fracking waste had been halted. Hence, radioactivity from conventionally drilled wells is the likely source of the high levels of radium in sediments downstream from these three treatment plants. Consequently, policies that prohibit disposal only of fracking waste fluids "are not adequate in preventing radioactive contamination in sediments at disposal sites." Permission to treat and release any type of oil and gas wastewater via centralized waste treatment facilities "should be reconsidered."[502]

- September 22, 2017 – State health regulators confirmed that unknown quantities of radioactive waste from drilling and fracking operations have been illegally buried in Colorado landfills not permitted to accept it.[503]

- November 23, 2016 – University of Iowa researchers evaluated radioactive materials—uranium, thorium, radium, lead, and polonium isotopes—from drill cutting samples extracted from a single well drilled in northern Pennsylvania. They found complex patterns of vertical stratification. For example, the deep drill cuttings had significantly more uranium (U) than the cuttings removed from shallow portions of the well. Noting that virtually all drill cutting waste from the Marcellus Shale is deposited in landfills, the authors examined the stability of the various radioactive materials by simulating different conditions of landfill leaching. The results suggested some environmental mobility of radionuclides in drill cuttings. In particular, as acidity increased, radionuclide leaching increased, with ^{238}U and ^{234}U being the most leachable radionuclides. The authors concluded, "Although previous studies have suggested that [radioactive materials] in drill cuttings pose a minimal health risk to the general public when deposited in landfills, our

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501 Geltman, E. A. G., & LeClair, N. (2018). Variance in state protection from exposure to NORM and TENORM wastes generated during unconventional oil and gas operations: Where we are and where we need to go. *New Solutions, 28*(2), 240-261. doi: 10.1177/1048291118755387

502 Lauer, N. E., Warner, N. R., & Vengosh, A. (2018). Sources of radium accumulation in stream sediments near disposal sites in Pennsylvania: Implications for disposal of conventional oil and gas wastewater. *Environmental Science & Technology, 52,* 955-962. doi: 10.1021/acs.est.7b04952

503 Finley, B. (2017, September 22). Colorado landfills are illegally burying low-level radioactive waste from oil and gas industry, Denver Post learns. *Denver Post.* Retrieved from https://www.denverpost.com/2017/09/22/colorado-landfills-illegally-burying-radioactive-waste-oil-gas/

results indicate that Marcellus Shale drill cuttings warrant further radiochemical investigation."[504]

- April 27, 2016 – Duke University researchers who studied oil and gas wastewater ("brine") spills reported that "the water contamination from brine spills is remarkably persistent in the environment, resulting in elevated levels of salts and trace elements that can be preserved in spill sites for at least months to years .…" In addition, radioactivity was elevated in soil and sediment sampled at spill sites, indicating that radium had accumulated in the soils of spill-affected areas.[505] The bigger the spill, the higher the soil radioactivity level. Study author Avner Vengosh told *InsideClimate News*, "We found even if you take away the spill water… you still left behind the legacy of radioactivity in the soils," where it can linger for thousands of years.[506]

- March 10, 2016 – Louisville's *Courier-Journal* reported on illegal dumping of radioactive oil and gas drilling wastes in two Kentucky landfills. Landfill operators in Greenup and Estill counties were issued violation notices for failing to "accurately characterize the waste for what it was, allowing what's considered an illegal release of a hazardous material into the environment." The illegal dumping at the Greenup County landfill alone consisted of 369 tons of radioactive drilling waste.[507]

- February 26, 2016 – Radioactive oil and gas waste from fracking operations in Ohio, Pennsylvania, and West Virginia was illegally sent to Estill County, Kentucky's Blue Ridge Landfill. The radioactive level of the material that was buried "was at least 340 times more than the amount that is allowed to be buried at a solid waste landfill," according to WKYT in Lexington. WKYT reported that Estill County leaders would "fight 'tooth and toenail' to get the bottom of how low-level radioactive waste ended up in a county landfill," and do its own testing at the landfill and nearby schools.[508]

- November 23, 2015 – Absence of federal oversight and, in some cases, a total lack of state regulations for handling radioactive oil and gas waste was the topic of a report in *High Country News*, which detailed the regulatory situation in six Western states: Colorado, Idaho, Montana, North Dakota, South Dakota, and Wyoming. North Dakota alone generates an estimated 70 tons a day of radioactive oil and gas waste. "Because the waste is often too radioactive to be disposed of in landfills, it sometimes gets dumped

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[504] Eitrheim, E. S., May, D., Forbes, T. Z., & Nelson, A. W. (2016). Disequilibrium of naturally occurring radioactive materials (NORM) in drill cuttings from a horizontal drilling operation. *Environmental Science & Technology Letters 3*, 425-29. doi: 10.1021/acs.estlett.6b00439
[505] Lauer, N. E., Harkness, J. S., & Vengosh, A. (2016). Brine spills associated with unconventional oil development in North Dakota. *Environmental Science & Technology, 50*(10), 5389–5397. doi: 10.1021/acs.est.5b06349
[506] Hirji, Z. (2016, April 29). Persistent water and soil contamination found at N.D. wastewater spills. *InsideClimate News*. Retrieved from http://insideclimatenews.org/news/29042016/north-dakota-wastewater-spill-water-soil-contaminiation-radium-selenium-bakken-oil
[507] Bruggers, J. (2016, March 10). State begins crackdown on radioactive waste. *Courier-Journal.* Retrieved from http://www.courier-journal.com/story/tech/science/environment/2016/03/08/state-orders-end-hauling-radioactive-waste/81496490/
[508] *WKYT*. (2016, February, 26). Estill County leaders to fight 'tooth and toenail' over radioactive waste in landfill. WKYT. Retrieved from http://www.wkyt.com/content/news/Estill-Co-leaders-to-fight-tooth-and-toenail-over-radioactive-waste-in-landfill-370308981.html

illegally." Proposed new rules in North Dakota would raise the radioactivity limit for the waste.[509]

- July 8, 2015 – Radium-226 is the dominant radioactive material in flowback water from hydraulically fractured wells in the Marcellus Shale. A Pittsburgh team of researchers studied its fate in three wastewater storage pits in southwestern Pennsylvania over a 2.5-year period of time. They found that radium-226 concentrations increased when flowback water was being reused for additional fracking operations. Also, radium-226 tended to accumulate in the bottom sludge. This sludge could be classified as radioactive solid waste because it exceeded the radium-226 limit for landfill disposal. A risk assessment showed that potential radiation dose equivalent levels around the three fracking waste pits were within the regulatory limit for the general public.[510]

- April 9, 2015 – A Johns Hopkins Bloomberg School of Public Health study found that levels of radon in Pennsylvania homes—a region with some of the highest indoor radon concentrations in the US—have been rising since 2004, around the time the fracking industry arrived in the state.[511] Radon exposure is the second leading cause of lung cancer worldwide, after cigarette smoking.[512] Researchers found that buildings in counties where the most fracking has taken place in the past decade have had significantly higher radon readings compared with those in low-fracking areas, a difference that did not exist before 2004. Use of well water was associated with 21 percent higher indoor radon concentrations than in buildings using public water sources. This study, the first to define and evaluate the predictors of indoor radon concentrations in Pennsylvania, concluded that radon's presence was related to geology, water sources, weather, and natural gas drilling.[513]

- April 2, 2015 – A team of toxicologists, geochemists, and radiation scientists led by the University of Iowa analyzed the contribution of various naturally occurring radioactive materials (NORM) to the total radioactivity of fracking waste fluids, finding evidence of long-lived, environmentally persistent radioactive decay products.[514] "NORM is emerging as a contaminant of concern in hydraulic fracturing/unconventional drilling

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[509] Peterson, J. (2015, November 23). States lack rules for radioactive drilling waste disposal. *High Country News*. Retrieved from http://www.hcn.org/articles/states-lack-rules-for-handling-radioactive-drilling-waste

[510] Zhang, T., Hammock, R. W., & Vidic, R. D. (2015). Fate of radium in Marcellus Shale flowback water impoundments and assessment of associated health risks. *Environmental Science & Technology 49*, 9347-54. doi: 10.1021/acs.est.5b01393

[511] Casey, J. A., Ogburn, E. L., Rasmussen, S. G., Irving, J. K., Pollak, J., Locke, P. A., & Schwartz, B. S. (2015). Predictors of indoor radon concentrations in Pennsylvania, 1989-2013. *Environmental Health Perspectives*. Advance online publication. doi: 10.1289/ehp.

[512] National Cancer Institute (2011, December 6). *Radon and cancer fact sheet.* Retrieved from http://www.cancer.gov/about-cancer/causes-prevention/risk/substances/radon/radon-fact-sheet

[513] Hurdle, J., & Phillips, S. (2015, April 9). New study raises possible link between gas drilling and radon levels. *StateImpact Pennsylvania.* Retrieved from http://stateimpact.npr.org/pennsylvania/2015/04/09/new-study-raises-possible-link-between-gas-drilling-and-radon-levels/

[514] Nelson, A. W., Eitrheim, E. S., Knight, A. W., May, D., Mehrhoff, M. A., Shannon, R., . . . Schultz, M.K. (2015). Understanding the radioactive in growth and decay of naturally occurring radioactive materials in the environment: An analysis of produced fluids from the Marcellus Shale. *Environmental Health Perspectives, 123*(7). doi: 10.1289/ehp.1408855

wastes, yet the extent of the hazard is currently unknown." The study determined that previous testing and study methods likely underestimate radioactivity by focusing only on radium. The researchers developed a new method to accurately predict the concentrations of uranium, thorium, and radium and their alpha-emitting progeny, polonium and lead, in fracking wastewater. They found that, under certain conditions, radioactivity increased over time, due to ingrowth of alpha-emitting radioactive progeny of long-lived parent radionuclides such as radium. The authors warned that these decay products may potentially contaminate recreational, agricultural, and residential areas, and that a more detailed understanding is needed of how radionuclides accumulate in higher organisms. In an accompanying article in *Environmental Health Perspectives*, James Burch, a University of South Carolina epidemiologist who was not involved in the study, said that fracking activities and wastewater disposal, which often take place in close proximity to where people live and work, raise risks for human exposure. "The technology is vastly outpacing what we know about the health effects."[515]

- May 8, 2014 – A group of leading medical experts and the American Lung Association of the Northeast detailed research and growing concerns about potential health impacts of radon and radium associated with natural gas production and the Marcellus Shale, in particular. High levels of radiation in the Marcellus Shale could pose health threats if high concentrations of radon and its decay products travel with natural gas, a problem compounded by the short distance Marcellus gas could travel in pipelines to people's homes.[516]

- March 24, 2014 – A team led by toxicology researchers at the University of Iowa identified high levels of radioactivity in fracking wastewater as a significant concern and noted that the testing methods used and recommended by state regulators in the Marcellus Shale region can dramatically underestimate the amount of radioactivity—specifically radium—in fracking wastewater.[517] Results obtained using EPA-recommended protocols can be obscured by the presence of other contaminant mixtures. Regarding the use of EPA protocols with fracking wastewater or other highly saline solutions, Duke University geochemist Avner Vengosh noted, "People have to know that this EPA method is not updated."[518]

- February 2014 – The Marcellus Shale is known to have high uranium and radium content. According to Mark Engle, USGS geochemist, the concentration of radium-226 can exceed 10,000 picoCuries/Liter (pCi/L) in the shale. Radium-226 has a half-life of

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[515] Konkel, L. (2015). What's NORMal for fracking? Estimating total radioactivity for produced fluids. *Environmental Health Perspectives, 123*(7). Retrieved from http://ehp.niehs.nih.gov/123-a186/

[516] Campbell, J. (2014, May 8). Fracking critics keep pushing for state-backed health study. *Politics on the Hudson*. Retrieved from http://polhudson.lohudblogs.com/2014/05/08/fracking-critics-keep-pushing-state-backed-health-study/

[517] Nelson, A. W., May, D., Knight, A. W., Eitrheim, E. S., Mehrhoff, M., Shannon, R., . . . Schultz, M. K. (2014). Matrix complications in the determination of radium levels in hydraulic fracturing flowback water from Marcellus shale. *Environmental Science & Technology, 1*(3), 204-208. doi: 10.1021/ez5000379

[518] Kelly, S. (2014, March 24). Research shows some test methods miss 99 percent of radium in fracking waste. *Desmogblog.com*. Retrieved from http://www.desmogblog.com/2014/03/23/some-testing-methods-can-miss-99-percent-radium-fracking-waste-new-research-reports

1,600 years. Radium and other naturally occurring radioactive materials (NORM) can be released from shale rock during drilling and fracking and can emerge with flowback and produced waters. It can thus enter the ambient environment and become concentrated in the sludge that results from treatment of flowback water, and in river sediment around water treatment facilities. It can also be found in landfills in which sludge and sediment have been disposed. Some radium can be found in drinking water. Geochemist Avner Vengosh warned, "Once you have a release of fracking fluid into the environment, you end up with a radioactive legacy."[519]

- October 2, 2013 – A peer-reviewed study of the impacts of drilling wastewater treated and discharged into a creek by a wastewater facility in western Pennsylvania documented radium levels approximately 200 times greater in sediment samples near the discharge location than in sediment samples collected upstream of the plant or elsewhere in western Pennsylvania. "The absolute levels that we found are much higher than what you allow in the U.S. for any place to dump radioactive material," one of the authors told *Bloomberg News.* The pollution occurred despite the fact that the treatment plant removed a substantial amount of the radium from the drilling wastewater before discharging it. The researchers wrote that the accumulation of radium in sludge removed from the wastewater "could pose significant exposure risks if not properly managed."[520, 521]

- February 2013 – In an analysis of fracking sludge samples from Pennsylvania, researchers "… confirmed the presence of alpha, beta, and gamma radiation in the soil and water in reserve pits located on agricultural land." Total beta radiation exceeded regulatory guideline values by more than 800 percent, and elevated levels of some of the radioactive constituents remained in a vacated pit that had been drained and leveled. It is imperative, the research team concluded, "that we obtain better knowledge of the quantity of radioactive material and the specific radioisotopes being brought to the earth's surface from these mining processes."[522]

- July 26, 2012 – Responding to concern about radon in natural gas produced from the Marcellus Shale, the USGS analyzed ten samples of gas collected near the wellheads of three Pennsylvania gas wells. The agency found radon levels ranging from 1-79 picocuries per liter, with an average of 36 and a median of 32. (The highest radon activity reported here would decay to 19.8 pCi/L in approximately a week; by comparison, the EPA's threshold for indoor air remediation is 4 pCi/L.) Asserting they knew of no

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[519] Brown V. J. (2014). Radionuclides in fracking wastewater. *Environmental Health Perspectives 122*(2), A50-A55. doi: 10.1289/ehp.122-A50
[520] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of shale gas wastewater disposal on water quality in Western Pennsylvania. *Environmental Science & Technology, 47*(20), 11849-11857. doi: 10.1021/es402165b
[521] Efstathiou, J., Jr. (2013, October 2). Radiation in Pennsylvania creek seen as legacy of fracking. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2013-10-02/radiation-in-pennsylvania-creek-seen-as-legacy-of-frackin.html
[522] Rich, A. L., & Crosby, E. C. (2013). Analysis of reserve pit sludge from unconventional natural gas hydraulic fracturing and drilling operations for the presence of technologically enhanced naturally occurring radioactive material (TENORM). *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 117-135. doi: 10.2190/NS.23.1.h

previous published measurements of radon in natural gas from the Appalachian Basin, which contains the Marcellus Shale, agency scientists concluded that the number of samples "is too small to … yield statistically valid results" and urged "collection and interpretation of additional data."[523]

- January 11, 2012 – In its review of the New York State Department of Environmental Conservation's (NYS DEC) Supplemental Generic Environmental Impact Statement (SGEIS) on high volume fracturing, the EPA expressed concerns about the diffusion of responsibility for the ultimate disposal of radioactive wastes generated by treatment or pretreatment of drilling wastewater. The EPA also raised concerns about the lack of analysis of radon and other radiation exposure. "Who is responsible for addressing the potential health and safety issues and associated monitoring related to external radiation and the inhalation of radon and its decay products?" the EPA asked. "Such potential concerns need to be addressed."[524]

- September 7, 2011 – The USGS reported that radium levels in wastewater from oil and gas wells in New York and Pennsylvania, including those in the Marcellus Shale, "have a distinctly higher median … than reported for other formations in the Appalachian Basin, and range to higher values than reported in other basins." The median level of radium found in Marcellus Shale wastewater in New York, 5,490 pCi/L, is almost 1,100 times the maximum contaminant level for drinking water, which is five pCi/L. In other words, if a million gallons of Marcellus Shale wastewater contaminated with the median level of radium found in New York were to spill into a waterway, 1.1 billion gallons of water would be required to dilute the radium to the maximum legal level.[525] (The EPA's health-based goal for radium in drinking water is zero.) Over time, radium naturally decays into radioactive radon gas. Thus, higher radium levels also suggest that higher levels of radon may also be present in natural gas produced from the Marcellus Shale.

- February 27, 2011 – The *New York Times* reported on the threat to New York's drinking water from Pennsylvania drilling waste due to the presence of chemical contaminants, including high levels of radioactivity. The investigation found that sewage treatment plants were neither testing for nor capable of removing that radioactivity, which was subsequently discharged into waterways that supply drinking water, and that, in some cases, wastewater contained radium levels that were hundreds of times higher than the drinking water standard. Drillers sent some of this waste to New York State for disposal even though, as the article noted, EPA scientists had warned the state about this very

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[523] Rowan, E. L., & Kraemer, T. F. (2012). *Radon - 222 content of natural gas samples from upper and middle Devonian sandstone and shale reservoirs in Pennsylvania: Preliminary data*. United States Geological Survey. (Rep.). Retrieved from http://pubs.usgs.gov/of/2012/1159/ofr2012-1159.pdf

[524] Environmental Protection Agency. (2012, January 11). *EPA comments on revised draft NYSDEC revised dSGEIS for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* [Press release]. Retrieved from http://www.epa.gov/region2/newsevents/pdf/EPA%20R2%20Comments%20Revised%20dSGEIS%20Enclosure.pdf

[525] Rowan, E. L., Engle, M. A., Kirby, C. S., & Kraemer, T. F. (2011, September 7). *Radium content of oil- and gas-field produced waters in the northern Appalachian basin (USA): Summary and discussion of data*. (Rep United States Geological Survey. Retrieved from http://pubs.usgs.gov/sir/2011/5135/ http://water.epa.gov/drink/contaminants/basicinformation/radionuclides.cfm

problem in a December 2009 letter that advised against sewage treatment plants accepting drilling waste with radium levels 12 or more times as high as the drinking water standard.[526]

- 2008-2009 – The New York State DEC found that wastewater from 11 of 13 vertical wells drilled in New York's Marcellus Shale in 2008 and 2009 contained radium levels ranging from 400 times to nearly 3,400 times EPA's safe levellimit for radium in drinking water. These figures later informed the 2011 study of radium in drilling wastewater conducted by the USGS.[527]

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[526] Urbina, I. (2011, February 26). Regulation lax as gas wells' tainted water hits rivers. *The New York Times*. Retrieved from http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=all&_r=0

[527] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (5-133, 5-141, 7-60, Appendix 12, Appendix 13, Rep.).

Occupational health and safety hazards

Drilling and fracking jobs are among the most dangerous jobs in the nation with a fatality rate that is four to seven times the national average. Irregularities in reporting practices mean that counts of on-the-job fatalities among oil and gas workers are likely underestimates. Contract workers are especially at risk. Occupational hazards include head injuries, traffic accidents, blunt trauma, burns, inhalation of hydrocarbon vapors, toxic chemical exposures, heat exhaustion, dehydration, and sleep deprivation. An investigation of occupational exposures found high levels of benzene in the urine of wellpad workers, especially those in close proximity to flowback fluid coming up from wells following fracturing activities. Exposure to silica dust, which is definitively linked to silicosis and lung cancer, was singled out by the National Institute for Occupational Safety and Health (NIOSH) as a particular threat to workers in fracking operations where silica sand is used. At the same time, research shows that many gas field workers, despite these serious occupational hazards, are uninsured or underinsured and lack access to basic medical care.

In 2018, the first independent investigation of its kind showed that pipeline construction workers die on the job 3.6 times more often than the average U.S. worker. Pipeline worker deaths occur from crushings, fires, and heat exhaustion. The number of miles of U.S. pipelines tripled from 2006 to 2016, and newer pipelines are less safe than older ones. Pipelines built after 2010 suffer higher failure rates than pipelines built at any other time.

- February 19, 2019 – An investigation into the death of oil worker Dennis Mason by *E&E News* shows how inhalation of toxic vapors is systematically overlooked as a possible cause of workplace mortality and “indicates that more than four years after worker safety officials started warning of the lethal dangers of inhaling petroleum gases, the danger is still ignored in some corners of the oil patch.”[528] NIOSH has linked at least 13 oil worker deaths to inhalation of petroleum gases, such as butane and propane. However, because medical examiners do not always test for the substances, and attribute the deaths to “natural causes,” there are likely more. In this case, The Occupational Safety and Health Administration (OSHA) investigators immediately suspected that Dennis Mason was killed by toxic vapors and sent information and materials to the responsible Oklahoma state medical examiner, but state officials said they did not receive them. These materials included a paper by an occupational medicine specialist describing how exposure to high concentrations of hydrocarbon gases and vapors in an oxygen-deficient atmosphere can result in sudden cardiac death among oil and gas extraction workers. Instead, the medical examiner tested only for illegal drugs and alcohol before attributing his death to natural causes.
- February 13, 2019 – A series of catastrophic explosions and fires at a gas-processing facility in Pascagoula, Mississippi shut the plant down for six months in June 2016. This facility receives raw gas from drilling operations and separates it into natural gas and hydrocarbon liquids, which are used to make petrochemicals. The U.S. Chemical Safety

[528] Soraghan, M. (2019, February 19). Missed connections leave questions in oil worker's death. *E&E News.* Retrieved from https://www.eenews.net/stories/1060121345

Board's final report identified "thermal fatigue" as the probable cause of the series of conditions leading to the explosions. A "major loss of containment" in a heat exchanger resulted in the release of methane, ethane, propane, and several other hydrocarbons, which subsequently ignited. The report's interactive 3D model showed that the heat exchanger used at the Enterprise Plant, as well as at over 500 other U.S. gas processing facilities, is innately vulnerable to thermal fatigue. The timing of the explosions at the Pascagoula Gas Plant, which occurred shortly before midnight, likely prevented injuries. According to the final report, had the event happened during the day, with many more workers present, the consequences could have been much worse. The report noted that many nearby residents chose to evacuate, and afterwards, a local community organization informed the Board that residents did not know how to respond to the explosions. "They felt uninformed and ill equipped to know if they were in harm's way." The final report's recommendations included the development of a "robust and engaged community alert network."[529]

- December 21, 2018 – In the decade between 2008 and 2017, 1,566 U.S. workers died from on-the-job injuries in the oil and gas drilling industry and related fields. These figures were derived from data collected by the U.S. Department of Labor's Bureau of Labor Statistics as part of a special investigative report that included participation by the *Texas Tribune*. In a slightly longer overlapping period, OSHA cited companies in the oil and gas extraction industry for 10,873 violations and investigated 552 accidents that had resulted in at least one worker death. Upstream drilling and fracking operations are exempt from safety rules that govern all downstream sectors of the oil and gas industry. Among these are rules that require refineries, petrochemical plants, and other high-hazard operations to adopt procedures to prevent fires, explosions, and chemical leaks. The investigation detailed a number of specific oil and gas industry deaths in Texas, highlighting the various preventative and regulatory failures associated with traumatic injury; exposure to toxic gases, including hydrogen sulfide; and blowout risk and fires.[530]

- October 11, 2018 – In addition to social isolation and the wide-ranging effects of job-related stress, the physical costs to wellpad workers are high, according to a qualitative study on oil workers' social, emotional, and psychological well-being. The study consisted of in-depth interviews with 14 oil industry workers in Alberta, Canada. Twelve were men and two were women. Thirteen of the fourteen workers were employed by third-party contractors. They included heavy-equipment operators, surveyors, health and safety specialists, environmentalists, biologists, wireline engineers, derrick hands, consultants, and drillers. All were rotational workers. Rotational work involves travel to various oil fields and working extended shift schedules, which typically involves 21 consecutive days of work followed by three days off. Most of the respondents said they experienced physical pain on a somewhat regular basis. These findings corroborate the results of other studies reviewed by the authors. "Rotational oil field workers are

[529] U.S. Chemical Safety Board. (2019, February 13). *Loss of containment, fires, and explosions at Enterprise Products Midstream Gas Plant.* Investigation Report No. 2016-02-I-MS. Retrieved from https://www.csb.gov/assets/1/6/final_case_study_-_enterprise.pdf
[530] Morris, J. (2018, December 21). Death in the oilfields. *Texas Tribune.* Retrieved from https://www.texastribune.org/2018/12/21/death-oilfields-fossil-fuel-boom-brings-mounting-risks/

vulnerable to personal, social, and economic stressors that may result in degraded wellbeing…. As we explored here, 'good jobs' in the patch come at a steep psychosocial and physical health cost to the labourers."[531]

- October 10, 2018 – The most "cohesive explanation yet" for one of the worst oil field accidents in U.S. history, the January 2018 Oklahoma well fire which killed five workers, came from a lawsuit based on dozens of depositions. OSHA had sought penalties but did not offer an explanation, and the U.S. Chemical Safety Board stated plans to issue a report over a year later. (See Emerging Trend 6 in the front matter of this report, regarding the findings of the final report.) The factors explained in the lawsuit included ignoring warnings about using a cheaper and lighter drilling mud, and a broken and locked door out of which the five workers may have been able to escape.[532] The operating company blamed contractors.[533] (See also entry below for August 16, 2018.)

- September 12, 2018 – In 2016, oil and gas pipeline construction workers died on the job 3.6 times more often than the average U.S. worker, as determined by the first independent investigation to compile and present fatality rates for those who build oil and gas pipelines in the United States. That same year oil and gas pipeline construction workers had the highest death rate and number of deaths for those employed in these jobs since 2012. "If we add the deaths of workers whose job it is to maintain and monitor the pipelines as they carry the fuels (pipeline transport), 2016 was the deadliest year for oil and gas pipeline workers since 2009."[534] Pipeline worker deaths occurred from crushings, fires, and heat exhaustion. The number of miles of U.S. pipelines carrying oil and other hazardous liquids tripled from 2006 to 2016, and newer pipelines are less safe than old ones. Pipelines built after 2010 suffer failures at a higher rate than pipelines built "at any time in the last century," with pipelines carrying natural gas over five times more disaster-prone. The author made available her complete methodology and references for the project, with a discussion of her methodology and other data sources, including strengths, weaknesses, and comparability. Her stated intention in building a first-of-its kind oil and gas pipeline fatality report was to be "as straightforward and replicable as possible."[535]

- August 20, 2018 – Nearly 1,000 workers have been killed in the ten years since hydraulic fracturing and horizontal drilling technologies rapidly expanded, although the current oil and gas worker fatality rate is down from its earlier high at seven times higher than across

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[531] Wright, A. C., & Griep, Y. (2019). Burning the midnight oil: Examining wellbeing and vulnerability in Alberta's oil patch. *The Extractive Industries and Society, 6,* 77–84. Advance online publication. doi: 10.1016/j.exis.2018.10.001
[532] Soraghan, M. (2018, October 10). Okla. company scrimped before deadly well fire. *E&E News.* Retrieved from https://www.eenews.net/stories/1060102139
[533] Soraghan, M. (2018, October 23). Well operator in fatal fire blames contractors. *E&E News.* Retrieved from https://www.eenews.net/stories/1060104019
[534] Juhasz, A. (2018, September 12). Death on the Dakota Access: An investigation into the deadly business of building oil and gas pipelines. *Pacific Standard.* Retrieved from https://psmag.com/magazine/death-on-the-dakota-access
[535] Juhasz, A. (2018, September 12). Methodology for calculating mortality rates. *Pacific Standard.* Retrieved from https://psmag.com/magazine/methodology-for-calculating-fatality-rates

all industries. Persistent fatality risk factors include the practice of manual tank gauging, vehicle crashes, and inexperienced workers.[536]

- August 16, 2018 – On January 22, 2018, five workers were killed during the drilling of a gas well in Pittsburg County, Oklahoma. While the drill pipe was being lifted, a mixture of mud and gas blew upwards out of the well, and the gas subsequently ignited and exploded. A "factual update" as part of the ongoing investigation by the U.S. Chemical Safety Board found that a piece of safety equipment designed to control the release of fluids from the well was unable to fully close on the day of the accident and that other safety corners had been cut.[537]

- April 29, 2018 – Improper or inadequate use of personal protective equipment was of highest concern in a survey of industry workers and regulators that was designed to find the frequency of "failure incidents" and near misses at wellhead sites. Workers and regulators also cited spills of flowback water due to equipment failure as a major concern, with regard to the welfare of both workers and the general public, as these spills "occur more frequently than any other scenario examined in this study."[538]

- April 26, 2018 – There were 63 deaths in oil and gas extraction in 2016, as reported in the 2018 edition of the AFL-CIO report, *Death on the Job, The Toll of Neglect.* The fatality rate for the overall mining sector, which includes oil and gas extraction, was 10.1 per 100,000 workers, nearly three times the national average. These 63 deaths in oil and gas accounted for 71 percent of the total number of fatal work injuries in the mining sector.[539]

- March 21, 2018 – The trade publication, *Industrial Safety & Hygiene News*, published a summary of January 2015 to February 2017 oil and gas extraction worker "incidents," which included 481 hospitalizations and 166 amputations. The article outlined the data gaps and limitations that make accurate tallies of severe injuries in upstream oil and gas operations hard to calculate:

    - State-run OSHA programs are not included in the count.
    - Reporting errors and underreporting are common. Based on workers compensation data, underreporting is estimated at 50 percent; self-reported incidents may lack crucial detail or information.
    - OSHA jurisdiction does not cover incidents that occur on public streets, highways, or during commuting.

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536 King, P. (2018, August 20). Even 1 death is too many. What does it take to get to 0? *E&E News.* Retrieved from https://www.eenews.net/stories/1060094701

537 U.S. Chemical Safety Board. (2018, August 16). CSB releases factual update on blowout and fire at Pryor Trust Gas Well in Pittsburg County, Oklahoma [Press release]. Retrieved from https://www.csb.gov/csb-releases-factual-update-on-blowout-and-fire-at-pryor-trust-gas-well-in-pittsburg-county-oklahoma-/

538 Abualfaraj, N., Gurian, P. L., & Olson, M. S. (2018). Frequency analysis of failure scenarios from shale gas development. *International Journal of Environmental Research and Public Health, 5*(5). pii: E885. doi: 10.3390/ijerph15050885

539 AFL-CIO. (2018). *Death on the job: The toll of neglect.* 27th Edition. Retrieved from https://aflcio.org/reports/death-job-toll-neglect-2018

- Trucking/hauling related incidents may be listed under other [National Association of Insurance Commissioners] codes.[540]

- December 6, 2017 – Two occupational fatalities and numerous injuries resulted from explosions and fires along oil and gas pipelines in Colorado in the time since two men were killed at home from such a blast in April 2016, according to a *Denver Post* investigation. One contract worker was killed and two others were injured in May while they "were changing 'dump lines' and 'one or more tanks exploded,' according to a report filed in [Colorado Oil and Gas Conservation Commission's] database." Another worker died of his burn injuries from a flash fire in November that broke out during work on a pipeline. "The COGCC did not receive a report on this incident… because the pipeline was a 'gathering line' outside the agency's regulatory purview." The investigation documented additional gaps in regulatory oversight and responses to deaths and injuries.[541]

- October 1, 2017 – An investigation by the *Toronto Star*, the *National Observer*, *Global News,* and four Canadian journalism schools reported on hydrogen sulphide (H_2S)-related health threats and incidents (including one occupational death) in Saskatchewan, and government and industry failure to prevent, warn, and respond to this threat. The more than 50 reporters involved "examined thousands of industry and government documents, analyzed terabytes of data and delved into dozens of freedom-of-information requests," documenting, for example, the existence of government data describing H_2S "hotspots" across the province, that were never released to the public despite agency deliberations. In addition, reporters wrote,

  > Ministry and industry met four times between 2012 and 2014 to plot strategy, including emergency planning zones, a public communications document, a code of practice and a licensing regime for high-risk, single-well batteries. Those plans were never adopted, a ministry statement confirms.

  An industry salesman was killed in 2014 while taking samples. A valve broke and the concentration of H_2S in the spewed fluids, according to the company, "was estimated at 40,000 parts per million, more than enough to bring near-instant death." The investigation found that four months after the death, "a secret ministry report listed 161 facilities 'that may be in violation of (the ministry's) sour gas emission control.'"[542]

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[540] Industrial Safety & Hygiene News (2018, March 21). Gaps in oil & gas extraction work fatalities and severe injury statistics. Retrieved from https://www.ishn.com/articles/108304-gaps-in-oil-gas-extraction-work-fatalities-and-severe-injury-statistics
[541] Finley, B. (2017, December 6). A dozen fires and explosions at Colorado oil and gas facilities in 8 months since fatal blast in Firestone. *Denver Post.* Retrieved from http://www.denverpost.com/2017/12/06/colorado-oil-gas-explosions-since-firestone-explosion/
[542] Cribb, R., Sonntag, P., Elliot, P. W., & McSheffrey, E. (2017, October 1). That rotten stench in the air? It's the smell of deadly gas and secrecy. *Thestar.com*. Retrieved from https://www.thestar.com/news/canada/2017/10/01/that-rotten-stench-in-the-air-its-the-smell-of-deadly-gas-and-secrecy.html

- August 24, 2017 – NIOSH's Fatalities in Oil and Gas Extraction (FOG) database identified 88 fatal incidents accounting for 101 fatalities, for the year 2014. In ten of the 88 incidents, more than one worker was fatally injured. The FOG database was established to collect detailed information about deaths related to U.S. oil and gas extraction. The report, which represents only a portion of the deaths that occurred in the industry due to the focus and limitations of the database, aims to provide a deeper understanding of the circumstances of the fatalities, such as the industry group the worker was employed by, and operations and types of activities occurring at the time of the fatal incident. The majority of fatalities in FOG, 45 percent, involved workers employed by servicing companies. These servicing company worker fatalities occurred throughout oil and gas extraction operations: completions (14 fatalities), production (11 fatalities), and well servicing, workover, or intervention (5 fatalities). The industry group responsible for the second highest number of fatalities was drilling companies, at 27 percent, with most of those deaths occurring during drilling operations (20 fatalities). FOG data for 2015-2016 data was not yet available.[543]

- May 30, 2017 – In a "rare, but not unprecedented" case, the U.S. Environmental Protection Agency (EPA) opened an investigation of air emissions from two North Dakota oil well sites where worker deaths occurred in 2012 and 2014. EPA requested information from both companies to determine Clean Air Act compliance on the day of the deaths. According to the *E&E News* report, it was not clear whether the agency was "looking at civil or criminal sanctions." Both workers, who were "flow testers," "assigned to regularly measure tank levels by hand," were found dead near tank hatches.[544] (No further information could be located on this investigation.)

- April 28, 2017 – Fatality rates for oil and gas extraction workers associated with falls increased two percent per year during 2003–2013, according to the Centers for Disease Control and Prevention's *Morbidity and Mortality Weekly Report.* These 63 fatal falls represented 15 percent of the fatal events among this group in the time period. The majority of those who were killed by falls worked for drilling contractors. In the vast majority of cases, "fall protection was required by regulation, but it was not used, was used improperly, or the equipment failed." Authors noted several limitations of their report, such as the lack of information on self-employed workers and lack of detail in some fatality reports.[545]

- April 26, 2017 – The 2017 edition of the AFL-CIO report, *Death on the Job: The Toll of Neglect,* which reported on the year 2015, showed that, although the number of deaths in the oil and gas extraction industries decreased compared to 2014 (89 compared to 144), employment in oil and gas extraction also decreased from 613,783 in 2014 to 533,184 in

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543 Ridl, S., Retzer, K., & Hill, R. (2017). *Oil and gas extraction worker fatalities 2014; NIOSH fatalities in oil and gas extraction (FOG) database.* Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH). Publication No. 2017-193.

544 Soraghan, M. (2017, May 30). EPA investigating emissions in tank deaths. *E&E News.* Retrieved from https://www.eenews.net/stories/1060055258

545 Mason, K. L., Retzer, K. D., Hill, R., & Lincoln, J. M. (2017). Occupational fatalities resulting from falls in the oil and gas extraction industry, United States, 2005–2014. *MMWR, 66*(16), 417–421. doi: http://dx.doi.org/10.15585/mmwr.mm6616a2

2015. The deaths in the oil and gas extraction industries "accounted for 74% of the fatal work injuries in the mining sector." Referring to the challenges of getting a firm handle on statistics in this industry, the report stated that, "[f]atality rate data for the oil and gas industry are limited, but available data during the past seven years show fatality rates in oil and gas extraction that are four to seven times the national fatality rate." Further, "[n]ot surprisingly, states with large amounts of oil and gas activity also have high job fatality rates." Citing the continuing problem of assigning cause of death in the case of possible inhalation of toxic fumes, the report stated, "[w]hile some deaths are appropriately classified as inhalation deaths, others can be labeled as cardiac arrhythmia or respiratory failure, without further investigation as to whether the health event was induced by acute chemical exposure." As in previous years, the report expressed concerns about the regulatory gaps in controlling a range of potentially fatal hazards in the industry.[546]

- February 1, 2017 – Caused by exposure to silica particles or dust, silicosis is a progressive, autoimmune disease that scars lung tissue and restricts the ability to breathe. Any level of exposure to respirable crystalline silica can trigger silicosis. A special report on the history of silicosis in the *Journal of Environmental Health* provided background on silicosis as a workplace threat in various industries and identified drilling and fracking operations as a source of contemporary exposure. The report predicts a future cluster of silicosis among well pad workers, noting that research has already identified "unacceptable levels" of silica dust in air samples collected at fracking operations and that workers are seldom offered appropriate respiratory equipment to prevent exposure. Fracking "has the potential for future clusters of silicosis cases to emerge."[547]

- February 1, 2017 – University of Tennessee Civil and Environmental Engineering faculty investigated the occupational inhalation risks from the emissions of chemical storage tanks in 60,644 fracking wells. They also analyzed the combined occupational inhalation risks caused by open flowback pits and the storage tanks. They used AERMOD, the air pollution dispersion modeling system developed by the American Meteorological Society and EPA, and inhalation risk assessment to determine potential acute non-cancer, chronic non-cancer, acute cancer, and chronic cancer risks. Their results showed the percentage of wells presenting these risks were 12.41, 0.11, 7.53, and 5.80, respectively. They also found that the storage tanks presented the majority of the cancer risks, and the non-cancer risks were associated primarily to the open pits. The known human carcinogen formaldehyde was "the dominant contributor" to both acute (4,267 wells) and chronic (3,470 wells) cancer risk. Authors also reported that volatile organic compound (VOC) emissions from nearby wells and other on-site sources means that the data used in their study "were lower than reported concentrations from field measurements where higher occupational inhalation risks for exposure may be expected." [548]

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[546] AFL-CIO. (2017). *Death on the job: The toll of neglect.* 26th Edition. Retrieved from https://aflcio.org/reports/death-job-toll-neglect-2017

[547] Quail, M. T. (2017). Overview of silica-related clusters in the United States: Will fracking operations become the next cluster? *Journal of Environmental Health, 79*(6), 20-27.

[548] Chen, H., & Carter, K. E. (2017). Modeling potential occupational inhalation exposures and associated risks of toxic organics from chemical storage tanks used in hydraulic fracturing using AERMOD. *Environmental Pollution, 224*, 300-309. doi: 10.1016/j.envpol.2017.02.008

- January 19, 2017 – A group of Canadian physicians published a report documenting ten intentional intoxications from the ingestion of fracking fluid. Each individual survived, which the authors attribute to "[r]apid case finding and diligent contact tracing." Their report, published in the *American Journal of Kidney Diseases,* focused on this appropriate response and treatment, but also described the "outbreak" challenge from a public health perspective and emphasized the need for prevention education and "requiring secure storage of these products." Though the professions or workplaces of the patients are not described, presumably they were oil and gas industry workers with easy access to fracking fluid.[549]

- September 25, 2016 – A four-chapter investigative series by the *Denver Post* explored in detail Colorado's 12-year record of an oil and gas worker dying, on average, every three months. The piece documented the obstacles present in even clarifying the occupational mortalities owing to the differing reporting practices of the Bureau of Labor Statistics, OSHA, and state officials. "Regulation is so disjointed that no one can even agree on the number of workers killed on the job." Investigating the details of the deaths through any available records, the *Post* described a "regulatory vacuum," as well as "little consequence" to the industry when deaths (or worksite violations) occur. Worker death circumstances examined in the piece included electrocutions, falls and collapsed structures, crushings by equipment, explosions, and a drowning in frack sand. The *Post* also identified five lawsuits over 15 years "in which workers alleged that they were punished for reporting injuries or safety hazards."[550]

- April 27, 2016 – According to the 2016 edition of the AFL-CIO report, *Death on the Job: The Toll of Neglect,* the fatality rate for workers in the oil and gas extraction industries is nearly five times the national average, and the states with prominent oil and gas industries are among the most dangerous states to work. In addition, the report emphasized, the industry has been exempted from some critical OSHA standards, including that for carcinogenic benzene. The report also emphasized the danger of silica dust exposure in hydraulic fracturing-related work and the significant delays in controlling workers' exposures in these operations. "Oil and gas extraction is subject to OSHA general industry and construction regulations, none of which are designed to address the particular safety and hazards in the oil and gas industry…. The escalating fatalities and injuries in the oil and gas extraction industry demand intensive and comprehensive intervention," the report stated.[551]

- April 21, 2016 – According to an updated report from the Bureau of Labor Statistics, fatal work injuries in oil and gas extraction industries in 2014 reached a new high of

[549] Collister, D., Duff, G., Palatnick, W., Komenda, P., Tangri, N., & Hingwala, J. (2017). A methanol intoxication outbreak from recreational ingestion of fracking fluid. *American Journal of Kidney Diseases, 69*(5), 696-700. doi: 10.1053/j.ajkd.2016.10.029
[550] Sangosti, R.J. (2016, September 25). Drilling through danger. *Denver Post.* Retrieved from http://extras.denverpost.com/oil-gas-deaths/index.html
[551] AFL-CIO. (2016). *Death on the job: The toll of neglect.* 25th Edition. Retrieved from http://www.aflcio.org/Issues/Job-Safety/Death-on-the-Job-Report

144.[552]

- February 29, 2016 – *Inside Energy's* report on high rates of hydrocarbon vapor poisoning among oilfield workers noted that an outdated reliance on manual measurements rather than automated monitoring contributes to ongoing toxic exposures of workers. Under federal oil and gas regulations, oil companies are effectively required to send workers "up on oil and gas tanks to manually measure crude oil, putting them at risk." The report explained that the Bureau of Land Management (BLM) allows just one kind of automated measurement. The method is expensive and uncommonly used: "there are only 1,500 in use, compared to more than 83,000 oil tanks on federal land. By being so inflexible, BLM's outdated rules make it very hard to use safer oil measuring devices while making manual oil tank measurement—which endangers workers—the most viable option for companies."[553]

- February 19, 2016 – The fatal injuries of a backhoe operator who struck and hit an unmarked, high-pressure gas line in July 2015 prompted an investigation by *StateImpact* in Pennsylvania. The news group noted that "there are no local, state or federal rules on how deep the lines should be buried underground, or even if they're buried at all. There are no standards for building and maintaining the lines. They don't have to be marked. And the operator of the line doesn't have to participate in PA One Call [a statewide communications system for preventing damage to underground facilities], which led to the fatality in Armstrong County."[554]

- January 15, 2016 – In a publication in Centers for Disease Control's *Mortality & Morbidity Weekly Report*, researchers urged local and state epidemiologists and medical examiners to not overlook hydrocarbon exposure as an underlying cause of death in gas and oil field workers. "Health and safety professionals need to recognize and act on nonfatal warning signs and symptoms, such as dizziness, confusion, immobility and collapse in oil and gas workers who might have been exposed to high concentrations of [hydrocarbon gas vapors] and to [oxygen]-deficient atmospheres." Only three of nine deaths that occurred between 2010 and 2015 in the oil and gas fields west of Appalachia were ruled by coroners to have resulted from exposure to gas vapors, although all nine had opened hatches of storage tanks and were exposed to hydrocarbon vapors and oxygen-deficient air.[555] The *Pittsburgh Post-Gazette* quoted emeritus professor at the University of Pittsburgh Bernard Goldstein saying, "Occupational health experts also

[552] U.S. Bureau of Labor Statistics. (2016, April 21). Revisions to the 2014 Census of Fatal Occupational Injuries (CFOI). Retrieved from http://www.bls.gov/iif/cfoi_revised14.htm
[553] Guerin, E. (2016, February 29). "Senseless exposures": How money and federal rules endanger oilfield workers. *Inside Energy*. Retrieved from http://insideenergy.org/2016/02/29/senseless-exposures-how-money-and-federal-rules-endanger-oilfield-workers/
[554] Phillips, S. (2016, February 19). Worker dies in pipeline accident, PUC steps up calls for reform. *StateImpact.* Retrieved from https://stateimpact.npr.org/pennsylvania/2016/02/19/worker-dies-in-pipeline-accident-puc-steps-up-calls-for-reform/
[555] Harrison, R. J., Retzer, K., Kosnett, M. J., Hodgson, M., Jordan, T., Ridl, S., & Kiefer, M. (2016). Sudden deaths among oil and gas extraction workers resulting from oxygen deficiency and inhalation of hydrocarbon gases and vapors — United States, January 2010–March 2015. *Morbity and Mortality Weekly Report, 65*(1), 6-9. Retrieved from http://www.cdc.gov/mmwr/volumes/65/wr/mm6501a2.htm

suspect that some deaths involving fires, falls, crashes and mishandling of equipment have resulted from faulty judgement or 'wooziness' associated with hydrocarbon vapor exposure … [b]ut that underlying factor rarely shows up in fatality reports."[556]

- December 14, 2015 – As reported in the *Guardian,* the suicide rate in the Canadian province of Alberta spiked by 30 percent spike in the first half of 2015, possibly linked to the boom-and-bust cycle of the fracking industry. At the time of reporting, 40,000 jobs had been lost in Alberta since the drop in oil prices in late 2014. Mental health professionals interviewed for the report included Edmonton social worker Leonard McEwan, who specializes in clinical crises intervention and whose patients include those directly or indirectly employed in the oil fields, noticed a sharp increase in suicides after the recent plunge in oil prices. As revealed in the investigative report, three in every four Alberta suicides are male and the vast majority are under 55. Gladys Blackmore, executive director of a mental health program that targets those employed in the industry, believes that young, male workers "living high-risk lifestyles, often in work camps, where they 'fly-in/fly-out' for up to 24 days at a time" are particularly vulnerable.[557]

- November 7, 2015 – The *Denver Post* reported on a "new federal database that was developed to more precisely capture the deadly nature of oil and gas extraction." For Colorado, the national Fatalities in Oil and Gas Extraction (FOG) database contained two additional oil and gas worker deaths for 2014 than did the Bureau of Labor Statistics. "'We knew from the Bureau of Labor Statistics data about the basics of what's killing workers,' said Kyla Retzer, an epidemiologist who led the effort to compile the FOG report. 'We just wanted to be more in-depth in finding out what were the types of operations and equipment were involved in these deaths.'"[558] (See entry for August 24, 2017 above for official report.)

- November 4, 2015 – San Antonio's *Express-News* Editorial Board called for specific actions to address Texas's status "a national leader in oil field deaths." The Board wrote that federal fines are too low and unchanged since 1991 and that there is no Level 1 trauma center south of San Antonio near the region's oil- and gas-producing counties.[559]

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[556] Litvak, A. (2016, January 25). Vapors linked to oxygen depletion present hazard for oil, gas workers. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/policy-powersource/2016/01/25/Vapors-linked-to-oxygen-depletion-present-hazard-for-oil-gas-workers/stories/201601220095

[557] Mouallem, O. (2015, December 14). The boom, the bust, the darkness: suicide rate soars in wake of Canada's oil crisis. *The Guardian*. Retrieved from https://www.theguardian.com/world/2015/dec/14/canada-oil-production-crisis-suicide-alberta?CMP=share_btn_fb

[558] Whaley, M. (2015, November 7). Colorado oil deaths greater in 2014 than previously calculated. *Denver Post.* Retrieved from http://www.denverpost.com/2015/11/07/colorado-oil-deaths-greater-in-2014-than-previously-calculated/

[559] *Express-News* Editorial Board. (2015, November 4). Take care of the state's oil, gas workers. *MySanAntonio.Com.* Retrieved from http://www.mysanantonio.com/opinion/editorials/article/Take-care-of-the-state-s-oil-gas-workers-6611077.php

- September 17, 2015 – The Bureau of Labor Statistic reported that the number of fatal work injuries in oil and gas extraction industries rose 27 percent between 2013 and 2014.[560]

- September 15, 2015 – E&E Publishing's *EnergyWire* reported on the potentially deadly risk of exposure to vapors from oil and gas field storage tanks, including deaths that were officially attributed to cardiac arrest, though inhalation of toxic gases and lack of oxygen played a role, as demonstrated in subsequent litigation. The reporter gave detail on the circumstances of several of the deaths, including that of a long-haul trucker who had heart disease and was diabetic, and whose death was classified as natural. "But he didn't suffer a heart attack that day, or a diabetic episode. Medical experts said he likely wouldn't have died outside the toxic atmosphere on the catwalk." A Denver cardiologist testified that "there was no other reason for him to have died that day."[561] (NIOSH has subsequently targeted outreach to medical examiners to improve their recognition of this hazard and potential cause of death; see above.)

- September 5, 2015 – In partnership with Rocky Mountain PBS I-News, *The Durango Herald* reported on the oil and gas industry's varied practices in their handling of silica sand with regard to worker protection. In 2012 the National Institute for Occupational Safety and Health issued an alert concerning workers at fracking sites being exposed to silica dust at levels that exceeded occupational exposure limits. Industry has resisted updates to the standards. The *Herald* report addressed technological and work practice controls to reduce exposure on the part of some companies. Still, authors wrote, silicosis "can hide for a decade before causing symptoms. No one knows how many oil and gas workers may have already been exposed."[562]

- June 29, 2015 – An investigation by the Center for Public Integrity (CPI) found that lung-damaging silica is not sufficiently regulated to prevent silicosis (which is incurable and has no effective treatment) or lung cancer in the workplace. Rules governing occupational exposure to silica dust are far outdated, and advocacy efforts to tighten them are four decades old. At particular risk, say the authors, are workers in oil and gas fields where silica sand is used in fracking operations. Citing research by NIOSH, the CPI team noted that nearly 80 percent of the air samples on the well pads were above the recommended exposure limit for silica dust.[563]

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[560] U.S. Department of Labor, Bureau of Labor Statistics (2015, September 17). *National census of fatal occupational injuries in 2014* (preliminary results). USDL-15-1789. Retrieved from http://www.bls.gov/news.release/pdf/cfoi.pdf

[561] Soraghan, B. (2015, September 14). SAFETY: How shale oil can kill. *E&E Publishing, LLC*. Retrieved from http://www.eenews.net/stories/1060024589

[562] Boiko-Weyrauch, A. (2015, September 5). Oil, gas industry responding to threat of worker lung disease. *Durango Herald.* Retrieved from http://www.durangoherald.com/article/20150905/NEWS02/150909741/Oil-gas-industry-responding-to-threat-of-worker-lung-disease-

[563] Morris, J., Hopkins, J. S., & Jameel, M. (2015, June 30). Unequal risk: Slow-motion tragedy for American workers. *The Center for Public Integrity.* Retrieved from http://www.publicintegrity.org/2015/06/29/17518/slow-motion-tragedy-american-workers

- June 15, 2015 – *EnergyWire* examined issues surrounding exposure to crystalline silica from frack sand mining, which is a health concern to those living near mines and to those working in the industry. Families living near industrial sand mining reported that their health has been compromised by sand mine development and are concerned that companies are not properly monitoring their extraction sites. The article noted that OSHA is working on a new exposure rule for workers that the agency estimates would save nearly 700 lives and prevent 1,600 new cases of silicosis annually. The oil and gas industry is fighting the rule because of the cost associated with complying with a more stringent permissible exposure limit. Crispin Pierce, public health researcher at the University of Wisconsin in Eau Claire, is in the midst of a three-pronged research project to look at the industry's air effects. Among other findings, his project's air monitors around sand plants have found consistently finding higher readings than the Wisconsin Department of Natural Resources' reported regional values.[564]

- June 15, 2015 – In an update, NIOSH noted that silicosis death rates are rising again, reversing an earlier, decade-long decline. In the list of job tasks with known high silica exposures, the update named hydraulic fracturing of gas and oil wells. These results are particularly concerning in light of earlier research showing significant under-detection of silicosis among deceased workers with known exposure to silica dust.[565]

- June 13, 2015 – Reporting on North Dakota's fracking boom, the Center for Investigative Reporting found that the major oil companies have largely written the rules governing their own accountability for accidents. Deeply entrenched corporate practices and weak federal oversight, according to the report, have led to high injury and death rates and a shift of assigned responsibility to others. Using data from U.S. and Canadian regulators, the journalists verified 74 on-the-job deaths among workers in Bakken Shale drilling and fracking operations since 2006. The actual number of deaths is likely higher than currently reported because federal regulators do not have a systematic way to record oil- and gas-related deaths, and OSHA does not include certain fatalities, including those of independent contractors. The report concluded that there was too little oversight from OSHA, that laws to protect workers were outdated, and that there was a culture of self-regulation by the industry.[566]

- May 29, 2015 – The Centers for Disease Control and Prevention published statistics on work-related fatalities during the fracking boom. The occupational fatality rate among U.S. oil and gas industry extraction workers between 2003 and 2013 remained an average of seven times higher than among U.S. workers in general (25.1 versus 3.7 deaths per 100,000 workers per year). Within this 11-year period, the industry doubled the size of its workforce and increased drilling rigs by 71 percent. The number of occupational deaths

[564] King, P. (2015, June 15). Frac sand towns question whether rules protect them against silica pollution. *EnergyWire*. Retrieved from http://www.eenews.net/stories/1060020192
[565] Mazurek, J. M., & Weissman, D. (2015, June 15). Silicosis update. *NIOSH Science Blog*. Retrieved from http://blogs.cdc.gov/niosh-science-blog/2015/06/15/silicosis-update/
[566] Gollan, J. (2015, June 13). In North Dakota's Bakken oil boom there will be blood. *Reveal; Center for Investigative Reporting.* Retrieved from https://www.revealnews.org/article/in-north-dakotas-bakken-oil-boom-there-will-be-blood/

increased 27.6 percent, with a total of 1,189 deaths, but it did not increase as much as the number of workers, resulting in an overall decrease in the fatality rate of 36.3 percent. Transportation accidents and contact with objects and equipment were the most frequent fatal events. Evidence suggests that the increased use of automated technologies on drilling rigs may be contributing to the decline in death rates.[567]

- April 22, 2015 – The AFL-CIO published data for job injuries, illnesses and deaths in a national and state-by-state profile of worker safety and health in the United States, presenting comparisons by state and industry. For the third year in a row, North Dakota had the highest on-the-job fatality rate in the nation: 14.9 deaths per 100,000 workers, a rate that is more than four times the national average, and which has more than doubled since 2007. The fatality rate in the mining and oil and gas extraction sector in North Dakota was 84.7 per 100,000, which is nearly seven times the national fatality rate of 12.4 per 100,000 in this industry.[568, 569]

- April 10, 2015 – In a study that was inclusive of fracking-based extraction but not specific to it, NIOSH researchers updated their investigation into the sudden deaths of nine oil and gas extraction workers found near hatches where hydrocarbons were stored. All nine victims died between 2010 and 2014 and were unobserved or working alone at the time of their deaths. The first report attributed the fatalities to "inhalation of volatile petroleum hydrocarbons."[570] The update noted that when workers open hatches on production tanks, a plume of hydrocarbon gases and vapors can be rapidly released due to high internal pressure. Exposure to high concentrations of these low-molecular-weight hydrocarbons creates asphyxiation and explosive hazards and can have narcotic effects, resulting in disorientation, dizziness, and light-headedness. The authors cited reports of other sudden deaths following butane and propane inhalation, exposure to which can induce irregular heartbeat, insufficient oxygen supply, and respiratory depression.[571] As reported by the *Denver Post*, most of the death certificates listed natural causes or heart failure as the cause likely because medical examiners can easily miss signs of toxic inhalation during a routine autopsy. The nomadic nature of the industry presents obstacles to proper training in tank handling techniques.[572] NIOSH issued

[567] Mason, K. L., Retzer, K. D., Hill, R., & Lincoln, J. M. (2015, May 29). Occupational fatalities during the oil and gas boom—United States, 2003-2013. *Morbidity and Mortality Weekly Report, 64,* 551-554. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6420a4.htm
[568] AFL-CIO Safety and Health Department, (2015, April 22). Death on the job: The toll of neglect. Retrieved from http://www.aflcio.org/Issues/Job-Safety/Death-on-the-Job-Report
[569] Kasperkevic, J. (2015, April 29). About 150 US workers are killed on the job every day – report. *Guardian.* Retrieved from http://www.theguardian.com/us-news/2015/apr/29/north-dakota-deadliest-state-workers-third-year-running
[570] NIOSH. (2015, March 15). Suspected inhalation fatalities involving workers during manual tank gauging, sampling, and fluid transfer operations on oil and gas well sites, 2010-2014. *CDC Workplace Safety & Health Topics*. Retrieved from http://www.cdc.gov/niosh/topics/fog/data.html#_ftn1
[571] King, B., Esswein, E., Retzer, K., Snawder, J., Ridl, S., Breitenstein, M. Alexander-Scott, M., & Hill, R. (2015, April 10*). NIOSH Science Blog*, Centers for Disease Control. Retrieved from http://blogs.cdc.gov/niosh-science-blog/2015/04/10/flowback-3/
[572] Whaley, M. (2015, May 18). Toxic vapors suspected in deaths of three Colorado oil and gas workers. *Denver Post.* Retrieved from http://www.denverpost.com/news/ci_28136543/colorado-oil-and-gas-workers-fell-victim-little

recommendations for worker protections, including respiratory protection training and engineering controls for remote gauging and venting.[573]

- February 15, 2015 – Burn injuries among North Dakota workers surged to more than 3,100 over the past five years as the area has become the epicenter of a massive drilling and fracking boom, as reported by the *Star Tribune*. Despite the flammability of Bakken crude oil and the danger of oil rig work, North Dakota has no burn centers, and burn victims must be transported out of state, typically to the Minneapolis-St. Paul area some 600 miles away. The article also covered the severe, debilitating, costly, and sometimes fatal aspects of these occupational injuries.[574]

- February 13, 2015 – NIOSH reported that while silicosis death rates declined between 2001 and 2010, silicosis deaths were still occurring among young persons aged 15 to 44 years old, indicating extremely high exposures to respirable silica dust. Among emerging new settings that put workers at risk for silicosis, the authors named oil and gas extraction industry workers.[575]

- January 14, 2015 – The *Charleston Gazette-Mail* reported that, due to an increase in workplace deaths that has accompanied the boom in natural gas drilling and production from the Marcellus Shale fields in Northern West Virginia, the Governor there has called for a study aimed at reversing that trend. "Between 2009 and 2013, as the industry boomed in the Marcellus region, 15 natural gas workers died on the job in West Virginia, according to the federal data. During the previous five-year period, from 2004 to 2008, three workers died in West Virginia's oil and gas industry, according to the [U.S. Bureau of Labor Statistics]."[576]

- January 12, 2015 – Oil and gas production employs less than one percent of the U.S. workforce, but in the past five years it has had more than ten percent of all workplace fatalities from fires and explosions. A review by *EnergyWire* of federal labor statistics last year found the industry had more deaths from fires and explosions than any other private industry. The only "industry" with more fire and explosion fatalities than oil and gas was firefighting, the report stated. These statistics are inclusive of deaths related to fracking operations but are not specific to them.[577]

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573 Associated Press. (2015, May 18). 9 oil well deaths lead to warning about inhaling chemicals. *Times-Call.* Retrieved from http://www.timescall.com/news/nationworldnews/ci_28138297/9-oil-well-deaths-lead-warning-about-inhaling

574 Rao, M. (2015, February 15). Twin Cities hospitals are front line in treating Bakken burn victims. StarTribune.com. Retrieved from http://www.startribune.com/lifestyle/health/291967611.htmlpage=all&prepage=1&c=y#continue

575 Bang, K. M., Mazurek, J. M., Wood, J. M., White, G. E., Hendricks, S. A., & Weston, A. (2015), Silicosis mortality trends and new exposures to respirable crystalline silica – United States, 2001-2010. *Morbidity and Mortality Weekly Report, 64*(05), 117-120. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6405a1.htm

576 Ward, K. (2015, January 14). Tomblin calls for study of increased deaths from gas-drilling boom. *Charleston Gazette*. Retrieved from https://www.wvgazettemail.com/news/politics/tomblin-calls-for-study-of-increased-deaths-from-gas-drilling/article_21d6342f-c5dd-54ee-bd91-534ece13373a.html

577 Soraghan, M. (2015, January 12). At least 16 drilling industry workers died in fires, explosions last year. *EnergyWire.* Retrieved from http://www.eenews.net/stories/1060011452

- December 26, 2014 – A report in the *Houston Chronicle* illustrated the difficulties oil and gas workers encounter when injured on the job. In one case a worker fell from a rig, injuring his head. Supervisors did not record the accident. After he became too ill to work, he was shifted to other jobs and soon after, sent home. His daughter filed a Worker's Compensation claim, which was denied for "late reporting, no knowledge of injury by employer and no medical reports." The article noted that oilfield injuries are generally undercounted nationally. These include injuries related to drilling and fracking operations as well as those linked to other techniques of extraction.[578]

- December 4, 2014 – Benzene, a naturally occurring component of crude oil and natural gas, is a known carcinogen, with no known threshold of safety. Although the American Petroleum Institute in 1948 stated that "the only absolutely safe concentration … is zero," the organization since then undertook an intensive campaign to combat strict exposure limits. An investigation by the Center for Public Integrity found that, "[f]or decades, the petrochemical industry spent millions on science seeking to minimize the dangers of benzene.… Taken together, the documents—put in context by interviews with dozens of lawyers, scientists, academics, regulators and industry representatives—depict a 'research strategy' built on dubious motives, close corporate oversight and painstaking public relations."[579]

- December, 2014 – In a report intended to inform employers and workers about the known hazards that result from hydraulic fracturing and flowback operations, OSHA noted that there is no publicly available worker injury, illness, or fatality data specific for fracking or flowback operations. At the same time, more workers are exposed to fracking- and flowback-related hazards due to the huge increase in the numbers of these operations over the past ten years. "In light of this, OSHA has determined that additional information concerning hydraulic fracturing and flowback operations hazards should be provided to educate and protect workers."[580]

- November 11, 2014 – University of Wisconsin toxicologist Crispin Pierce documented super-fine dust drifting from facilities that process silica sand for fracking operations. Pierce and his team detected silica dust in ambient air near frac sand operations at levels that exceed EPA air quality standards by a factor of four. Occupational exposure to respirable crystalline silica is linked in adult workers to silicosis, lung cancer, and pulmonary tuberculosis. Health threats to the general public from frac sand-related air pollution have not yet been studied directly. One of the first investigations of silica dust levels in the community environment, the Wisconsin study will appear next year in the

[578] Olsen, L. (2014, December 16). Many oilfield injuries go unreported. *Houston Chronicle.* Retrieved from http://www.houstonchronicle.com/news/houston-texas/houston/article/Many-oilfield-injuries-go-unreported-5980350.php
[579] Lombardi, K. (2014, December 4). Benzene and worker cancers: 'An American tragedy.' The Center for Public Integrity. Retrieved from http://www.publicintegrity.org/2014/12/04/16320/benzene-and-worker-cancers-american-tragedy
[580] U.S. Department of Labor, Occupational Safety and Health Administration. (2014). Hydraulic fracturing and flowback hazards other than respirable silica. OSHA 3763-12 2014.

Journal of Environmental Health.[581] (See entry for November 6, 2015 in Sand mining and processing.)

- November 11, 2014 – A high-pressure water line ruptured, killing one worker and seriously injuring two others during the hydraulic fracturing of an oil well in Weld County, Colorado.[582]

- October 6, 2014 – Toxicologist Peter Thorne, chair of University of Iowa's Department of Occupational and Environmental Health, warned the Winneshiek County Board of Supervisors about potential community impacts and cancer risks of silica exposure from sand used for fracking operations. Thorne's ongoing investigation, which involves air sampling, risk assessments, and inhalation toxicology studies, focuses on the public health hazards of mining, processing, and storing sand. His team has documented spikes in silica particulate matter related to the transport of the silica sand by rail. The study aims to determine if mining poses an "unacceptable exposure" to the public and quantify the level of risk. For silica-exposed workers, NIOSH continues to identify needed heath protections. Thorne noted, "Workers handling materials should be using respirators, but most are not."[583]

- September 25, 2014 – The Civil Society Institute's Boston Action Research, in cooperation with Environmental Working Group and Midwest Environmental Advocates, issued a report on the hazards of silica mining. The report noted that frac sand mining is expanding rapidly in the United States and poses a little-understood threat to public health, the environment, and local economies. Given the pace of the drilling and fracking boom, silica extraction could spread to a dozen other states with untapped or largely untapped sand deposits, including Illinois, Maine, Massachusetts, Michigan, Missouri, New York, North Carolina, South Carolina, Pennsylvania, Tennessee, Vermont, and Virginia. The *International Business Times* published a summary of the findings.[584, 585]

- August 29, 2014 – In a peer-reviewed study, NIOSH partnered with oil and gas operators and service companies to evaluate worker exposures to, and internal uptake of, volatile organic chemicals at six sites in Colorado and Wyoming where wells were being

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581 Kremer, R. (2014, November 11). High levels of super-fine dust are detected around Wisconsin frac sand mines. *Wisconsin Public Radio*. Retrieved from http://www.wpr.org/high-levels-super-fine-dust-are-detected-around-wisconsin-frac-sand-mines?utm_content=buffer8947f&utm_medium=social&utm_source=facebook.com&utm_campaign=buffer

582 Paul, J. (2014, November 11). Brighton man ID'd as victim in fatal Weld County fracking blast. *The Denver Post.* Retrieved from http://www.denverpost.com/news/ci_26937782/brighton-man-idd-victim-fatal-weld-county-fracking?source=pkg

583 Strandberg, S. (2014, October 6). U of I researcher informs supervisors about frac-sand impact. *Decorah Newspapers*. Retrieved from http://www.decorahnewspapers.com/Content/Home/Home/Article/U-of-I-researcher-informs-supervisors-about-frac-sand-impact/-2/-2/35735

584 Chapman, E., Hopkins, L., Jasset, A., Sheldon, S., & Smith, G. (2014, September 25). Communities at risk: Frac sand mining in the Upper Midwest–A report by Boston Action Research (a project of Civil Society Institute). Retrieved from http://216.30.191.148/fracsandmining/ and www.bit.ly/fracsandmining

585 Gallucci, M. (2014, September 25). US oil & gas fracking boom could drive silica sand mining operations in 12 more states, environmental groups say. *International Business Times.* Retrieved from http://www.ibtimes.com/us-oil-gas-fracking-boom-could-drive-silica-sand-mining-operations-12-more-states-1695246

prepared for production. The study found benzene in the urine of well pad workers. Benzene is "naturally present in flowback fluids and the time spent working around flowback and production tanks … appears to be the primary risk factor for inhalation exposures." In some cases, airborne concentrations of benzene exceeded the NIOSH Recommended Exposure Limit concentrations and, in a few instances, the American Conference of Governmental Industrial Hygienists' Threshold Limit Value, "when workers performed work tasks near a point source for benzene emissions."[586]

- July 29, 2014 – As part of an investigation into the health impacts of drilling and fracking on animal health, veterinarian Michelle Bamberger and Cornell biochemist Robert Oswald, published an interview with a twenty-year oil and gas industry worker about his experiences and worker safety. His account included injuries, 16-hour workdays, fatigue, exposure to chemicals, and inadequate health and safety training. "No one out there tells you about stuff that has latency. That is the last thing they are going to do is tell you that something that you are handling will take you out in 20 years or 10 years or cause you some kind of ailment, or you can potentially drag this home to your family."[587]

- July 14, 2014 – As part of an analysis of safety and research needs associated with drilling and fracking, researchers at the Colorado School of Public Health and the College of Health Sciences at the University of Wyoming documented high injury and on-the-job mortality rates among gas and oilfield workers. The occupational fatality rate was 2.5 times higher than that of the construction industry and seven times higher than that of general industry. By contrast, injury rates were lower than the construction industry, suggesting that injuries are underreported. Researchers documented crystalline silica levels above occupational health standards and identified the existence of other hazards, including particulate matter, benzene, noise, and radiation. The team called for exposure assessments for both chemical hazards and physical hazards that lead to occupational illness (noise, radioactivity); screening and surveillance systems to assess incidence and prevalence of occupational illness; industry/academic collaboration to conduct occupational epidemiologic studies; and assessment of the effectiveness of industry interventions to reduce exposures.[588]

- July 2014 – The British labor journal *Hazards* identified health concerns in the drilling and fracking industry: increased rate of death on the job, toxic releases, silica exposure, and exposure to hydrocarbons and endocrine disruptors. The union that organizes the construction, rig, and transport workers, on which fracking would rely, agreed at its July 2014 national conference to lobby for a moratorium on fracking because "[d]elegates want union members to be made aware of the dangers of fracking and be advised not to

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[586] Esswein, E., Snawder, J., King, B., Breitenstein, M., Alexander-Scott, M., & Kiefer, M. (2014). Evaluation of some potential chemical risks during flowback operations in unconventional oil and gas extraction: Preliminary results. *Journal of Occupational and Environmental Hygiene*, *11*, D174-0184.

[587] Bamberger, M., & Oswald, R. (2015). The shale gas revolution from the viewpoint of a former industry insider. *New Solutions: A Journal of Environmental and Occupational Health Policy, 24*(4), 585-600. Advance online publication. doi: 10.2190/NS.EOV.1

[588] Witter, R. Z., Tenney, L., Clark, S., & Newman, L. S. (2014). Occupational exposures in the oil and gas extraction industry: State of the science and research recommendations. *American Journal of Industrial Medicine, 57*(7), 847-856. doi: 10.1002/ajim.22316

work on fracking sites."[589]

- June 29, 2014, and August 31, 2014 – An initial report and follow-up analysis in *The Columbus Dispatch* examined fire hazards at well pads. In one notable case, malfunctioning hydraulic tubing allowed a well pad fire in Monroe County, Ohio to spread rapidly, prompting evacuations. Local firefighters had neither the correct equipment nor did they know the chemicals they were trying to extinguish. One firefighter was treated for smoke inhalation.[590, 591]

- May 19, 2014 – Underscoring the dangerous nature of chemicals used in fracking operations, NIOSH reported that at least four gasfield workers have died since 2010 from acute chemical exposures during flowback operations and warned that flowback operations can "result in elevated concentrations of volatile hydrocarbons in the work environment that could be acute exposure hazards." The agency further noted that such volatile hydrocarbons "can affect the eyes, breathing, and the nervous system and at high concentrations may also affect the heart causing abnormal rhythms."[592, 593]

- May 16, 2013 – A NIOSH study revealed that worker exposure to crystalline silica dust from sand used in fracking operations exceeded "relevant occupational health criteria" at all eleven tested sites, and the magnitude of some exposures exceeded NIOSH limits by a factor of 10 or more. "[P]ersonal respiratory protection alone is not sufficient to adequately protect against workplace exposures." Inhalation of crystalline silica can cause incurable silicosis, lung cancer, chronic obstructive pulmonary disease, kidney disease and autoimmune diseases.[594] Although community exposures distant from mines are possible, there are no federal or state standards for silica in ambient air.[595]

- May 8, 2014 – A report by the AFL-CIO found that the fracking boom has made North Dakota the most dangerous state for U.S. workers—with a fatality rate five times higher than the national average—and that North Dakota's fatality rate has doubled since 2007. The AFL-CIO called North Dakota "an exceptionally dangerous and deadly place to

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589 O'Neill, R. (editor). (2014). Chemicals, dust and deaths and the new rush for oil and gas. *Hazards Magazine*. Special Online Report. Retrieved from http://www.hazards.org/oil/fracking.htm#top
590 Richards, J. S. (2014, June 29). Glitch sparks smoky fire at gas well. *Columbus Dispatch.* Retrieved from http://www.dispatch.com/content/stories/local/2014/06/29/glitchsparks-smoky-fire-at-gas-well.html
591 Arenschield, L. (2014, August 31). Fracking fire points out failings. *Columbus Dispatch* Retrieved from http://www.dispatch.com/content/stories/local/2014/06/29/glitchsparks-smoky-fire-at-gas-well.html
592 Snawder, J., Esswein, E., King, B., Breitenstein, M., Alexander-Scott, M., Retzer, K., . . . Hill, R. (2014, May 19). Reports of worker fatalities during flowback operations [Web log post]. *NIOSH Science Blog.* Retrieved from http://blogs.cdc.gov/niosh-science-blog/2014/05/19/flowback/
593 Iafolla, R. (2014, May 20). Four fatalities linked to used fracking fluid exposure during 'flowback,' NIOSH reports. *Bloomberg BNA*. Retrieved from http://www.bna.com/four-fatalities-linked-n17179890610/
594 Esswein, E. J., Breitenstein, M., Snawder, J., Kiefer, M., & Sieber, W. K. (2013). Occupational exposures to respirable crystalline silica during hydraulic fracturing. *Journal of Occupational and Environmental Hygiene, 10*(7), 347-356. doi: 10.1080/15459624.2013.788352
595 University of Iowa Environmental Health Sciences Research Center. (2012). Exposure assessment and outreach to engage the public on health risks from frac sand mining. Retrieved from http://cph.uiowa.edu/ehsrc/fracsand.html

work." U.S. Secretary of Labor Thomas E. Perez called the rising rate of workplace deaths suffered in the oil and gas sector "unacceptable."[596]

- April 24, 2014 – A University of Texas San Antonio report commissioned by the Methodist Healthcare Ministries found that many oil and gas field workers in the Eagle Ford Shale are uninsured or underinsured and that "the most noticeable health impacts so far are work-related illnesses and injuries: heat exhaustion, dehydration, sleep deprivation, exposure to oil and gas spills and accidents." The study also noted that oil and gas production has put strain on healthcare facilities.[597]

- April 10, 2014 –West Virginia University researcher Michael McCawley reported that some of the nation's highest rates of silicosis are in heavily drilled areas within the Northern Panhandle of West Virginia and southwestern Pennsylvania. A disease that hardens the lungs through inflammation and development of scar tissue, silicosis is entirely attributable to exposure to silica dust, a known occupational hazard at drilling and fracking operations. Two years earlier, OSHA and NIOSH issued a joint "Hazard Alert" to warn fracking workers of the health hazards of exposure to silica dust, including silicosis.[598]

- February 25, 2014 – A year-long investigation by the *Houston Chronicle* found that fracking jobs are deadly, with high fatality rates and high rates of serious injury. Within just one year in Texas, 65 oil and gas workers died, 79 lost limbs, 82 were crushed, 92 suffered burns and 675 broke bones. From 2007 to 2012, at least 664 U.S. workers were killed in oil and gas fields.[599, 600]

- December 27, 2013 – National Public Radio (NPR) reported spiking rates of fatalities related to oil and gas drilling operations, which had increased more than 100 percent since 2009. NPR noted that in the previous year, 138 workers were killed on the job, making the fatality rate among oil and gas workers nearly eight times higher than the average rate of 3.2 deaths for every 100,000 workers across all industries.[601]

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[596] Picchi, A. (2014, May 8). The most dangerous U.S. state for workers. *CBS News*. Retrieved from http://www.cbsnews.com/news/the-most-dangerous-us-state-for-workers/

[597] Ghahremani, Y. (2014, April 24). Fractured Healthcare: Pumping Resources Back into the Eagle For Shale Communities/Executive Summary: Methodist Healthcare Ministries and Center for Community and Business Research at the University of Texas San Antonio. Retrieved from http://www.joomag.com/en/newsstand/fractured-healthcare-pumping-resources-back-into-the-eagle-ford-shale-communities-apr-2014/0368470001398347080

[598] Hicks, I. (2014, April 10). Gas workers risk silica exposure. *The Intelligencer, Wheeling News-Register*. Retrieved from http://www.news-register.net/page/content.detail/id/598589/Gas-Workers-at-Risk-Of-Silica-Ex---.html

[599] Olsen, L. (2014, February 22). Houston Chronicle exclusive: Drilling boom, deadly legacy. Retrieved from http://www.houstonchronicle.com/news/special-reports/article/Houston-Chronicle-exclusive-Drilling-boom-5259311.php#/0

[600] Hsieh, S. (2014, February 25). Why are so many workers dying in oil fields? Retrieved from http://www.thenation.com/blog/178523/why-are-so-many-workers-dying-oil-fields

[601] Schneider, A., & Geewax, M. (2013, December 27). On-the-job deaths spiking as oil drilling quickly expands. Retrieved from http://www.npr.org/2013/12/27/250807226/on-the-job-deaths-spiking-as-oil-drilling-quickly-expands

- October 30, 2012 – In a policy statement, the American Public Health Association (APHA) asserted that, high volume horizontal hydraulic fracturing (HVHF) "poses potential risks to public health and the environment, including groundwater and surface water contamination, climate change, air pollution, and worker health." The statement also noted that the public health perspective has been inadequately represented in policy processes related to HVHF.[602] The policy statement added:

  > [H]ydraulic fracturing workers are potentially exposed to inhalation health hazards from dust containing silica. There may also be impacts on workers and communities affected by the vastly increased production and transport of sand for HVHF. Inhalation of fine dusts of respirable crystalline silica can cause silicosis. Crystalline silica has also been determined to be an occupational lung carcinogen.

- 2005 – A researcher at Stanford University examined hazards associated with oil and gas extraction from exposure to radiation and determined that inhalation of high levels of radon gas is a serious concern to workers and those living nearby. Because the boiling point of radon lies between those of propane and ethane, gaseous radon (222Rn) will concentrate in ethane and propane fractions. "Elevated Rn activity concentration values have been measured at several processing plant sites…. It is well known that the radiological impact of the oil and gas-extracting and processing industry is not negligible."[603]

- May 9, 2003 – A New York Medical College study re-evaluated the chest X-rays of patients with exposure to silica who died from various respiratory problems and found that more than eight percent had undiagnosed silicosis. The study suggested that occupational lung disease may be undercounted in high-risk occupations. The authors of this study said that improved OSHA standards, with ongoing exposure monitoring and medical surveillance, would significantly improve the recognition of cases and justify more stringent preventive measures to reduce exposure. They further noted that practitioners need skills in taking an occupational exposure history. Although ten years have passed since this study was published, both recommendations have yet to be implemented.[604]

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[602] American Public Health Association. (2012, October 30). The environmental and occupational health impacts of high-volume hydraulic fracturing of unconventional gas reserves. Retrieved from http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1439

[603] Steinhäusler, F. (2005). Radiological impact on man and the environment from the oil and gas industry: Risk assessment for the critical group. *Nato Science Series: IV: Earth and Environmental Sciences.* doi: 10.1007/1-4020-2378-2_19. http://rd.springer.com/chapter/10.1007/1-4020-2378-2_19

[604] Goodwin, S. S., Stanbury, M., Wang, M.-L., Silbergeld, E., & Parker, J. E. (2003). Previously undetected silicosis in New Jersey decedents. *American Journal of Industrial Medicine, 44,* 304-11. doi: 10.1002/ajim.10260

Public health effects, measured directly

By several measures, evidence for fracking-related health problems has emerged across the United States and Canada. Studies of birth outcomes in regions of intensive unconventional oil and gas extraction continue to point to reproductive risks, including low birth weight and preterm births. In Oklahoma and Colorado, birth defects were elevated among infants whose mothers lived near drilling and fracking sites while pregnant.

As shown by multiple studies in Pennsylvania, as the number of gas wells increase in a community, so do rates of hospitalization, and community members experience sleep disturbance, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, wheezing, and nausea. Also in Pennsylvania, hospitalizations for pneumonia among the elderly are elevated in areas of fracking activity, and one study found significantly elevated rates of bladder and thyroid cancers. In Colorado, children and young adults with leukemia were 4.3 times more likely to live in an area dense with oil and gas wells. Drilling and fracking operations in multiple states are variously correlated with increased rates of asthma; increased hospitalizations for pneumonia and kidney, bladder, and skin problems; high blood pressure and signs of cardiovascular disease; elevated motor vehicle fatalities; symptoms of depression; ambulance runs and emergency room visits; and incidence of sexually transmitted diseases.

Benzene levels in ambient air surrounding drilling and fracking operations are sufficient to elevate risks for future cancers in both workers and nearby residents, according to studies. Animal studies show numerous threats to fertility and reproductive success from exposure to various concentrations of oil and gas chemicals at levels representative of those found in drinking water. A recent study found that 43 chemicals used in drilling and fracking operations are classified as known or presumed human reproductive toxicants, while 31 others are suspected human reproductive toxicants. An earlier study identified two dozen chemicals commonly used in fracking operations as endocrine disruptors that can variously disrupt organ systems, lower sperm counts, and cause reproductive harm at realistically expected exposure levels.

- January 21, 2019 – Increased hospitalizations for diseases of the genitourinary system, such as urinary tract infections, kidney infections, and kidney stones, were "strongly and positively associated with cumulative [unconventional natural gas] well density" in Pennsylvania.[605] The strongest association for the genitourinary hospitalization rates was for women aged 20 to 64, particularly for kidney infections, stones in the ureter, and urinary tract infections. The researchers compared yearly hospitalization rates for each of Pennsylvania's 67 counties with the number of new fracking wells drilled, the total number of wells, and the density of wells by land area for each county by year, from 2003-2014. Noting that hospitalizations, in contrast with outpatient physician visits, reflect acute illness or serious exacerbations of chronic disease, the research team pointed

[605] Denham, A., Willis, M., Zavez. A., & Hill, E. (2019). Unconventional natural gas development and hospitalizations: evidence from Pennsylvania, United States, 2003-2014. *Public Health, 168,* 17-25. doi: 10.1016/j.puhe.2018.11.020

out that these same health problems addressed in an outpatient setting, or not addressed at all, were likely also rising but would not have been counted in this study. The findings also revealed a link between cumulative gas well exposure measures and hospitalization rates for skin problems, particularly among men aged 20 to 64.

- December 12, 2018 – University of Oklahoma public health scientists found a significantly increased prevalence of neural tube defects among children whose birth residence was located within two miles of a drilling and fracking site, compared to those which were not.[606] The researchers examined records of all 476,600 singleton births and congenital anomalies in Oklahoma from 1997 through 2009, together with historical location and production data on active natural gas wells for each year of the study. No stillbirths were included in this study. Hence, as the researchers note, the link they found would likely be an underestimate "if natural gas activity is related to severe anomalies with high prenatal mortality."

- December 6, 2018 – Early signs of cardiovascular disease—including high blood pressure, changes in the stiffness of blood vessels, and markers of inflammation—occurred more often in people who live in communities with more intense oil and gas development, according to a study of 97 adults living in northeastern Colorado between October 2015 and May 2016.[607] Artery stiffness, as measured by augmentation index, was highest among people living in areas with the greatest drilling and fracking activity, as was systolic and diastolic blood pressure (for those not taking prescription medications). This was the first study to evaluate, with direct measurements, indicators of cardiovascular disease and the intensity of oil and gas activity. The results are consistent with previous research showing increased rates of cardiology inpatient hospital admission in these areas.

- August 28, 2018 – The top 10 oil and gas producing counties in Colorado had higher truck accident rates than the remaining 54 counties in an analysis by Colorado School of Public Health researchers. Researchers also performed an additional geospatial study technique called a "grid level analysis" using the Colorado Oil and Gas information System (COGIS), census population information, and home locations. These results showed that grid cells with more homes and/or wells were associated with more truck accidents, as well as with more multi-vehicle truck accidents with an injury.[608]

- August 13, 2018 – Babies in Pennsylvania whose mothers lived near at least one gas well during their pregnancies were at higher risk for adverse birth outcomes, according to a study published in the *Journal of Health Economics.* This investigation examined state-

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[606] Janitz, A. E., Dao, H. D., Campbell, J. E., Stoner, J. A., & Peck, J. D. (2019). The association between natural gas well activity and specific congenital anomalies in Oklahoma, 1997–2009. *Environment International, 122,* 381–388. Advance online publication. doi: 10.1016/j.envint.2018.12.011

[607] McKenzie, L. M., Crooks, J., Peel, J. L., Blair, B.D., Brindley, S., Allshouse, W. B., . . . Adgate, J. L. (2019). Relationships between indicators of cardiovascular disease and intensity of oil and natural gas activity in Northeastern Colorado. *Environmental Research, 170,* 56-64. doi: 10.1016/j.envres.2018.12.004

[608] Blair, B. D., Hughes, J., Allshouse, W. B., McKenzie, L., & Adgate, J. L. (2018). Truck and multivehicle truck accidents with injuries near Colorado oil and gas operations. *International Journal of Environmental Research and Public Health, 15,* 1861. doi: 10.3390/ijerph15091861

based data on the locations of 2,459 natural gas wells drilled between 2006 and 2010 together with restricted-access birth and mortality data for the years 2003–2010.[609] Mothers living within 2.5 kilometers (1.5 miles) of gas wells gave birth to infants with increased incidence of low birth weight and small for gestational age (SGA). SGA generally increases with exposure to environmental pollution and helps determine immediate health care needs, as well as predicting long-term adverse health outcomes. In addition, the study found term birth weight for these infants was lower on average, and the prevalence of APGAR scores less than eight was increased by 26 percent. APGAR scores are used to evaluate the health of infants immediately after birth. This study builds on growing evidence that air pollution from shale gas development damages infant health and stands out for thoroughly controlling for predictors of infant health and for estimating the extensive and intensive margins of drillings. Within the intensive margin (which includes an estimation of the impact of well density), one additional well was associated with a seven percent increase in low birth weight, a five gram reduction in term birth weight, and a three percent increase in premature birth. Each of these adverse outcomes carries high associated medical costs. The author conservatively estimated the added cost associated with one low birth weight infant to be $96,500 in the first year alone, not counting any loss of parent income. The author noted that these impacts are "likely to persist throughout these children's lives."

- August 10, 2018 – A study of Pennsylvania counties focusing on the period 2003–2012 found that counties with fracking activities have higher rates of gonorrhea and chlamydia infections (up 7.8 percent and 2.6 percent, respectively), as well as a 19.7 percent higher rate of prostitution-related arrests.[610] Authors found no evidence that confounding factors such as opioid prescription rates, viral hepatitis deaths, or drug abuse arrests influenced these results. These findings provide "strong evidence that unconventional or shale gas development poses significant risks to public health and that unconventional or shale gas development has policy implications beyond the economic and environmental impacts often cited."

- July 28, 2018 – Road fatalities in the Permian Basin region of west Texas have risen and fallen with the price of oil, according to an investigative piece in *Bloomberg* using New York Mercantile Exchange and Texas Department of Transportation data.[611] Interviewees in the article pointed to inexperienced and exhausted drivers, sinkholes, oversized trucks on roads not designed for the amount of traffic they now carry, and other factors as reasons for the ongoing fatalities.

- July 27, 2018 – In this study of almost 5,000 Pennsylvanians, a team of medical and public health scientists found a link between living closer to more and bigger

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[609] Hill, E. (2018). Shale gas development and infant health: Evidence from Pennsylvania. *Journal of Health Economics, 61*, 134–150. doi: 10.1016/j.jhealeco.2018.07.004

[610] Beleche, T., & Cintina, I. (2018). Fracking and risky behaviors: Evidence from Pennsylvania. *Economics and Human Biology, 31,* 69-82. doi: 10.1016/j.ehb.2018.08.001

[611] Collins, R., & Adams-Heard, R. (2018, July 28). \`Death Highway' is where oil prices, truck fatalities intersect. *Bloomberg.* Retrieved from https://www.bloomberg.com/news/articles/2018-07-28/-death-highway-is-where-oil-prices-truck-fatalities-intersect

unconventional shale gas wells and increased symptoms of depression. This is the first epidemiologic study to address a mental health outcome with regard to proximity to fracking and related operations. The researchers combined information from a mailed questionnaire, electronic health record data, and residential proximity to more and bigger wells, using well data from three agencies. Size of wells was ascertained by combining data on total well depth and volume of natural gas produced. Researchers concluded that drilling and fracking activities "may be associated with adverse mental health in Pennsylvania" and called for including potential mental health consequences in future risk-benefit calculations.[612]

- June 21, 2018 – Using individual inpatient data for the whole state of Pennsylvania from 2003 through 2014, researchers found consistent associations between childhood asthma hospitalizations and nearby drilling and fracking activity. When they compared unexposed children to children in the top third of patients exposed to shale gas drilling, the research team found that, during the same calendar quarter a gas well was drilled, the odds of children and adolescents being hospitalized for asthma increased by 25 percent. If there was ever a well drilled within a zip code, the odds of these pediatric asthma-related hospitalizations increased by 19 percent. This finding demonstrates that the increased risk remains for years after wells are drilled.[613] This study is notable because it is the first to control for 180 pre-existing respiratory health risks. Researchers also considered specific air emissions from drilling and fracking sites. They found that increased levels of 2,2,4-trimethylpentane, carbon dioxide, formaldehyde, nitrous oxide, volatile organic compounds (VOCs), and x-hexane were associated with increased risks of pediatric asthma hospitalizations across age groups, as well as links for younger children to additional pollutants.

- May 21, 2018 – Using the most stringent classification within and across countries internationally, researchers examined reproductive toxicity among chemicals used in drilling and fracking operations for oil and gas. They found that 43 chemicals are classified as known or presumed human reproductive toxicants, while 31 others are suspected human reproductive toxicants. The team, which included Yale School of Medicine and School Public of Health researchers, further analyzed the 43 reproductive toxicants for their carcinogenic and mutagenic properties and found that seven reproductive toxicants doubled as carcinogens and mutagens. They are potassium dichromate, cadmium, benzene, ethylene oxide, nickel sulfate, N,N-dimethylformamide, and lead. Of these, benzene and lead are found in both fracking fluid and in fracking wastewater. Researchers noted that their study was limited to 157 chemicals previously identified as having evidence of reproductive toxicity, which is only a fraction of the more than 1000 chemicals identified as being present in fracking fluid, fracking wastewater, and fracking-related air emissions. They recommended that their framework

[612] Casey, J. A., Wilcox, H. C., Hirsch, A. G., Pollak, J., & Schwartz, B.S. (2018). Associations of unconventional natural gas development with depression symptoms and disordered sleep in Pennsylvania. *Scientific Reports, 8.* doi: 10.1038/s41598-018-29747-2

[613] Willis, M. D., Jusko, T. A., Halterman, J. S., & Hill, E. L. (2018). Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania. *Environmental Research, 166,* 402-408. doi: 10.1016/j.envres.2018.06.022

be extended to all those chemicals.[614] (See also entry for January 6, 2016 in Water Contamination.)

- May 1, 2018 – In a laboratory study, prenatal exposure to fracking-related chemicals triggered immune problems in mice, especially females. All three immune system illnesses tested—a house dust mite-induced allergic disease, influenza A virus, and a disease similar to multiple sclerosis—were impaired in mice exposed in the womb to a mixture of fracking chemicals.[615] Using a chemical mixture "laced with chemicals at levels similar to those found in groundwater near fracking sites" and already demonstrated to have harmful developmental and reproductive effects, the researchers found sex-linked effects.[616] The exposed female mice showed more severe damage to their immune systems and ability to resist disease. In addition, the multiple scleroris-like disease, experimental autoimmune encephalomyelitis, developed earlier and more severely in female mice as compared to male mice. Authors concluded, "These observations suggest that developmental exposure to complex mixtures of water contaminants, such as those derived from [drilling and fracking] operations, could contribute to immune dysregulation and disease later in life."

- March 23, 2018 – Yale University public health scientists investigated possible connections between shale gas drilling and sexually transmitted diseases in Ohio. They found that, compared to counties with no shale gas activity, counties with high activity had 21 percent increased rates of chlamydia and 19 percent increased rates of gonorrhea.[617] They classified all 88 counties in the state as having none, low, and high shale gas activity in each year from 2000 through 2016, using Ohio Department of Natural Resources data. Their findings showed magnitude of effect for the association with gonorrhea that is similar to a prior analysis, adding strength to observed associations. Speaking to the *Columbus Dispatch*, the lead author noted, "Although there has been a decrease in new permits in recent years, [sexually transmitted infection] rates continue to climb because once a disease is introduced… it can be exchanged within the communities even after the workers leave."[618]

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[614] Inayat-Hussain, S. H., Fukumura, M., Muiz Aziz, A., Jin, C. M., Jin, L.W., Garcia-Milian, R., . . . Deziel, N. C. (2018). Prioritization of reproductive toxicants in unconventional oil and gas operations using a multi-country regulatory data-driven hazard assessment. *Environment International, 117,* 348-358. doi: 10.1016/j.envint.2018.05.010

[615] Boulé, L. A., Chapman, T. J., Hillman, S. E., Kassotis, C. D., O'Dell, C., Robert, J., . . . Lawrence, B. P. (2018). Developmental exposure to a mixture of 23 chemicals associated with unconventional oil and gas operations alters the immune system of mice. *Toxicological Sciences, 163*(2), 639–654. doi: 0.1093/toxsci/kfy066

[616] Adams, B. (2018, May 1). Exposure to chemicals used in fracking impairs immune system of mice in URMC study. *WXXI News*. Retrieved from https://www.wxxinews.org/post/exposure-chemicals-used-fracking-impairs-immune-system-mice-urmc-study

[617] Deziel, N. C., Humeau, Z., Elliott, E. G., Warren, J. L., & Niccolai, L. M. (2018). Shale gas activity and increased rates of sexually transmitted infections in Ohio, 2000–2016, *PLoS ONE 13*(3). doi: 10.1371/journal.pone.0194203

[618] Marshall, A. (2018, 22 July). Study suggests potential link between fracking industry and increased sexually transmitted infections. *Columbus Dispatch.* Retrieved from https://www.dispatch.com/news/20180722/study-suggests-potential-link-between-fracking-industry-and-increased-sexually-transmitted-infections

- March 20, 2018 – In the Texas Barnett Shale, women with homes within a half-mile radius of the most dense gas drilling activity or gas production activity at the time of their child's birth had, respectively, 20 percent and 15 percent higher risk of preterm birth, compared with women with no such activity near their residence. The greatest proximity-related risk was for extremely premature births (prior 28 weeks gestation): mothers living near the densest drilling activity and the densest production activity were, respectively, 100 percent and 53 percent more likely to give birth to extremely premature babies.[619, 620] For purposes of this study, the drilling phase included drilling of the wellbore, installation of casing, and fracking, whereas the production phase, which can last for years, included the flowback of gas, condensate, and produced water, as well as possible on-site storage of these materials. Researchers noted that they did not have access to information that would have allowed more refined classification of phases. The study included 13,332 preterm birth cases and 66,933 term births in the 24-county Barnett Shale region between 2010 and 2012. The study also addressed trimester-specific differences in risk, finding little evidence for that factor. (See also entry for September 19, 2017.)

- March 13, 2018 – A research team found higher rates of hospitalizations for pneumonia among individuals ages 65 and older in Pennsylvania counties with drilling and fracking operations compared to those without. This result is consistent with other studies reporting links between respiratory problems and air pollution. This study, which used enhanced county-specific data from 2001 to 2013, expands on earlier research in its geographical reach and longer time horizon. The research team also found higher average hospitalization rates for other air pollution-sensitive diseases (acute myocardial infarction, chronic obstructive pulmonary disease, asthma, and upper respiratory infections) in counties containing unconventional natural gas wells than in those without wells, but those links were not as strong statistically as for pneumonia among the elderly. Noting that their study design may actually underestimate the impact of natural gas development on pneumonia, the research team stated that their study "helps establish a consistent link between unconventional natural gas extraction and higher rates of disease."[621]

- February 7, 2018 – Female mice exposed to a mixture of 23 fracking chemicals during early life developed dose-specific abnormalities in their mammary glands. The researchers saw changes in tissue morphology, cell proliferation, "and the induction of unique intraductal hyperplasias."[622] (Intraductal hyperplasia is an overgrowth of cells that is considered a marker for future breast cancer risk.) Researchers used four doses; the lower two used were equivalent to concentrations found in drinking water in fracking

[619] Whitworth, K. W., Marshall, A. K., & Symanski, E. (2018). Drilling and production activity related to unconventional gas development and severity of preterm birth. *Environmental Health Perspectives, 126*(3). doi: 10.1289/EHP2622
[620] Konkel, L. (2018). Drilling into critical windows of exposure: Trimester-specific associations between gas development and preterm birth, *Environmental Health Perspectives, 126*(10). doi: 10.1289/EHP3762
[621] Peng, L., Meyerhoefer, C., & Chou, S.-Y. (2018). The health implications of unconventional natural gas development in Pennsylvania. *Health Economics, 27,* 956–983 doi: 10.1002/hec.3649
[622] Sapouckey, S. A., Kassotis, C. D., Nagel, S. C., & Vandenberg, L. N. (2018). Prenatal exposure to unconventional oil and gas operation chemical mixtures altered mammary gland development in adult female mice. *Endocrinology, 159,* 1277–1289. doi: 10.1210/en.2017-00866

regions and the highest dose represented concentrations that have been measured in industry wastewater. Mammary gland effects varied for each the doses, but all groups developed intraductal hyperplasia. According to a co-author, "This study shows that a mixture of [fracking] chemicals can affect the long-term health of the mouse mammary gland, even after low level exposures in the womb."[623]

- January 15, 2018 – A study of urban oil drilling in two Los Angeles neighborhoods found elevated asthma rates among residents living within 1,500 feet of oil wells. Researchers compared diagnosed asthma rates in these areas to a representative comparison area (the California Health Interview Survey's "SPA6" in South Los Angeles) and to Los Angeles County as a whole.[624] The diagnosed asthma rates in the two study areas were statistically significantly higher (16.1 percent and 23.6 percent) than the comparison area (9.8 percent). Asthma prevalence in one of the two study areas was significantly higher than that in Los Angeles County as a whole. Households with smokers were excluded from the analysis. This interdisciplinary team worked in partnership with the local residents to conduct this community-based survey with limited resources and urged further studies with more complex scientific design.

- December 13, 2017 – A team of health economists analyzed fracking's health impacts on infants. They examined birth certificates for all 1.1 million infants born in Pennsylvania between 2004 and 2013 and combined these data with maps showing when and where gas wells were drilled in the state. Their results indicated that the introduction of fracking "reduces health among infants born to mothers living within 3 km (1.9 miles) of a well site during pregnancy." For mothers living within one kilometer (.6 miles), they found a 25 percent increase in the probability of low birth weight, "significant declines" in average birth weight, as well as declines in other measures of infant health. They also observed reductions in infant health when mothers lived within one to three kilometers of a fracking site; these were about one-third to one-half of the declines of those mothers living closer.[625] The researchers estimated that "about 29,000 out of the nearly 4 million U.S. births (0.7 percent) annually occur within 1 kilometer of a fracking site and 95,500 are born within 3 kilometers." "For policymakers weighing the costs and benefits of fracking before deciding whether to allow it in their communities, this study provides a clear cost: an increase in the probability of poorer health for babies born near these sites."[626]

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[623] University of Massachusetts at Amherst. (2018, February 7). Changes in mouse breast tissue after exposure to fracking chemicals. *ScienceDaily.* Retrieved from https://www.sciencedaily.com/releases/2018/02/180207090108.htm

[624] Shamasunder, B., Collier-Oxandale, A., Blickley,. J, Sadd,. J, Chan,. M, Navarro, S., . . . Wong, N. J. (2018). Community-based health and exposure study around urban oil developments in South Los Angeles. *International Journal of Environmental Research and Public Health, 15*. doi: 10.3390/ijerph15010138

[625] Currie, J., Greenstone, M., & Meckel, K. (2017). Hydraulic fracturing and infant health: New evidence from Pennsylvania. *Science Advances, 3*(12), e1603021. doi: 10.1126/sciadv.1603021

[626] Currie, J., Greenstone, M., & Meckel, K. (2017). Hydraulic fracturing and infant health: New evidence from Pennsylvania (Research Summary). *Energy Policy Institute at the University of Chicago.* Retrieved from https://epic.uchicago.edu/sites/default/files/EPIC_121017_FrackingResearchSummary_Final.121317.pdf

- November 6, 2017 – As part of a pilot project, a team of Montreal-based public health researchers evaluated exposure of pregnant mothers to VOCs in an area of intensive fracking in northeastern British Columbia. At least 28,000 unconventional natural gas wells had been drilled to date in the Peace River Valley. Analyzing the urine of 29 pregnant women, researchers found high concentrations of muconic acid, which is a degradation product of benzene, a widely studied developmental toxicant and an air contaminant in the vicinity of gas wells. The median concentration of this chemical was approximately 3.5 times higher in the study group than in the general Canadian population. In five of the 29 women, the concentration of muconic acid exceeded an exposure index by the American Conference of Governmental Industrial Hygienists that was designed for workplace settings. (No guidelines for the public exist.) By design, this small pilot study sets the groundwork for more extensive biomonitoring and environmental analysis.[627]

- September 19, 2017 – University of Texas Health Science Center researchers conducted a case-control study nested within their larger cohort of women with single births (see entry for July 21, 2017, below) in the 24-county Barnett Shale between November 30, 2010 and November 29, 2012. Its specific purpose was to consider timing of unconventional gas development activity "during potentially sensitive windows of exposure," as well as "potential differences in risk by UGD drilling phase," with regard to preterm births. Results suggest a link between maternal residential proximity to UGD-activity and preterm births, which were similar by drilling phase and "slightly stronger in the first two trimesters of pregnancy."[628]

- September 14, 2017 – Researchers reviewed health assessments taken between February 2012 and October 2015 of adults in Pennsylvania communities with intense unconventional natural gas development (UNGD). The most frequently reported symptoms were sleep disturbance, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, wheezing, nausea, each occurring in over 20 percent of the sample. Over 43 percent of the sample reported sleep disturbance. To meet the inclusion criteria, as developed and implemented by a physician and nurse practitioner, the symptoms were reviewed to ensure no plausible cause relating to "past medical and surgical history, concurrent medical conditions, family and social history, and environmental exposures unrelated to UNGD. For example, if the social history indicated a ½ pack/day smoking history, the symptom of 'difficulty breathing' was not included." Independently, the timing of the exposure for each symptom that met the inclusion criteria was determined, using the beginning drilling date for each unconventional natural gas well within one kilometer (.6 miles) of the patient's residence;

[627] Caron-Beaudoina, É, Valter, N., Chevrier, J., Ayotte, P., Frohlich, K., & Verner, M.-A. (2017). Gestational exposure to volatile organic compounds (VOCs) in Northeastern British Columbia, Canada: A pilot study. *Environment International, 110,* 131-138. doi: 10.1016/j.envint.2017.10.022
[628] Marshall, A. K., Symanski, E., & Whitworth, K. W. (2017). The association between unconventional gas development and preterm birth: Evaluating drilling phases and critical windows of susceptibility [Abstract]. *Annals of Epidemiology, 27*(8), 530.

records were excluded if it was not possible to verify at least one gas well within this distance.[629]

- August 21, 2017 – Using county-level data from 2003 to 2013, researchers found that, all together, counties in the Marcellus Shale region that experienced a boom in hydraulic fracturing showed a 20 percent increase in the incidence rate of gonorrhea.[630]

- July 21, 2017 – A University of Texas Health Science Center School of Public Health team assessed the links between the residential proximity of pregnant mothers to unconventional natural gas development activity and various newborn health problems: preterm birth, small-for-gestational age (SGA), fetal death, and low birth weight. They found evidence of a "moderate positive association" between residential proximity to UGD-activity and increased odds of preterm birth, and a "suggestive association" with fetal death. Nearly 159,000 births and fetal deaths from November 30, 2010 to November 29, 2012 in the 24-county Barnett Shale area were considered.[631]

- February 15, 2017 – A study from the University of Colorado School of Public Health and Anschutz Medical Campus showed that children and young adults between the ages of 5 and 24 with acute lymphocytic leukemia (ALL) were 4.3 times more likely to live in area dense with active oil and gas wells. The researchers did not find such a link with ALL cases in 0-4 year olds, or with incidence of non-Hodgkin lymphoma. The study focused on rural areas and towns in 57 Colorado counties and did not include cities of more than 50,000 people. Authors wrote, "Because oil and gas development has potential to expose a large population to known hematologic carcinogens, such as benzene, further study is clearly needed to substantiate both our positive and negative findings."[632]

- October 26, 2016 – A study that investigated possible links between fracking and cancer incidence in southwest Pennsylvania found elevated rates of bladder and thyroid cancers in six counties with shale gas activity.[633] Bladder cancer was elevated in both males and females, with a 10 percent increase in the number of observed cases from 2000 to 2012. Over the same time period, thyroid cancer jumped even more dramatically. "There was a huge 91.2% increase in the number of observed cases from 2000 to 2012." Patterns of leukemia incidence were less clearly related to shale gas activity. The author expressed caution in attributing these trends solely to shale gas development due to "the multiple

[629] Weinberger, B., Greiner, L. H., Walleigh, L., & Brown, D. (2017). Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive Medicine Reports, 8,* 112-115. doi: 10.1016/j.pmedr.2017.09.002
[630] Komarek, T., & Cseh, A. (2017). Fracking and public health: Evidence from gonorrhea incidence in the Marcellus Shale region. *Journal of Public Health Policy, 38*(4), 464-481. doi: 10.1057/s41271-017-0089-5
[631] Whitworth, K. W., Marshall, A. K., & Symanski, E. (2017). Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas. *PLOS ONE, 12*(7), e0180966. doi: 10.1371/journal.pone.0180966
[632] McKenzie, L. M., Allshouse, W. B., Byers, T. E., Bedrick, E. J., Serdar, B., & Adgate, J. L. (2017). Childhood hematologic cancer and residential proximity to oil and gas development. *PLOS ONE, 12*(2), e0170423. doi: 10.1371/journal.pone.0170423
[633] Finkel, M. L. (2016). Shale gas development and cancer incidence in southwest Pennsylvania. *Public Health, 141,* 198-206. doi: 10.1016/j.puhe.2016.09.008

sources of potentially toxic, harmful exposures in southwest Pennsylvania, many dating back decades," the long latency time required for many cancers to develop, and possible synergisms between exposures from shale gas development and past toxic exposures.

- August 25, 2016 – Researchers found that Pennsylvanians residing near intensive unconventional gas well activity were significantly more likely to experience chronic rhino sinusitis (at least three months of nasal and sinus symptoms), migraine headaches, and higher levels of fatigue than residents who do not live near such activity.[634] Data were gathered from nearly 8,000 patients of Geisinger Health System from 40 counties in north and central Pennsylvania, and matched with the proximity of respondents to all phases of gas drilling activity and intensity, using information from the Pennsylvania Departments of Environmental Protection (PA DEP) and Conservation and Natural Resources, as well as satellite imagery. According to lead author Aaron W. Tustin, MD, MPH, resident physician in the Department of Environmental Health Sciences at the Johns Hopkins Bloomberg School of Public Health, "[t]hese three health conditions can have debilitating impacts on people's lives… In addition, they cost the health care system a lot of money."[635]

- July 18, 2016 – Living near fracking operations significantly increases asthma attacks, according to a Johns Hopkins University study of 35,000 medical records of people with asthma in north and central Pennsylvania, from 2005 to 2012.[636] The data show that those who live near a higher number of, or larger, active gas wells were 1.5 to 4 times more likely to suffer from asthma attacks compared to those who live farther away, with the closest group having the highest risk. There was increased risk in all three types of exacerbations defined: mild (new oral corticosteroid medication order), moderate (emergency department encounter), or severe (hospitalization). In addition, researchers identified increased risk during all four phases of well development: pad preparation, drilling, stimulation (fracking), and production. The study was praised for its "rigorous research methods," by a scientist not part of the team.[637]

- July 5, 2016 – Researchers from five universities and the U.S. Geological Survey (USGS) identified a link between exposure to fracking and drilling chemicals and adverse reproductive and developmental outcomes in laboratory mice. The study used 23 oil and gas chemicals in four different concentrations, representing concentrations found in drinking water and groundwater, to higher concentrations found in oil and gas industry

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634 Tustin, A. W., Hirsch, A. G., Rasmussen, S. G., Casey, J. A., Bandeen-Roche, K., & Schwartz, B. S. (2017). Associations between unconventional natural gas development and nasal and sinus, migraine headache, and fatigue symptoms in Pennsylvania. *Environmental Health Perspectives, 125,* 189-197. doi: 10.1289/EHP281
635 Phillips, S. (25 August, 2016). New study links gas drilling to migraines, fatigue and chronic sinus symptoms. *State Impact Pennsylvania.* Retrieved from https://stateimpact.npr.org/pennsylvania/2016/08/25/new-study-points-to-association-between-gas-drilling-to-migraines-fatigue-and-chronic-sinus-symptoms/
636 Rasmussen, S. G., Ogburn, E. L., McCormack, M., Casey, J. A., Bandeen-Roche, K. Mercer, D. G., & Schwartz, B. S. (2016). Association between unconventional natural gas development in the Marcellus Shale and asthma exacerbations. *JAMA Internal Medicine.* Advance online publication. doi: 10.1001/jamainternmed.2016.2436
637 Song, L., & Kusnetz, N. (2016, July 18). Increased asthma attacks tied to exposure to natural gas production. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/18072016/asthma-study-marcellus-shale-pennsylvania-natural-gas-fracking

wastewater. Offspring of pregnant laboratory mice consuming these mixtures were compared to those that did not. Results suggested "numerous potential threats to fertility and reproductive success … including altered pituitary hormone levels, reproductive organ weights, and disrupted ovarian follicle development." Researchers observed these negative outcomes even in the offspring exposed to the lowest dose of chemicals. Building on previous research showing reduced sperm counts in male offspring, they also reported on "tentative mechanistic information for the observed adverse health effects."[638]

- February 9, 2016 – An exploratory study of hospitalization rates for three study areas in Queensland, Australia showed rates for specific types of hospital admissions increased more quickly in a coal seam gas study area than in other study areas (a coal mining area and a rural/agricultural area). Coal seam gas is the methane trapped in pores and fractures in underground coal deposits; its exploitation is a form of unconventional natural gas development. A portion of coal seam gas extraction uses fracking. This preliminary study found the strongest link between increased hospitalization rates over time in a coal seam gas area to be for the category of 'Blood/immune' diseases.[639]

- October 14, 2015 – Using an animal model, an interdisciplinary research team measured the endocrine-disrupting activities of 24 chemicals used and/or produced by oil and gas operations, finding that 23 of them "can activate or inhibit the estrogen, androgen, glucocorticoid, progesterone, and/or thyroid receptors, and mixtures of these chemicals can behave synergistically, additively, or antagonistically." Further, the researchers tested prenatal exposures to the chemicals and found effects on multiple organs, including adverse reproductive effects on the matured offspring.[640] This study is the first to demonstrate that endocrine-disrupting chemicals, which are commonly used in fracking operations, can harm the reproductive health of mice, at levels of exposure that are realistic for humans. The study's senior author told *ScienceDaily,* "In addition to reduced sperm counts, the male mice exposed to the mixture of chemicals had elevated levels of testosterone in their blood and larger testicles. These findings may have implications for the fertility of men living in regions with dense oil and/or natural gas production."[641]

- October 8, 2015 – Pregnant women who live near active fracking operations in Pennsylvania were at a 40 percent increased risk of giving birth prematurely and at a 30 percent increased risk for having obstetrician-labeled high-risk pregnancies, according to a study by Johns Hopkins Bloomberg School of Public Health and other researchers.

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[638] Kassotis, C. D., Bromfield, J. J., Klemp, K. C., Meng, C-X., Wolfe, A., Zoeller, R. T., . . . Nagel, S. C. (2016). Adverse reproductive and developmental health outcomes following prenatal exposure to a hydraulic fracturing chemical mixture in female C57Bl/6 Mice. *Endocrinology, 157*(9), 3469–3481. doi: 10.1210/en.2016-1242

[639] Werner, A. K., Watt, K., Cameron, C. M., Vink, S., Page, A., & Jagals, P. (2016). All-age hospitalization rates in coal seam gas areas in Queensland, Australia, 1995–2011. *BMC Public Health, 16*(125). doi: 10.1186/s12889-016-2787-5

[640] Kassotis, C.D., Klemp, K.C., Vu, D.C., Lin, C.-H., Meng, C.-X., Besch-Williford, C.L., . . . Nagel, S.C. (2015). Endocrine-disrupting activity of hydraulic fracturing chemicals and adverse health outcomes after prenatal exposure in male mice. *Endocrinology 156*(12), 4458–4473. doi: 10.1210/en.2015-1375

[641] Endocrine Society. (2015, October 14). Fracking chemicals tied to reduced sperm count in mice. *ScienceDaily.* Retrieved from www.sciencedaily.com/releases/2015/10/151014134533.htm

High-risk pregnancies were those that included hypertension, high pre-pregnancy body mass index, and asthma. The study used data from the Geisinger Health System on 9,384 pregnant women and their 10,496 newborns between January 2009 and January 2013; Geisinger covers 40 counties in north and central Pennsylvania. Researchers developed an index for proximity to fracking wells based on distance from the women's homes, stage of drilling and depth of wells dug, and the amount of gas that was produced at those wells during the pregnancies. The highest-activity quartile had the highest rates of premature births and high-risk pregnancies.[642, 643]

- July 22, 2015 – Using a mammal model, New York University School of Medicine scientists, together with other U.S. and Chinese researchers, demonstrated cancerous changes linked to exposure to wastewater from Marcellus fracking operations. Their study also documented elevated levels of barium and strontium in exposed animal cells. The wastewater studied originated in Pennsylvania and was stored for a time to allow radioactivity and levels of short-lived VOCs to decline. The results suggest that "even aged flow back water could pose substantial health threats to exposed humans."[644]

- July 15, 2015 – A study by University of Pennsylvania and Columbia University researchers found that drilling and fracking activity was associated with increased rates of hospitalization in Pennsylvania. During a period of dramatic increase in drilling and fracking activity between 2007 and 2011, inpatient prevalence rates surged for people living near shale gas wells. Cardiology inpatient prevalence rates were significantly associated with number of wells per zip code and their density, while neurology inpatient prevalence rates were significantly associated with density of wells. Hospitalizations for cancer, skin conditions, and urological problems also rose significantly. During the same time period, no such increase in health problems was observed in a control Pennsylvania county without any drilling and fracking activity. In communities with the most wells, the rate of cardiology hospitalizations was 27 percent higher than in control communities with no fracking. "While the clinical significance of the association remains to be shown, [fracking] has just begun in Pennsylvania, and thus observing a significant association over this short time is striking.… Our study also supports the concept that health care utilization should be factored into the value (costs and benefits) of hydraulic fracturing over time."[645] In a related *Newsweek* story, lead researcher Reynold Panettieri, Jr. said, "At this point, we suspect that residents are exposed to many toxicants, noise and social stressors due to hydraulic fracturing near their homes and this may add to the increased

[642] Casey, J. A., Savitz, D. A., Rasmussen, S. G., Ogburn, E. L., Pollak, J., Mercer, D. G., & Schwartz, B. S. (2016). Unconventional natural gas development and birth outcomes in Pennsylvania, USA. *Epidemiology 27*(2), 163–172. doi: 10.1097/EDE.0000000000000387
[643] Johns Hopkins Bloomberg School of Public Health. (2015, October 8). Study: fracking industry wells associated with premature birth. Retrieved from http://www.jhsph.edu/news/news-releases/2015/study-fracking-industry-wells-associated-with-premature-birth.html
[644] Yao, Y., Chen, T., Shen, S. S., Niu, Y., DesMarais, T. L., Linn, R., . . . Costa, M. (2015). Malignant human cell transformation of Marcellus Shale gas drilling flow back water. *Toxicology and Applied Pharmacology, 288,* 121-130. doi: 10.1016/j.taap.2015.07.011
[645] Jemielita T., Gerton G. L., Neidell, M., Chillrud S., Yan B., Stute, M., . . . Panettieri, Jr., R. A. (2015), Unconventional gas and oil drilling is associated with increased hospital utilization rates. *PLoS ONE 10*(7), e0131093. doi: 10.1371/journal.pone.0131093

number of hospitalizations."[646]

- July 9, 2015 – As part of a scientific assessment of well stimulation treatments, including fracking, the California Council on Science and Technology studied the potential impacts of well stimulation on human health in California. The risk factors directly attributable to well stimulation stem largely from the use of a very large number and quantity of stimulation chemicals. The unknown number and toxicity of chemicals that are mixed together in well stimulation fluids made it difficult to fully quantify risk to the environment and to human health, but the study highlighted the potential health risks from exposure to fracking-related air pollution for the people of Los Angeles, 1.7 million of whom live or work within one mile of an active oil or gas well.[647] Jane Long, co-author, said, "officials should fully understand the toxicity and environmental profiles of all chemicals before allowing them to be used in California's oil operations," according to the *Los Angeles Times*.[648]

- June 22, 2015 – A longtime midwife reported her personal analysis of an ongoing spike in infant deaths, miscarriages, and placental abnormalities in Utah's Uintah Basin that has followed the advent of drilling and fracking activity there and appears linked to air pollution episodes.[649]

- June 3, 2015 – A University of Pittsburgh study linked fracking to low birthweight in three heavily drilled Pennsylvania counties. The more exposure a pregnant woman had to gas wells, the higher her risk for a smaller-than-normal baby. Exposure was determined as proximity and density of wells in relation to the residence of the pregnant woman. Compared to mothers whose homes had the fewest surrounding gas wells, mothers whose homes were nearest to a high density of wells were 34 percent more likely to have babies who were "small for gestational age," meaning they weighed significantly less than expected for the number of weeks of pregnancy. Although the study did not investigate mechanisms, researchers identified air as the likely route of exposure. They supported this argument by referencing another study done in Western Pennsylvania where airborne particulate pollution correlated with low birth weight and by noting that particulates are established shale gas infrastructure emissions.[650, 651] Low birth weight is a leading cause

[646]Schlanger, Z. (2015, July 15). Living near fracking wells linked to increased hospitalization rates. *Newsweek*. Retrieved from http://www.newsweek.com/living-near-fracking-wells-linked-increased-hospitalization-rates-354093

[647] Shonkoff, S. B. C., Maddalena, R. L., Hays, J., Stringfellow, W., Wettstein, Z. S., Harrison, R., Sandelin, W., & McKone, T. E. (2015, July 9). Potential impacts of well stimulation on human health in California, in California Council of Science and Technology and Lawrence Berkeley National Laboratory, *An Independent Scientific Assessment of Well stimulation in California, vol. 2: Potential Environmental Impacts of Hydraulic Fracturing and Acid Stimulations*. Retrieved from http://ccst.us/publications/2015/2015SB4-v2.pdf

[648] Cart, J. (2015, July 9). Water and wildlife may be at risk from fracking's toxic chemicals, panel finds. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/lanow/la-me-california-science-panel-warns-that-fracking-poses-unknown-risk-20150709-story.html

[649] Solotaroff, P. (2015, June 22). What's killing the babies of Vernal, Utah? *Rolling Stone*. Retrieved from http://www.rollingstone.com/culture/features/fracking-whats-killing-the-babies-of-vernal-utah-20150622

[650] Shaina, L. S., Brink, L. L, Larkin, J. D., Sadovsky, Y, Goldstein, B. C., Pitt, B. R., & Talbott, E. O. (2015). Perinatal outcomes and unconventional natural gas operations in southwest Pennsylvania. *PLoS One, 10,* e0126425. doi: 10.1371/journal.pone.0126425

of infant mortality.

- March 3, 2015 – A follow-up study of 21 case studies from five states found that the distribution of symptoms in animals and humans affected by nearby fracking operations was, since 2012, unchanged for humans and companion animals. In food animals, reproductive problems decreased over time while respiratory problems and growth problems increased. "This longitudinal case study illustrates the importance of obtaining detailed epidemiological data on the long-term health effects of multiple chemical exposures and multiple routes of exposure that are characteristic of the environmental impacts of unconventional drilling operations."[652]

- March 3, 2015 – A cross-sectional study by Yale University School of Medicine researchers using companion animals as sentinels of human exposure to fracking-related chemicals investigated possible associations between reported health conditions of companion and backyard animals in Southwest Pennsylvania and household proximity to drilling and fracking operations. Among dogs living in households located less than one kilometer from a gas well, risks for health problems were elevated, especially for dermal conditions, compared to animals living more than two kilometers from a well.[653]

- January 1, 2015 – A Yale-led team studied the relationship between household proximity to drilling and fracking operations and reported health symptoms in Washington County, Pennsylvania where 624 gas wells were in active operation, most of which had been drilled in the past five to six years. Researchers found that health symptoms reported by residents increased in frequency as distance between household and gas wells decreased. Among persons living less than one kilometer from drilling and fracking operations, rashes and upper respiratory problems were more prevalent. The authors of this study, the largest to date on the link between reported symptoms and natural gas drilling activities, say that their findings are "… consistent with earlier reports of respiratory and dermal conditions in persons living near natural gas wells." They also cite literature demonstrating the biological plausibility of a link between oil and gas extraction activities and both categories of health effects reported.[654]

- December 17, 2014 – As part of a lengthy review that became the foundation for New York State's ban on high volume hydraulic fracturing, the New York State Department of

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[651] Preidt, R. (2015, June 3). 'Fracking' linked to low birth weight babies, *WebMD*. Retrieved from http://www.webmd.com/parenting/baby/news/20150603/fracking-linked-to-low-birth-weight-babies

[652] Bamberger, M., & Oswald, R. E. (2015). Long-term impacts of unconventional drilling operations on humans and animal health. *Journal of Environmental Science and Health, Part A*: *Toxic/Hazardous Substances and Environmental Engineering, 50,* 447-59. doi: 10.1080/10934529.2015.992655

[653] Slizovskiy, I. B., Conti, L. A., Trufan, S. J., Reif, J. S., Lamers, V. T., Stowe, M. H., Dziura, J., & Rabinowitz, P. M. (2015). Reported health conditions in animals residing near natural gas wells in southwestern Pennsylvania, *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, *50*(5), 473-481, doi: 10.1080/10934529.2015.992666

[654] Rabinowitz, P. M. Slizovskiy, I. B, Lamers, V., Trufan, S. J., Holford, T. R., Dziura, J. D., … Stowe, M. H. (2015). Proximity to natural gas wells and reported health status: results of a household survey in Washington County, Pennsylvania. *Environmental Health Perspectives, 123*, 21-26. doi: 10.1289/ehp.1307732. See also footnote 29.

Health (NYS DOH) identified environmental problems associated with fracking that could contribute to adverse public health impacts. Among them: air pollution (particulate matter, ozone, diesel exhaust, and VOCs) that could affect respiratory health; drinking water contamination from underground migration of methane and/or fracking chemicals associated with faulty well construction or seismic activity; drinking water contamination from inadequate water treatment of fracking waste or from surface spills of fracking chemicals or wastewater; earthquakes and the creation of fissures; increased vehicle traffic; increased noise; increased demand for housing and medical care; and public health problems related to climate change impacts from methane and other greenhouse gas emissions into the atmosphere. The NYS DOH Public Health Review also discussed findings from surveys of health symptoms among residents living near high volume hydraulic fracturing activities. These included skin rash, nausea or vomiting, abdominal pain, breathing difficulties, cough, nosebleed, anxiety, stress, headache, dizziness, eye irritation, and throat irritation in populations living near drilling and fracking operations. The NYS DOH Public Health Review noted that ongoing studies by both government agencies and several academic institutions were exploring the public health risks and impacts of fracking but that many of these studies were years from completion. The review concludes:

> … significant gaps exist in the knowledge of potential public health impacts from [high volume hydraulic fracturing]…. The existing science investigating associations between [high volume hydraulic fracturing] activities and observable adverse health outcomes is very sparse and the studies that have been published have significant scientific limitations. Nevertheless, studies are suggestive of potential public health risks related to [high volume hydraulic fracturing] activity that warrant further careful evaluation.

In an accompanying letter to the New York State Department of Environmental Conservation, Health Commissioner Howard Zucker, MD, concluded,

> … the overall weight of the evidence from the cumulative body of information contained in this Public Health Review demonstrates that there are significant uncertainties about the kinds of adverse health outcomes that may be associated with [high volume hydraulic fracturing], the likelihood of the occurrence of adverse health outcomes and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health. Until the science provides sufficient information to determine the level of risk to public health from [fracking] to all New Yorkers and whether the risks can be adequately managed, DOH recommends that high volume hydraulic fracturing should not proceed in NYS.[655]

- October 13, 2014 – According to the North Dakota Health Department, the number of HIV and AIDS cases in North Dakota more than doubled between 2012 and 2014, and

[655] New York State Department of Health. (2014, December 17). *A public health review of high volume hydraulic fracturing for shale gas development*. Retrieved from http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

cases were shifting to the state's western oil fields, where 35-40 percent of all new cases occurred. Previously, only 10 percent of cases were in that region.[656] This trend followed on the heels of an upsurge in sexually transmitted chlamydia cases in the same region. The North Dakota state director of disease control, Kirby Kruger, attributed the uptick in HIV cases to the drilling and fracking industry and attempted to spread HIV prevention messages at the "man camps" that house young male workers in the oil industry.[657] Human trafficking for purposes of prostitution accompanied the fracking boom, but there was a shortage of medical professionals to address this public health crisis, according to Kruger, who noted that it was difficult to hire nurses and medical staff who could live in the area on a public health wage.

- October 2, 2014 – According to researchers from the University of Pennsylvania's Center of Excellence in Environmental Toxicology, an increasing number of gas wells in Pennsylvania is significantly correlated with inpatient rates of hospitalization. The research team collected data from seven different insurance providers for three counties; the study's publication is forthcoming.[658]

- September 11, 2014 – In Texas, commercial vehicle accidents have increased more than 50 percent since 2009 when the state's ongoing drilling and fracking boom began, according to an investigation by the *Houston Chronicle* and Houston Public Media News 88.7. "For six decades, highway deaths have dropped steadily all across the United States…. But in Texas all motor vehicle fatalities – and accidents involving commercial trucks – have turned back upward since the state's oil drilling and fracking boom began in 2008." This rising motor vehicle death toll is especially felt in formerly rural counties in the Eagle Ford and Permian Basin, now places of heavy drilling and fracking. A new Department of Public Safety "Road Check" program finds annually, "27 to 30 percent of Texas' commercial trucks shouldn't be operating at all due to potentially life-threatening safety problems like defective brakes, bald tires, inoperable safety lights and unqualified, unfit or intoxicated drivers."[659, 660]

- August 3, 2014 – Hospitals in the Bakken Shale region reported a sharp rise in ambulance calls and emergency room visits after 2006. "Mercy Medical Center in Williston and the Tioga Medical Center in neighboring Williams County saw their ambulance runs increase by more than 200 percent. Tioga's hospital saw a staggering leap in trauma patients by 1,125 percent. Mercy had a 373 percent increase." Drugs (including overdoses of

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[656] Associated Press. (2014, October 13). North Dakota HIV/AIDs rate rises with population growth. *Billings Gazette.* Retrieved from http://billingsgazette.com/news/state-and-regional/montana/north-dakota-hiv-aids-rate-rises-with-population-growth/article_a939fed6-f737-5cfb-957f-ab800673f4d7.html
[657] Heitz, D. (2014, September 30). Oil boom helps fuel surge in HIV in North Dakota. *HealthlineNews.* Retrieved from http://www.healthline.com/health-news/oil-boom-helps-fuel-hiv-surge-north-dakota-093014#1
[658] Skrapits, E. (2014, October 2). Study: More gas wells in area leads to more hospitalizations. *The Citizen's Voice*. Retrieved from http://citizensvoice.com/news/study-more-gas-wells-in-area-leads-to-more-hospitalizations-1.1763826
[659] Olsen, L. (2014, 11 September). Fatal truck accidents have spiked during Texas' ongoing fracking and drilling boom. *Houston Chronicle.* Retrieved from http://www.houstonchronicle.com/news/article/Fracking-and-hydraulic-drilling-have-brought-a-5747432.php?cmpid=email-premium&cmpid=email-premium&t=1a9ca10d49c3f0c8a9#/0
[660] Schneider, A. (2014, 12 October). In Texas, traffic deaths climb amid fracking boom. *National Public Radio*. Retrieved from http://www.npr.org/2014/10/02/352980756/in-texas-traffic-deaths-climb-amid-fracking-boom

prescription drugs, methamphetamine, and heroin) explain many of the cases, with oilfield related injuries such as “fingers crushed or cut off, extremity injuries, burns and pressure burns” accounting for 50 percent of the cases in one of the region’s hospital emergency rooms.[661]

- May 21, 2014 – Raising questions about possible links to worsening air pollution from the Uintah Basin’s 11,200 oil and gas wells, health professionals reported that infant deaths in Vernal, Utah, rose to six times the normal rate over the past three years. Physician Brian Moench said, “We know that pregnant women who breathe more air pollution have much higher rates of virtually every adverse pregnancy outcome that exists…. And we know that this particular town is the center of an oil and gas boom that’s been going on for the past five or six years and has uniquely high particulate matter and high ozone.”[662] Although it formerly had pristine air quality, Uintah County, Utah received a grade “F” for ozone in the American Lung Association’s 2013 State of the Air Report.[663]

- January 28, 2014 – Congenital heart defects, and possibly neural tube defects in newborns, were associated with the density and proximity of natural gas wells within a 10-mile radius of mothers’ residences in a study of almost 25,000 births from 1996 to 2009 in rural Colorado. The researchers note that natural gas development emits several chemicals known to increase risk of birth defects (teratogens).[664]

- January 4, 2014 – Preliminary data from researchers at Princeton University, Columbia University, and MIT showed elevated rates of low birthweight among infants born to mothers living near drilling and fracking operations during their pregnancies.[665]

- October 2013 – A preliminary study of the health impacts of oil and gas extraction on infant health in Colorado found that proximity to wells—linked with air pollutants from fracking operations—was associated with reductions in average birthweight and length of pregnancy as well as increased risk for low birthweight and premature birth.[666] A study by the same author, currently under review, which analyzed births to Pennsylvania mothers residing close to a shale gas well in Pennsylvania from 2003 to 2010, also identified increased risk of adverse effects. This includes low birth weight, as well as a 26 percent increase in APGAR scores under 8. (APGAR—or American Pediatric Gross

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[661] Bryan, K. J. (2014, August 3). Drugs, oilfield work, traffic pushing more people through doors of Watford City ER. *Bakken Today.* Retrieved from http://www.bakkentoday.com/event/article/id/37101/
[662] Schlanger, Z. (2014, May 21). In Utah boom town, a spike in infant deaths raises questions. *Newsweek*. Retrieved from http://www.newsweek.com/2014/05/30/utah-boom-town-spike-infant-deaths-raises-questions-251605.html
[663] American Lung Association. (2013). American Lung Association state of the air 2013. Retrieved from http://www.stateoftheair.org/2013/states/utah/uintah-49047.html
[664] McKenzie, L. M., Guo, R., Witter, R. Z., Savitz, D. A., Newman, L. S., & Adgate, J. L. (2014). Birth outcomes and maternal residential proximity to natural gas development in rural Colorado. *Environmental Health Perspectives, 122*, 412-417. doi: 10.1289/ehp.1306722
[665] Whitehouse, M. (2014, January 4). Study shows fracking is bad for babies. *Bloomberg*. Retrieved from http://www.bloombergview.com/articles/2014-01-04/study-shows-fracking-is-bad-for-babies
[666] Hill, E. L. (2013, October). The impact of oil and gas extraction on infant health in Colorado. Retrieved from http://www.elainelhill.com/research

Assessment Record—is a measure of newborn responsiveness. Scores of less than 8 predict an increase in the need for respiratory support.)[667] (See entry above for August 13, 2018.)

- August 26, 2013 – Medical experts at a rural clinic in heavily-drilled Washington County, Pennsylvania reported case studies of 20 individuals with acute symptoms consistent with exposure to air contaminants known to be emitted from local fracking operations.[668, 669]

- May 2, 2013 – A community-based participatory research study in Pennsylvania tested air and water quality and surveyed self-reported health symptoms of more than 100 residents living near drilling and fracking operations. The team detected a total of 19 VOCs in ambient air sampled outside of homes. The reported health symptoms closely matched the established effects of chemicals detected through air and water testing at those nearby sites. Moreover, those symptoms occurred at significantly higher rates in households closer to the gas facilities than those farther away.[670] Indicative of the growing prevalence of such health impacts in the state, a poll showed that two-thirds of Pennsylvanians support a moratorium on fracking because of concern about negative health impacts.[671]

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[667] Hill, E. L. (2013, December). Shale gas development and infant health: Evidence from Pennsylvania (under review). Retrieved from http://www.elainelhill.com/research.

[668] Abrams, L. (2013, August 26). Fracking's real health risk may be from air pollution. *Salon*. Retrieved from http://www.salon.com/2013/08/26/frackings_real_health_risk_may_be_from_air_pollution/

[669] Dyrszka, L., Nolan, K., & Steingraber, S. (2013, August 27). *Statement on preliminary findings from the Southwest Pennsylvania Environmental Health Project study* [Press release]. Concerned Health Professionals of NY. Retrieved from http://concernedhealthny.org/statement-on-preliminary-findings-from-the-southwest-pennsylvania-envir. . .

[670] Steinzor, N., Subra, W., & Sumi, L. (2013). Investigating links between shale gas development and health impacts through a community survey project in Pennsylvania. *New Solutions: A Journal of Environmental and Occupational Health Policy, 23*(1), 55-83. doi: 10.2190/NS.23.1.e

[671] Phillips, S. (2013, May 14). Poll shows support for a drilling moratorium in Pennsylvania. *StateImpact*. Retrieved from http://stateimpact.npr.org/pennsylvania/2013/05/14/poll-shows-support-for-a-drilling-moratorium-in-pennsylvania/

Noise pollution, light pollution, and stress

Drilling and fracking operations and ancillary infrastructure expose workers and nearby residents to continuous noise and light pollution that is sustained for periods lasting many months. Chronic exposure to light at night is linked to adverse health effects, including breast cancer. Sources of fracking-related noise pollution include blasting, drilling, flaring, generators, compressor stations, and truck traffic. Exposure to environmental noise pollution is linked to cardiovascular disease, cognitive impairment, and sleep disturbance. In Colorado, noise measured during construction and drilling of a large, multi-well pad in a residential area exceeded levels knowns to increase the risk of cardiovascular diseases and hypertension. In rural Canada, residents living near drilling and fracking operations experienced community upheaval and showed multiple signs of trauma. Oil and gas production noise may be disrupting wildlife health in protected areas. Workers and residents whose homes, schools, and workplaces are in close proximity to well sites are at risk from these exposures as well as from related stressors. Existing "setback distances" may not be adequate to reduce public health threats, especially for vulnerable populations. A UK Health Impact Assessment (HIA) identified stress and anxiety resulting from drilling-related noise—as well as from a sense of uncertainty about the future and eroded public trust—as key public health risks related to fracking operations.

- October 8, 2018 – Researchers collected noise measurements from residential areas, inside and outside homes, near two different gas well pads and a compressor station, north and south of Pittsburgh, Pennsylvania. Measurements from all of the outside areas had at least some decibel levels exceeding the recommended limits of the U.S. Environmental Protection Agency (EPA), and one indoor measurement near the compressor station exceeded the recommended level for noise measured inside homes. An accompanying survey documented that 96 percent of respondents were "worried about their overall health as a result of the noise." Fifty-seven percent were bothered "a great deal" by the noise, and slightly more than half of respondents said that their sleep was disturbed "a great deal" by the noise.[672]

- October 4, 2018 – In the month following one or more earthquakes greater than magnitude 4 experienced in an Oklahoma county, motor vehicle crashes increased 4.6 percent. Anxiety-inducing life events increase the risk of motor vehicle crashes, and earthquakes are known to increase anxiety. University of California, Berkeley public health researchers used data on Oklahoma earthquakes between 2010 and 2016, known to have drastically increased in the state due to fracking wastewater injection, and county-level monthly vehicle crash counts. Authors noted "the high economic and social costs of such vehicle crashes," which were $2.9 billion in Oklahoma in 2010.[673]

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[672] Richburg, C. M., & Slagley, J. (2018). Noise concerns of residents living in close proximity to hydraulic fracturing sites in Southwest Pennsylvania. *Public Health Nursing, 36,* 3-10. doi: 10.1111/phn.12540
[673] Casey, J. A., Elser, H., Goldman-Mellor, S., & Catalano, R. (2018). Increased motor vehicle crashes following induced earthquakes in Oklahoma, USA. *Science of the Total Environment, 650,* 2974-2979. doi: 10.1016/j.scitotenv.2018.10.043

- May 30, 2018 – Anxiety-related Google searches increased 5.8 percent during months when there was more than one magnitude 4 or higher earthquake experienced in Oklahoma, from January 2010 to May 2017. Google searches for anxiety peaked three weeks after magnitude 4 or higher quakes, University of California, Berkeley public health researchers found. Oil and gas wastewater injection has dramatically increased seismicity in Oklahoma; in the study period, there were 8,908 earthquakes across the state of Oklahoma, an average of 218 earthquakes per month. Authors noted, "excessive anxiety… may disable individuals and has long-term implications for health and functioning," and that "excessive symptoms of anxiety occur more readily in response to a recurrent and unpredictable stressor, such as the Oklahoma earthquakes included in our study."[674]

- May 11, 2018 – Over 40 percent of daytime and 23.6 percent of nighttime audible noise measurements taken during construction and drilling of a large, multi-well pad in a residential area were found to exceed the level that research has demonstrated to increase the risk of health effects, such as cardiovascular diseases and hypertension. When the researchers used an additional measurement that captures low frequency noise levels, these results showed that 97.5 percent of daytime and 98.3 percent of nighttime measurements exceeded the level "recommended to minimize impacts such as nausea and headaches." The measurements collected during this study were from four locations, over three months, in residential areas with oil and gas development in Colorado. Researchers concluded that the distances from the well pad at which some of their measurements were taken, highlight "that homes in closer proximity to operations will likely experience noise exposure at levels of concern even with the implementation of sound mitigation best management practices."[675]

- December 29, 2017 – Every participant reported experiencing effects in one or more of five categories—psychological stress, social stress, environment, physical health, and traffic—in a study of how residents of two adjacent counties in Ohio are impacted by unconventional natural gas development. Most respondents reported impacts in three or more of the five categories. Types of psychological stress reported included general stress and uncertainty about the future; feeling frustrated and manipulated after interactions with the oil and gas industry; experiencing stress from noise or light pollution; and regional displacement. Researchers found that experiences of social stress extended to include divisions among family or community; fears of, or direct experiences of, environmental health harms; observing dying, unhealthy trees; and traffic-related effects. Nearly all residents interviewed had experienced dangerous encounters with oil and gas truck drivers and observed that damaged roads had become increasingly common.[676]

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[674] Casy, J. A., Goldman-Mellor, S., & Catalano, R. (2018). Association between Oklahoma earthquakes and anxiety-related Google search episodes. *Environmental Epidemiology, 2*, e016. doi: 10.1097/EE9.0000000000000016

[675] Blair, B. D., Brindley, S., Dinkeloo, E., McKenzie, L. M., & Adgate, J. L. (2018). Residential noise from nearby oil and gas well construction and drilling. *Journal of Exposure Science & Environmental Epidemiology, 28,* 538–547. doi: 10.1038/s41370-018-0039-8

[676] Fisher, M. P., Mayer, A., Vollet, K., Hill, E L., & Haynes, E. N. (2018). Psychosocial implications of unconventional natural gas development: Quality of life in Ohio's Guernsey and Noble Counties. *Journal of Environmental Psychology, 55,* 90-98. Advance online publication. doi: 10.1016/j.jenvp.2017.12.008

- July 28, 2017 – A Canadian case study of the social impacts of fracking in a conservative, upper middle class, rural region of southern Alberta found that residents experienced "complete upheaval in their beliefs, and for many, their experiences with contamination, and fears of future exposure, dominate their lives."[677] Participants described acute impacts to their own health, to family members' health, to their livestock (including fertility problems), and to their land (included disrupted crop production and abrupt changes to the landscape). The study further reported that authorities failed to respond, "in a manner expected by the victims" to these problems. In addition, "corrosion of community" occurred at a time when victims needed community support the most. The author posited, following a consideration of the literature on toxic contamination and trauma, that her interviewees had experienced the three key indications of trauma: loss of agency, hyperarousal, and ontological insecurity linked to the negative effects on normal daily routines, a sense of order and continuity, and human dignity. The author noted that the contamination experienced by the interviewees reflected a "new normal of non-conventional fossil fuel industries."

- May 5, 2017 – Oil and gas production was one of the main anthropogenic noise sources (though the proportion for which it was responsible was not determined) in a study that quantified the degree and extent of noise pollution in U.S. protected areas (PAs) and critical habitat for endangered species. Authors "compared noise pollution among land management and protection status and investigated sources responsible for generating noise across PAs." The team of biologists and engineers found that human-caused noise doubled background sound in 63 percent of U.S. protected areas, and produced a tenfold or greater increase in 21 percent of protected areas. These levels are "known to interfere with human visitor experience and disrupt wildlife behavior, fitness, and community composition." Researchers also found a 10-fold increase in sound levels in 14 percent of critical habitats of endangered species.[678]

- April 3, 2017 – A University of Maryland team conducted a pilot study of noise pollution at eight homes located less than a half mile (750 meters) from natural gas compressor stations in West Virginia and compared decibel levels to those collected from homes located further away. They found that daytime and nighttime noise levels were higher at properties located closer to a compressor, as measured both inside and outside the homes. Five of six homes that were monitored for a full 24-hour period had combined day-night indoor average noise levels that exceed 60 decibels (dBA), which exceeds both EPA's recommended limits for chronic noise exposure as well those recommended by the World Health Organization. To date, no federal noise standards exist for oil and gas operations. Noting that noise exposure has been associated in previous studies with sleep disruption, poor academic performance, and hypertension, the authors conclude, "Findings indicate that living near natural gas compressor stations could potentially result

[677] Davidson, D. J. (2018) Evaluating the effects of living with contamination from the lens of trauma: A case study of fracking development in Alberta, Canada, *Environmental Sociology, 4*(2), 196-209. Advance online publication. doi: 10.1080/23251042.2017.1349638
[678] Buxton, R. T., McKenna, M. F., Mennitt, D., Fristrup, K., Crooks, K., Angeloni, L., & Wittemyer, G. (2017). Noise pollution is pervasive in U.S. protected areas. *Science, 356* (6337), 531-533. doi: 10.1126/science.aah4783

in high environmental noise exposures. Larger studies are needed to confirm these findings and evaluate potential health impacts and protections measures."[679]

- December 9, 2016 – A review analyzing the relevant scientific literature on the potential public health impacts of ambient noise related to unconventional oil and gas development found that "oil and gas activities produce noise at levels that may increase the risk of adverse health outcomes, including annoyance, sleep disturbance, and cardiovascular disease." The team of environmental and occupational health scientists collected available measurements of noise levels at oil and gas operations and analyzed the data with established noise standards. Authors stated that many noise sources from fracking operations are similar to those of conventional oil and gas development, but that high-volume hydraulic fracturing activities present additional noise risks. These arise from conditions including four to five times the length of time needed to drill the well, and the much greater volume of water and higher pressures needed, compared to a traditional vertical well. They described the complexity of noise associated with oil and gas operations, including both intermittent and continuous noise, varying in intensities. The review included focus on vulnerable populations, including children, the elderly, and the chronically ill. Authors noted that existing "setback distances" – already often the result of political compromise and not evidence-based – may be insufficient to reduce public health threats, and that maximum allowable noise levels should be lower for schools and hospitals.[680]

- July 9, 2015 – As part of its assessment of potential health impacts, the California Council of Science and Technology looked at the impacts of noise and light pollution from oil and gas operations in California. The researchers noted that a number of activities associated with drilling and fracking generated noise at levels considered dangerous to public health. Noise is a biological stressor that can aggravate or contribute to the development of hypertension and heart problems. In California, noise from well stimulation was associated with both sleep disturbance and cardiovascular disease in a dose-response relationship. Exposure to artificial light at night has been linked to breast cancer in women, although almost no research has been conducted on the public health implications of light pollution from oil and gas extraction specifically.[681]

- December 17, 2014 – The New York State Department of Health (NYS DOH) identified community impacts related to noise as a potential contributor to a variety of negative health impacts from drilling and fracking operations but noted that considerable scientific uncertainty remains on the issue of noise exposure per se as a risk factor. Noise, air

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[679] Boyle, M. D., Soneja, S., Quirós-Alcalá, L., Dalemarre, L., Sapkota, A. R., Sangaramoorthy, T. … Sapkota, A. (2017). A pilot study to assess residential noise exposure near natural gas compressor stations. *PLoS ONE, 12*(4), e0174310. doi: 10.1371/journal.pone.0174310

[680] Hays, J., McCawley, M., & Shonkoff, S. B. C. (2016). Public health implications of environmental noise associated with unconventional oil and gas development. *Science of the Total Environment, 580,* 448-556. doi: 10.1016/j.scitotenv.2016.11.118

[681] Shonkoff, S. B. C., Jordan, P., Hays, J., Stringfellow, W. T., Wettstein, Z. S., Harrison, R., . . . McKone, T. E. (2015, July 9). Volume II, Chapter 6: Potential impacts of well stimulation on human health in California. In: *An Independent Scientific Assessment of Well Stimulation in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from http://ccst.us/publications/2015/vol-II-chapter-6.pdf

pollution, traffic, vibration, odors, and nighttime lighting may all increase together as proximity to a drilling site decreases.[682]

- December 1, 2014 – Range Resources Corporation warned supervisors in Pennsylvania's Donegal Township that a "big burn" natural gas flare will continue for as long as a week and "will produce a continuous noise of as much as 95 decibels at the well pad. Sustained decibel levels between 90 and 95 can result in permanent hearing loss, but workers will be equipped with ear protection." Township supervisor Doug Teagarden expressed concern for residents, saying, "They told us the flare would be double the size of other well flares, and the noise will be like a siren on a firetruck…. There are houses within a couple of hundred yards of the well pad, and those folks are going to hear it."[683]

- November 6, 2014 – Sakthi Karunanithi, Director of Public Health in Lancashire, UK, reported on a Health Impact Assessment (HIA) of the two proposed shale gas exploration sites in Lancashire. Karunanithi's study determined that key risks to the health and well-being of the residents who live near the two proposed sites in Lancashire include stress and anxiety from uncertainty that could lead to "poor mental wellbeing," and noise-related health effects due to continuous drilling. The HIA also noted a lack of public trust and confidence.[684, 685]

- September 2014 – The Ohio Shale Country Listening Project, a collaborative effort to solicit, summarize, and share the perspectives and observations of those directly experiencing the shale gas build out in eastern Ohio, found that the more shale gas wells a community has, the less popular the oil and gas industry becomes. Many residents reported that they had not experienced the economic benefits promised by the oil and gas industry. They complained of increased rents and costs of gas and groceries, an influx of out-of-state workers, more vehicular accidents, road destruction from large trucks, and damaged landscape and cropland. Locals reported feeling less secure and more financially strapped.[686]

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[682] New York State Department of Health. (2014, December 17). *A public health review of high volume hydraulic fracturing for shale gas development*. Retrieved from http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

[683] Hopey, D. (2014, December 1). Gas flare to light up part of Washington County. *Pittsburgh Post Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/companies-powersource/2014/12/01/Gas-flare-to-light-up-part-of-Washington-County/stories/201411250224

[684] Karunanithi, S. (2014, November 6). Potential health impacts of the proposed shale gas exploration sites in Lancashire. *Reported at a meeting of the Lancashire County Council Cabinet, Thursday, 6th November, 2014 at 2.00 pm in Cabinet Room 'B' - County Hall, Preston, Item 9 on the agenda(1-68).* Retrieved from http://council.lancashire.gov.uk/documents/b11435/Potential%20Health%20Impacts%20of%20the%20Proposed%20Shale%20Gas%20Exploration%20Sites%20in%20Lancashire%2006th-Nov-2014%2014.pdf?T=9

[685] Dunkley, E. (2014, November 7). Fracking in Lancashire 'may affect mental health', report finds. *BBC NEWS Lancashire.* Retrieved from http://www.bbc.com/news/uk-england-lancashire-29944212

[686] Ohio Organizing Collaborative (OOC)'s Communities United for Responsible Energy (CURE), with support from the Ohio Environmental Council (OEC), FracTracker.org, and Laborers Local 809 of Steubenville. (2014, September). Ohio Shale Country Listening Project. Retrieved from http://carrollconcernedcitizens.org/uploads/2014_Shale_Report__small_.pdf

- June 20, 2014 – In its discussion of "Oil and Gas Drilling/Development Impacts," the U.S. Office of Indian Energy and Economic Development detailed noise pollution from bulldozers, drill rigs, diesel engines, vehicular traffic, blasting, and flaring of gas. "If noise-producing activities occur near a residential area, noise levels from blasting, drilling, and other activities could exceed the U.S. Environmental Protection Agency (EPA) guidelines. The movement of heavy vehicles and drilling could result in frequent-to-continuous noise…. Drilling noise would occur continuously for 24 hours per day for one to two months or more depending on the depth of the formation."[687] Exposure to chronic noise can be deadly. The World Health Organization has documented the connection between environmental noise and health effects, including cardiovascular disease, cognitive impairment, sleep disturbance, and tinnitus. At least one million "healthy life years" are lost every year from traffic-related noise in the western part of Europe.[688]

- February 24, 2014 – In a review of the health effects from unconventional gas extraction published in the journal *Environmental Science & Technology*, leading researchers noted, "Noise exposure is a significant hazard due to the presence of multiple sources, including heavy equipment, compressors, and diesel powered generators. Loud continuous noise has health effects in working populations. It is likely that exposure to noise is substantial for many workers, and this is potentially important for health because drilling and servicing operations are exempt from some sections of the Occupational Safety and Health Administration noise standard." They noted that research should investigate stressors such as noise and light in the context of drilling and fracking operations in order to understand the overall effect of chemical and physical stressors together.[689]

- May 30, 2014 – The *Denver Post* reported that in order to help meet Colorado's noise limits for fracking operations in suburban neighborhoods (and partially block the glare of floodlights), Encana Oil and Gas erected 4-inch-thick polyvinyl walls up to 32 feet high and 800 feet long. Residents said that the plastic walls do not completely solve the problem.[690]

- October 25, 2013 – An analysis of well location and census data by the *Wall Street Journal* revealed that at least 15.3 million Americans now live within a mile of a well that has been drilled since 2000. According to this investigation, the fracking boom has ushered in "unprecedented industrialization" of communities across wide swaths of the

[687] Oil and Gas Drilling/Development Impacts. (n.d.). *Oil and gas drilling/development impacts*. Retrieved from http://teeic.indianaffairs.gov/er/oilgas/impact/drilldev/index.htm
[688] Rodier, G. (2011, June 1). Burden of disease from environmental noise - Quantification of healthy life years lost in Europe. *WHO*. Retrieved from http://www.who.int/quantifying_ehimpacts/publications/e94888/en/
[689] Adgate, J. L., Goldstein, B. D., & McKenzie, L. M. (2014). Potential public health hazards, exposures and health effects from unconventional natural gas development. *Environmental Science & Technology 48*(15), 8307-20. doi: 10.1021/es404621d
[690] Finley, B. (2014, May 29). Oil and gas industry building giant walls to try to ease impact. *The Denver Post*. Retrieved from http://www.denverpost.com/ci_25859469/oil-and-gas-industry-building-giant-walls-try

nation and, with it, “24/7” industrial noise, stadium lighting, earth-moving equipment, and truck traffic.[691]

- April 16, 2013 – In a presentation on oil field light pollution for a conference on “Sustainable Environment and Energy: Searching for Synergies,” Roland Dechesne of the Royal Astronomical Society of Canada described problems of “light trespass,” glare, and poorly-aimed fixtures in oil fields in Alberta. He described resulting “mass waterfowl mortality” linked to artificial illumination and other biochemical impacts of light pollution on wildlife, as well as the possibility of these effects on humans, including circadian disruption, melatonin suppression, and possible resulting hormonally-linked diseases.[692] Known to have ecological impacts, outdoor light pollution from drilling and fracking operations may also be linked to artificial light-associated health effects documented in humans, including breast cancer.[693]

- April 2013 – Led by the University of Pittsburgh Graduate School of Public Health, a study of community members living in proximity to Marcellus Shale drilling in Pennsylvania found adverse impacts to mental health, with stress the most frequently reported symptom. At least half of all respondents in each set of interviews reported these specific stressors, including: being taken advantage of; health concerns; concerns/complaints ignored; corruption; denied information or provided with false information. Many also reported the desire to move or leave community, estrangement from community, and financial damages. Researchers noted that stress can result in direct health impacts.[694] Notably, mounting evidence indicates that chronic stress magnifies individuals’ susceptibility to effects of pollution; for children, this interactive effect can begin during prenatal life.[695]

- September 7, 2011 – A study by researchers at Boise State University and Colorado State University at Fort Collins modeled the potential impacts of compressor station noise from oil and gas operations on Mesa Verde National Park in Colorado. The study found the sound of 64 compressors outside Mesa Verde elevated the sound level within the park by 34.8 decibels on average, and by 56.8 decibels on the side of the park located closest to

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[691] Gold, R., & McGinty, T. (2014, Oct. 25). Energy boom puts wells in America’s backyards. *The Wall Street Journal.* Retrieved from http://online.wsj.com/news/articles/SB10001424052702303672404579149432365326304
[692] Dechesne, R. (2013). Limiting oil field light pollution for safety and the environment. Sustainable Environment and Energy CPANS 2013 Conference. Retrieved from http://www.cpans.org/assets/Uploads/Presentations/NewFolder/Session-46Roland-Dechesne.pdf
[693] Chepesiuk, R. (2009). Missing the dark: Health effects of light pollution. *Environmental Health Perspectives,117*(1), A20–A27.
[694] Ferrar, K. J., Kriesky, J., Christen, C. L., Marshall, L. P., Malone, S. L., Sharma, R. K., . . . Goldstein, B.D. (2013). Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region. *International Journal of Occupational & Environmental Health*, *19*(2),104-112. doi: 10.1179/2049396713Y.0000000024
[695] Cooney, C.M. (2011). Stress–pollution interactions: An emerging issue in children’s health research. *Environmental Health Perspectives, 119*, a430-a435. http://dx.doi.org/10.1289/ehp.119-a430

the compressors. According to the EPA, 55 decibels is the highest “safe noise level” to avoid damage to the human ear.[696]

[696] Barber, J. R., Burdett, C.L., Reed, S. E., Warner, K.A., Formichella, C., Crooks, K.R., . . . Fristrup, K. M. (2011). Anthropogenic noise exposure in protected natural areas: Estimating the scale of ecological consequences. *Landscape Ecology, 26*(9), 1281-1295. doi: 10.1007/s10980-011-9646-7

Earthquakes and seismic activity

Definitive evidence from Ohio, Arkansas, Texas, Oklahoma, Kansas, and Colorado links fracking wastewater disposal wells to earthquakes of magnitudes as high as 5.8, in addition to swarms of minor earthquakes. Both the U.S. Geological Survey (USGS) and state geological agencies such as the Oklahoma Geological Survey now acknowledge that earthquakes can be caused by wastewater injection into disposal wells. Many recent studies focus on the mechanical ability of pressurized fluids to trigger seismic activity by unclamping stressed faults. In some cases, and especially in Canada, Oklahoma, Ohio, and China, the fracking process itself has been linked to earthquakes. Emerging evidence suggests that risk of earthquakes can continue to rise for years after waste injection and cannot be prevented through "proper" fracking protocols or by solely limiting the rate or volume of injected fluid. Injecting fracking waste into shallower zones is one method for reducing earthquake risk, but shallow injection raises the risk for groundwater contamination. The question of what to do with fracking wastewater remains a problem with no viable, safe solution.

- March 27, 2019 – The USGS deployed additional seismometers in the area around south Alabama and the Florida Panhandle following the detection of five earthquakes in the course of a week. The earthquakes, ranging in magnitude from 2.1 to 3.7, occurred in an area flagged as likely experiencing more seismic activity over the past decade due to oil and gas operations in the area.[697] In 1997, a series of earthquakes, including the second largest in Alabama's history (at magnitude 4.9), occurred in the same region and was tentatively linked to oil and gas drilling and two associated injection wells nearby.[698]

- March 8, 2019 – Over a two-day period in February 2019, three earthquakes struck a farming community in an area of China's Sichuan Province that is experiencing a fracking boom. Two people were killed, 13 injured, 20,000 homes destroyed, and 1,600 people displaced. In response to citizen protests, fracking operations were suspended.[699]

- March 1, 2019 – A USGS-led team monitored leakage and fluid pressure over time in a permeable bedrock formation used for disposal of fracking waste in Osage County, Oklahoma. By inserting specially designed instruments into an unused disposal well within this formation, the team demonstrated an overall trend of increasing fluid pressure. "The only conceivable source of this increase is due to the injection of wastewater." The results also showed evidence that fracking waste is leaking out of the reservoir where it is being injected "at a significant rate." The direction of the leakage appears mostly downward into the basement rock below. The authors note that disposal of fracking waste

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[697] Pillion, D. (2019, March 27). Did fracking cause south Alabama earthquakes? Federal researchers investigating. *Al.com.* Retrieved from https://www.al.com/news/mobile/2019/03/did-fracking-cause-south-alabama-earthquakes-federal-researchers-investigating.html

[698] Gomberg, J., & Wolf, L. (1999). Possible cause for an improbable earthquake: The 1997 M_w 4.9 southern Alabama earthquake and hydrocarbon recovery. *Geology, 27*(4), 367-370. doi: 10.1130/0091-7613(1999)027<0367:<PCFAIE>2.3CO;2

[699] Myers, S. L. (2019, March 8). China experiences a fracking boom, and all the problems that go with it. *New York Times.* Retrieved from https://www.nytimes.com/2019/03/08/world/asia/china-shale-gas-fracking.html?smid=nytcore-ios-share

is the leading cause of pressure changes on faults in Oklahoma and that fluid pressure changes are, in turn, the leading cause of earthquakes in Oklahoma.[700]

- December 12, 2018 – For six continuous years, hydraulic fracturing and related activities have triggered multiple earthquakes of varying magnitudes in northwestern Alberta and northeastern British Columbia, with the operations of one company linked to tremors that have jolted Fort St. John from 2012 to 2018.[701] Between September 2013 and January 2015 alone, researchers in western Alberta, Canada detected than 900 seismic events, ranging in magnitude from 1 to 4. Real-time recordings of seismic activity were generally consistent with published empirical and point-source simulation models. Approximately 80 percent of the events in the compiled database occurred "in distinct clusters in time and space that are characteristic of induced events."[702] These induced earthquakes pose hazards to roads, pipelines, dams, groundwater, and public safety. Canadian scientists question whether any regulatory system could effectively forecast, control, or prevent them. In some cases, cessation of injection activities following large, potentially damaging earthquakes appears to a sufficient response. However, in other cases, quakes occur months after injection activities, falling outside the windows of immediate intervention that most "traffic light systems" are put in place to address.[703] Further, companies are allowed to continue their activities despite predictions that considerable seismic activity may result, including earthquakes of much greater magnitude than predicted.[704]

- November 28, 2018 – Noting that fracking is a microseismic event, a research team investigated whether the activity of hydraulic fracturing itself, and not just the disposal of fracking waste, can trigger earthquakes and might be contributing to the dramatic increases in frequency of seismic events across the central and eastern United States. The team focused on Oklahoma where they identified roughly 700 fracking-induced earthquakes, including 12 with magnitude between 3 and 3.5. Previous reports had described only two fracking-induced earthquakes in Oklahoma. Results also confirmed that, in Oklahoma, proximity of an injection site to a critically stressed fault is a better predictor of induced seismicity than a more commonly accepted general approach based on proximity to the Precambrian basement layer. These results demonstrate that public research provides far greater detail and accuracy than data and notifications voluntarily released by drilling operators.[705]

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[700] Barbour, A. J., Xue, L., Roeloffs, E., & Rubinstein, J. L. (2019). Leakage and increasing fluid pressure detected in Oklahoma's wastewater disposal reservoir. *JGR Solid Earth, 124*(3), 2896-2919. doi: 10.1029/2019JB017327
[701] Nikiforuk, A. (2018, December 12). Company linked to tremors that jolted Fort St. John triggered previous quakes. *The Tyee.* Retrieved from https://thetyee.ca/News/2018/12/12/Fort-St-John-Tremors/
[702] Novakovic, M., & Atkinson, G. M. (2015). Preliminary evaluation of ground motions from earthquakes in Alberta. *Seismological Research Letters, 86*(4). doi: 10.1785/0220150059
[703] Nikiforuk, A. (2018, December 4). Fracking linked to quake that jolted Fort St. John. *The Tyee.* Retrieved from https://thetyee.ca/News/2018/12/04/Fracking-Linked-Quake-Jolted-Fort-St-John/
[704] Little, S. (2018, December 22). Fort St. John earthquakes were caused by fracking: BC Oil and Gas Commission. *Global News.* Retrieved from https://globalnews.ca/news/4789210/fort-st-john-frackqing-earthquakes/
[705] Skoumal, R. J., Ries, R., Brudzinski, M. R., Barbour, A. J., & Currie, B. S. (2018). Earthquakes induced by hydraulic fracturing are pervasive in Oklahoma. *Journal of Geophysical Research: Solid Earth, 123,* 10,918-10,935. doi: 10.1029/2018JB016790

- November 11, 2018 – In Lancashire, England, fracking has triggered at least 37 minor earthquakes. Regulations require suspension of fracking activities when seismicity exceeds magnitude 0.5. Energy company Cuadrilla, which had previously supported these limits, lobbied the government to relax the regulations in order to allow fracking to continue. These calls have been rejected by the energy minister.[706]

- October 31, 2018 – A holistic analysis of fracking waste disposal practices and seismicity compared intensely drilled regions across the United States, including the Bakken, Eagle Ford, and Permian shale basins, as well as basins in Oklahoma. Results showed consistent links between increased seismicity and increased depth of wastewater injection, increased rate of injection, and increased regional injection volumes. Shallower disposal wells help lower the risk of earthquakes. However, they raise the risk of groundwater contamination as increased pressures can push fluids through "faults or fractures or through abandoned oil wells that have not been properly plugged." The researchers also noted that deep waste disposal carries the risk of introducing toxic fluids into karstified areas where there is "limited geologic characterization of the disposal zone." These deep, cave-like zones may transmit fluids in an unknown, unpredictable fashion.[707]

- August 31, 2018 – To delineate possible mechanisms for the induction of earthquakes at unexpectedly large distances from injection wells, researchers looked at data in the public domain from around the world. They found two patterns. One type of seismicity, manifesting a "direct pressure effect," clusters near wells and tends to be shallow, of modest magnitude, and to decay abruptly. The second type of seismicity, potentially triggered by elastic stresses, tends to occur in deeper layers, decay slowly, and exhibit larger spatial footprints and magnitudes. Both shallow and deep formations present unique risks, and these should be included in mitigation strategies.[708] With low to moderate-sized human-made earthquakes putting 1 in 50 people in the United States at risk according to a recent USGS analysis, injection practices for oil and gas wastewater are "creating a ripple effect far beyond … drilling locations."[709]

- April 27, 2018 – The use of fracking to enhance geothermal energy recovery activated two faults in a previously unknown fault system and triggered a magnitude 5.5 earthquake near Pohang, South Korea. Using primarily publicly available data, the researchers characterized the fault dimensions, faulting mechanism, and depth of

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706 Vaughan, A. (2018, November 11). Fracking firm boss says it didn't expect to cause such serious quakes. *The Guardian.* Retrieved from https://www.theguardian.com/environment/2018/nov/11/fracking-firm-boss-says-it-didnt-expect-to-cause-such-serious-quakes-lancashire?fbclid=IwAR2BEOJ3ySPm-7WiigVilQQyyjdzqAxOHbZxYGEH4s9RFbObbUfPwKGW9dM

707 Scanlon, B. R., Weingarten, M. B., Murray, K. E., & Reedy, R. C. (2018). Managing basin-scale fluid budgets to reduce injection-induced seismicity from the recent U.S. shale oil revolution. *Seismological Research Letters*, *90*(1), 171-182. doi: 10.1785/0220180223

708 Goebel, T. H. W., & Brodsky, E. E. (2018). The spatial footprint of injection wells in a global compilation of induced earthquake sequences. *Science, 361*(6405), 899–904. doi: 10.1126/science.aat5449

709 Guarino, B. (2018, August 30). How energy companies set off earthquakes miles away from their waste dumps. *Washington Post.* Retrieved from https://www.washingtonpost.com/science/2018/08/30/how-energies-companies-set-off-earthquakes-miles-away-their-waste-dumps/?utm_term=.ee67ec5d693a

earthquake activity, which correlated with surface deformation at the time of the earthquake activity. The earthquake's main shock caused extensive structural damage to buildings in and around Pohang and injured 70 people.[710]

- March 16, 2018 – Utilizing satellite radar imagery, researchers observed and analyzed ground deformation, earthquake activity, and subsidence (depressions and sinkholes) that appear to be the result of "decades of oil activity and its effects on rocks below the earth's surface."[711, 712] Noting that West Texas has been "punctured like a pincushion with oil wells and injection wells since the 1940s," the team documented an "alarming rate" of heaving and sinking across a 4,000-square-mile area.[713] The researchers documented visible surface-level and subsurface changes from fracking, fracking waste injection, carbon dioxide injection that is used to aid in oil and gas exraction, and abandoned and uncapped wells. Some data may help sort out why hazards manifest in one site rather than another. Satellite assessments of deformation can provide crucial safety information to protect roadways, homes, businesses, industrial facilities, pipelines, and people from "potential larger catastrophic events."

- February 27, 2018 – Since December 2016 in Oklahoma, 74 earthquakes of at least 2.5 magnitude have been linked directly to fracking. As a result, state regulators tightened mitigation protocols and required operators to use seismic arrays to detect underground movement and pause their work when earthquakes exceed magnitude 2.5.[714] These changes make Oklahoma's new regulations tougher than Canada's, where "the industry holds the record for causing magnitude 4-plus earthquakes by high volume fracking."[715] Described by industry sources as "a cautious move forward, limiting though not hamstringing [the] oil industry," the new regulations will be evaluated in the field for their effectiveness in reducing the frequency of earthquakes large enough to be felt at the surface.[716]

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[710] Grigoli, F., Cesca, S., Rinaldi, A. P., Manconi, A., López-Comino, J. A., Clinton, J. F., . . . S. Wiemer, S. (2018). The November 2017 Mw 5.5 Pohang earthquake: A possible case of induced seismicity in South Korea. *Science*, *360*(6392), 1003-1006. doi: 10.1126/science.aat2010

[711] Kim, J.-W., & Lu, Z. (2018). Association between localized geohazards in West Texas and human activities, recognized by Sentinel-1A/B satellite radar imagery. *Scientific Reports, 8,* 4727. doi: 10.1038/s41598-018-23143-6

[712] Greene, S. (2018, March 22). Large portions of West Texas sinking at alarming rate, new report finds. *Texas Tribune.* Retrieved from https://www.texastribune.org/2018/03/22/report-says-large-portions-west-texas-counties-are-sinking-alarming-ra/

[713] Allen, M. (2018, March 20). Radar images show large swath of West Texas oil patch is heaving and sinking at alarming rates. *SMU Research News.* Retrieved from https://blog.smu.edu/research/2018/03/20/radar-images-show-large-swath-of-texas-oil-patch-is-heaving-and-sinking-at-alarming-rates/

[714] Oklahoma Corporation Commission, & Oklahoma Geological Survey. (2018, February 27). Moving forward: New protocol to further address seismicity in state's largest oil and gas play. Retrieved from https://earthquakes.ok.gov/wp-content/uploads/2018/03/02-27-18-PROTOCOL.pdf

[715] Nikiforuk, A. (2018, March 9). Spooked by quakes, Oklahoma toughens fracking rules. *The Tyee.* Retrieved from https://thetyee.ca/News/2018/03/09/Oklahoma-Toughens-Fracking-Rules/

[716] Oil Industry News. (2018, March 2). Oklahoma toughens oil fracing rules as shale earthquakes climb. *oilandgaspeople.com.* Retrieved from https://www.oilandgaspeople.com/news/16214/oklahoma-toughens-oil-fracing-rules-as-shale-earthquakes-climb/

- February 20, 2018 – Researchers in Kansas used high-precision data from an extensive seismometer network to detail features of a surge of earthquakes that they concluded were induced by wastewater injection in southern Kansas. Some areas were free from earthquakes, despite injection activities, suggesting that unknown local geological conditions play a role in determining seismic activity. Lack of seismic activity in these areas is "either due to a lack of fluid pathways to the basement [deep geological layer] or due to the absence of faults that are close to failing." Regional influences led to more prolonged seismicity and were observed from wastewater injection wells located 10 or more kilometers away.[717]

- February 15, 2018 – In Kansas, swarms of earthquakes near oil wastewater disposal wells began in 2013. By 2017, the prodigious volumes of injected fluid created sufficient pressure to trigger earthquakes more than 50 miles away and form a "triggering front" that advanced at an average rate of nearly 10 miles per year along a permeable fault zone.[718] A mapping project based on gravity loads, magnetic fields, and seismic activity dating to 1979 revealed a previously unidentified subsurface fault running from central Nebraska 200 miles southeast to Kansas.[719]

- February 5, 2018 – Focusing their investigation on areas in Ohio that are isolated from fracking waste injection activities, researchers found that fracking itself induced earthquakes in two distinct manners. In some cases, earthquake activity occurred in shallow subsurface layers and was of short duration and small magnitude. In other, more troubling cases, earthquakes were more powerful and took place in very deep layers, far below the layers being fracked, even when fracking did not directly contact faults in the basement rock. At three of five sites, earthquake activity continued for over a month after fracking activities ceased. These results support a causal role for poroelastic stress, sometimes operating over long distances, in addition to more predictable pore fluid pressure changes, in the generation of earthquakes by fracking.[720, 721]

- January 19, 2018 – Some of the largest earthquakes related to fracking have occurred near Fox Creek, Alberta, in Canada. Using publicly available data, researchers studied earthquakes induced both by fracking waste injection and by hydraulic fracturing itself. In both cases, the volume of fluid injected, rather than injection rate or injection pressure,

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[717] Rubinstein, J. L., Ellsworth, W. L., & Dougherty, S. L. (2018). The 2013–2016 Induced Earthquakes in Harper and Sumner Counties, Southern Kansas. *Bulletin of the Seismological Society of America*, *108*(2), 674-689. doi: 10.1785/0120170209

[718] Peterie, S. L., Miller, R. D., Intfen, J. W., & Gonzales, J. B. (2018). Earthquakes in Kansas induced by extremely far-field pressure diffusion. *Geophysical Research Letters, 45,* 1395-1401. doi: 10.1002/2017GL076334

[719] Dunker, C. (2018, April 21). Spate of Nebraska earthquakes might be linked to Kansas tremors, UNL student researcher says. *Lincoln Journal Star.* Retrieved from https://journalstar.com/news/local/education/spate-of-nebraska-earthquakes-might-be-linked-to-kansas-tremors/article_b81d0bdc-5b0e-5c98-a155-5f6499356b4d.amp.html?__twitter_impression=true

[720] Kozłowska, M., Brudzinski, M. R., Friberg, P., Skoumal, R. J., Baxter, N. D., & Currie, B. S. (2018). Maturity of nearby faults influences seismic hazard from hydraulic fracturing. *PNAS, 115*(8), E1720-E1729. doi: 10.1073/pnas.1715284115

[721] Kowalski, K. M. (2018, February 7). Fracking in shale plays could trigger earthquakes in deeper faults: Study. *Energy News Network*. Retrieved from https://energynews.us/2018/02/07/midwest/fracking-in-shale-plays-could-trigger-earthquakes-in-deeper-faults-study/

was most strongly correlated with seismic activity. Geologic factors also played a role, with earthquakes more likely if fracking and disposal activities were conducted closer to faulting and areas of stress. Combining injected volume with geologic factors, researchers developed a model that can predict 96 percent of the seismic variability in the region, improving hazard estimations. Calculating a "seismogenic activation potential," particularly if coupled with microseismic monitoring in real time to detect previously unknown faulting, may improve earthquake forecasting.[722]

- November 24, 2017 – A team of geologists confirmed conclusively that recent earthquakes in Texas' Fort Worth Basin were induced by underground injection of fracking waste that caused deep, critically stressed faults to slip.[723] The authors of this study employed a classical structural geology analysis that relied on high-resolution seismic reflection imaging, described in an interview with geophysical researcher Maria Magnani as "a little bit like an ultrasound."[724] Maps of the seismically active faults in the Fort Worth Basin show no evidence of previous motion over the past millions of years and instead have been "sleeping" for approximately the past 300 million years until "awakened" at the start of the 2008 earthquake swarm associated temporally with extensive wastewater injection activities.[725]

- October 21, 2017 – Extending the findings of two previous studies, an investigation of earthquakes in the Raton Basin along the border of New Mexico and Colorado identified wastewater injection wells as the cause of the quakes and identified a mechanism.[726] All together, the location of the earthquakes, modeled pore pressures, and the direct correlation between cumulative volume of injected waste in nearby wells and the number of quakes show that seismicity in the Raton Basin is likely induced, and that elevated pore pressures deep underground are "well above earthquake-triggering thresholds."[727]

- September 14, 2017 – An investigation by *Politico* found that the U.S. crude oil storage hub in Cushing, Oklahoma—the world's largest store of oil—was not designed with

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[722] Schultz, R., Atkinson, G., Eaton, D. W., Gu, Y. J., & Kao, H. (2018). Hydraulic fracturing volume is associated with induced earthquake productivity in the Duvernay play. *Science, 359,* 304-308. doi: 10.1126/science.aao0159

[723] Magnani, M. B., Blanpied, M. L., DeShon, H. R., & Hornbach, M. J. (2017). Discriminating between natural versus induced seismicity from long-term deformation history of intraplate faults. *Science Advances, 3*(11), e1701593. doi: 10.1126/sciadv.1701593

[724] Guarino, B. (2017, November 24). Oil and gas industry is causing Texas earthquakes, a 'landmark' study suggests. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/speaking-of-science/wp/2017/11/24/fracking-and-other-human-activities-are-causing-texas-earthquakes-study-suggests/?tid=ss_tw&utm_term=.02bfff4181f1

[725] Kuchment, A. (2017, November 24). Drilling reawakens sleeping faults in Texas, leads to earthquakes. *Scientific American.* Retrieved from https://www.scientificamerican.com/article/drilling-reawakens-sleeping-faults-in-texas-leads-to-earthquakes/?utm_source=newsletter&utm_medium=email&utm_campaign=weekly-review&utm_content=link&utm_term=2017-11-29_featured-this-week

[726] Nakai, J. S., Weingarten, M., Sheehan, A. F., Bilek, S. L., & Ge, S. (2017). A possible causative mechanism of Raton Basin, New Mexico and Colorado earthquakes using recent seismicity patterns and pore pressure modeling. *Journal of Geophysical Research: Solid Earth, 122.* doi: 10.1002/2017JB014415

[727] Scott, J. (2017, October 24). Raton Basin earthquakes linked to oil and gas fluid injections. *University of Colorado Boulder.* Retrieved from https://www.colorado.edu/today/2017/10/24/raton-basin-earthquakes-linked-oil-and-gas-fluid-injections

seismic considerations in mind, nor are there seismic regulations in place for its 250,000-barrel oil tanks, which are under the purview of the Department of Transportation's Pipeline and Hazardous Materials Safety Administration. Central Oklahoma, where Cushing is located, became seismically active about five years ago when "wastewater injection and other fracking-related activities changed the seismic face of Oklahoma in dramatic fashion."[728] (See also entry below for November 8, 2016.)

- August 11, 2017 – Using multiple lines of evidence, researchers in China determined that a series of high-magnitude earthquakes between 2014 and 2017 in Sichuan Basin was triggered by fracking activities that re-activated pre-existing faults. "The present study shows that short-term injections (continuing over several months) for shale gas hydraulic fracturing are … very likely to induce M_W 4–5 class earthquakes in sites with similar geological and tectonic conditions within the southern Sichuan Basin."[729]

- May 3, 2017 – Studying two patterns of fracking waste injection in Oklahoma, geologists observed a large, unexpected impact on seismic activity at sites where injection rates drastically changed in recent years, as compared with those whose injection volumes held steady. They demonstrated that, in addition to direct pore pressure effects, deformations due to fluid flows ("poroelastic effects") play an important role in generating earthquake activity. Elevated risks for earthquakes can persist years after fracking waste is injected underground. Their findings also showed that the "magnitude of the initial change in injection rate is particularly important, but the opposite effect occurs in the transition to zero injection" (i.e., shut-in or closing a well). This result implies that "in certain faulting regimes it is theoretically possible to mitigate damaging effects of rapid shut-in by carefully tapering injection rates."[730] Geophysicist Andrew Barbour, lead author of the study, said that fluctuating injection rates likely have a "profound effect" on earthquake risk.[731] These findings suggest that the 2016 Pawnee earthquake, the strongest earthquake ever recorded in Oklahoma, may have been triggered by pulses of underground oil and gas activity years earlier.[732]

- April 27, 2017 – Recognizing that increased seismicity from both hydraulic fracturing and underground disposal of fracking wastewater poses a hazard to critical infrastructure, such as large dams, a Canadian geologist proposed strategies to keep the likelihood of

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[728] Ogrocki, S. (2017, September 24). How man-made earthquakes could cripple the U.S. economy. *Politico.* Retrieved from http://www.politico.com/magazine/story/2017/09/14/earthquakes-oil-us-economy-fracking-215602
[729] Lei, X., Huang, D., Su, J., Jiang, G., Wang, X., Wang, H., . . . Fu, H. (2017). Fault reactivation and earthquakes with magnitudes of up to M_w4.7 induced by shale-gas hydraulic fracturing in Sichuan Basin, China. *Scientific Reports, 7,* 7971. doi: 10.1038/s41598-017-08557-y
[730] Barbour, A. J., Norbeck, J. H., & Rubinstein, J. L. (2017). The effects of varying injection rates in Osage County, Oklahoma, on the 2016 Mw 5.8 Pawnee earthquake. *Seismological Research Letters, 88*(4), 1040-1053. doi: 10.1785/0220170003
[731] Jones, C. (2017, May 7). USGS study 'strongly suggests' short-term variations in disposal volumes served as trigger for Pawnee earthquake. *Tulsa World.* Retrieved from http://www.tulsaworld.com/earthquakes/usgs-study-strongly-suggests-short-term-variations-in-disposal-volumes/article_97de08d5-9327-505d-8b51-adbc716d6c69.html
[732] Wertz, J. (2017, May 4). Study links pulse of oil-field wastewater to Oklahoma's strongest earthquake. *StateImpact Oklahoma.* Retrieved from https://stateimpact.npr.org/oklahoma/2017/05/04/study-links-pulse-of-oil-field-wastewater-to-oklahomas-strongest-earthquake/

high-failure consequences under one per ten thousand per year.[733] The primary strategy is the creation of "no frack" exclusion zones with a 5-kilometer (3.1 mile) radius that would surround vulnerable, critical facilities. In a larger ring beyond the exclusion zone, to approximately 25 kilometers (15.5 miles), monitoring and response protocols would be used.[734]

- March 1, 2017 – Despite decreases of up to 40 percent in the volume of fracking wastewater injected underground in Oklahoma, researchers from the USGS Earthquake Hazard Program forecasted that seismic hazards would remain significantly elevated there throughout 2017, with the odds of damage from induced earthquakes within the next year "similar to that of natural earthquakes in high-hazard areas of California." About three million people in Oklahoma and southern Kansas now live with continuing increased potential for damaging shaking from induced seismicity."[735] According to Mark Petersen, chief of the USGS National Seismic Hazard Mapping Project, the hazard risk remains "hundreds of times higher than before man-made activity began."[736]

- February 17, 2017 – Pennsylvania's Department of Environment Protection (PA DEP) announced that a series of small earthquakes in Lawrence County had been induced by fracturing of wells in the Utica Shale.[737] PA DEP officials held a webinar to discuss the situation and formulate "procedures to reduce seismic risk going forward," but no formal report or regulatory changes have yet been made public.[738]

- December 20, 2016 – In an attempt to reduced the risk of earthquakes caused directly by fracking, the Oklahoma Corporation Commission's Oil and Gas Conservation Division introduced monitoring and response guidelines that include provisions requiring oil producers to "implement mitigation plans following an earthquake of magnitude 2.5 or more and to suspend operations following a quake of magnitude 3.5 or greater."[739]

- November 17, 2016 – A study of fault activation found a connection between fracking and earthquake activity in a region of Alberta, Canada that had previously been

[733] Atkinson, G. M. (2017). Strategies to prevent damage to critical infrastructure due to induced seismicity. *FACETS, 2,* 374–394. doi: 10.1139/facets-2017-0013
[734] Nikiforuk, A. (2017, July 24). Earthquake expert proposes 'no frack zone' around critical infrastructure. *The Tyee.* Retrieved from https://thetyee.ca/News/2017/07/24/Critical-Infrastructure-No-Frack-Zone/
[735] Petersen, M. D., Mueller, C. S., Moschetti, M. P., Hoover, S. M., Shumway, A. M., McNamara, D. E., . . . Rukstales, K.S., (2017). 2017 one-year seismic-hazard forecast for the central and eastern United States from induced and natural earthquakes. *Seismological Research Letters, 88*(3). doi: 10.1785/0220170005
[736] Wilmoth, A. (2017, March 1). Oklahoma considered at 'significant potential' for damaging earthquakes. *News OK.* Retrieved from http://newsok.com/article/5539785https://mail.google.com/mail/u/0/
[737] Legere, L. (2017, February 17). DEP links Lawrence County earthquakes to fracking. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/policy-powersource/2017/02/16/DEP-Pennsylvania-Lawrence-County-earthquakes-appear-linked-to-fracking-Hilcorp-Energy/stories/201702160176
[738] Pennsylvania Department of Environmental Protection. (2017, February 17). *Advisory – Department of Environmental Protection to hold webinar on 2016 Lawrence County seismic events.* Retrieved from http://www.ahs.dep.pa.gov/NewsRoomPublic/articleviewer.aspx?id=21145&typeid=1
[739] Hampton, L. (2016, December 20). Oklahoma's new fracking guidelines aim to reduce quake risk. *Reuters.* Retrieved from https://www.reuters.com/article/us-oklahoma-quake-rules/oklahomas-new-fracking-guidelines-aim-to-reduce-quake-risk-idUSKBN1492R6

seismically quiescent. The researchers demonstrated that new earthquake activity in the Fox Creek area was tightly spatially correlated with hydraulic fracturing activities. Their findings further suggested that seismic activity resulted from "stress changes due to the elastic response of the rockmass to hydraulic fracturing," as well as "pore-pressure changes due to fluid diffusion along a permeable fault zone."[740] In contrast to the central United States, where induced seismic activity is primarily caused by massive underground disposal of fracking waste, these findings pointed to the fracking process itself as the trigger. In an interview with the *New York Times,* co-author David Eaton compared fracking to a series of "small underground explosions" that travel into the rock formation and "rapidly change the stress patterns within." These stress changes can be sufficient to trigger a slip at a critically stressed, previously undetected fault.[741]

- November 17, 2016 – An investigation by the *Dallas Morning News* chronicled a pattern of corruption and regulatory failings at the Texas Railroad Commission, the state agency charged with overseeing the oil and gas industry, in its disregard of evidence linking fracking waste disposal to earthquakes in North Texas.[742]

- November 8, 2016 – On November 6, 2016, a magnitude 5.0 earthquake struck Cushing, Oklahoma near the oil hub where 60 million barrels of crude oil were stored. The quake injured one, damaged more than 40 buildings, closed a school, and triggered evacuations. Oil infrastructure was not damaged.[743] (See also entry above for September 14, 2017.)

- October 7, 2016 – The EPA recommended a moratorium on the underground injection of fracking wastewater in certain earthquake-prone parts of Oklahoma after a 5.8 earthquake struck near Pawnee on September 3, 2016.[744] The strongest in Oklahoma's history, the Pawnee earthquake was felt by residents in five states and prompted a state of emergency declaration as well as an order from state regulators to shut down 67 wastewater disposal wells in the area.[745, 746]

- September 22, 2016 – A study using satellite-based radar imagery found that the earth's surface rose, by 3 millimeters per year, in areas of fracking waste injection. Underground

[740] Bao, X., & Eaton, D. W. (2016). Fault activation by hydraulic fracturing in western Canada. *Science,* aag2583. doi: 10.1126/science.aag2583
[741] Fountain, H. (2016, November 17). In Canada, a direct link between fracking and earthquakes. *The New York Times.* Retrieved from https://www.nytimes.com/2016/11/18/science/fracking-earthquakes-alberta-canada.html?mtrref=www.google.com&gwh=535A4330D3C30EF6934E1739AC62D5DA&gwt=pay
[742] Thompson, S., & Kuchment, A. (2016, November 17). Seismic denial: Why Texas won't admit fracking wastewater is causing earthquakes. *Dallas Morning News.* Retrieved from http://interactives.dallasnews.com/2016/seismic-denial/#_ga=2.247990020.202656599.1515906987-1750807308.1515724730
[743] Philips, M. (2016, November 8). Why Oklahoma can't turn off its earthquakes. *Bloomberg Businessweek.* Retrieved from http://www.bloomberg.com/news/articles/2016-11-08/why-oklahoma-can-t-turn-off-its-earthquakes
[744] Soraghan, M. (2016, October 7). EPA suggests partial disposal moratorium in Okla. *E&E EnergyWire.* Retrieved from http://www.eenews.net/energywire/stories/1060043991
[745] U.S. Geological Survey. (2016, September 3). M5.8 – 14 km NW of Pawnee, Oklahoma. Retrieved from http://earthquake.usgs.gov/earthquakes/eventpage/us10006jxs#executive
[746] Oklahoma Corporation Commission. (2016, September 12). *Latest action regarding Pawnee area* [Press release]. Retrieved from https://www.occeweb.com/News/2016/09-12-16Pawnee%20Advisory.pdf

pore pressures for this area exceeded those known to trigger earthquakes. These findings provide proof that the migration of fracking wastewater into faults increased pressures in ways that triggered a 4.8 magnitude earthquake in east Texas in 2012. The researchers emphasized that pore pressure elevation and propagation from fracking wastewater injection may evolve over periods of months to years before affecting critically stressed faults.[747]

- September 14, 2016 – Researchers from the USGS used a newly deployed seismic monitoring network to document the rupture of a fault plane that set off a magnitude 4.9 earthquake in Milan, Kansas in 2014, immediately following a rapid increase in fracking wastewater injection nearby.[748]

- May 2016 – In a study that has "far-reaching implications for assessment of induced-seismicity hazards," a Canadian team of researchers determined that hydraulic fracturing itself is linked to earthquake swarms in western Canada, in contrast to the central United States where disposal of fracking waste is the cause of most induced seismicity. Furthermore, lowering the volume of injected fluid may not be sufficient to prevent quakes. In the Western Canada Sedimentary Basin, "it appears that the maximum-observed magnitude of events associated with hydraulic fracturing may exceed the prediction of an often-cited relationship between the volume of injected fluid and the maximum expected magnitude…. Rather, we propose that the size of the available fault surface that is in a critical state of stress may control the maximum magnitude…. Our results indicate that the maximum magnitude of induced events for hydraulic fracturing may not be well correlated with net injected fluid volume."[749]

- April 29, 2016 – Five small earthquakes in one 24-hour period originated in an area in Lawrence County, Pennsylvania near a fracking operation that was drilling into the deep Utica Shale at the time. Quoted in the *Pittsburg Post-Gazette*, researchers noted that it is very difficult for operators to avoid areas with faults because their locations are very often unknown.[750]

- March 28, 2016 – A summary of the evidence linking drilling and fracking activities to earthquakes appeared in *Scientific American.* Emerging data suggests that pressure changes caused by fracking wastewater injection can migrate for years before encountering a geological fault and altering stresses in ways that allow for slippage. In this way, earthquake risks can spread out over both time and space—traveling for miles

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[747] Shirzaei, M., Ellsworth, W. L., Tiampo, K. F., Gonzalez, P. J., & Manga, M. (2016). Surface uplift and time-dependent seismic hazard due to fluid injection in eastern Texas. *Science, 353*(6306). doi: 10.1126/science.aag0262
[748] Choy, G. L., Rubenstein, J. L., Yeck, W. L., McNamara, D. E., Mueller, C. S., & Boyd, O. S. (2016). A rare moderate-sized (Mw 4.9) earthquake in Kansas: Rupture process of the Milan, Kansas, earthquake of 12 November 2014 and its relationship to fluid injection. *Seismological Research Letters, 87.* doi: 10.1785/0220160100
[749] Atkinson, G. M., Eaton, D. W., Ghofrani, H., Walker, D., Cheadle, B., Schultz, R. . . . Kao, H. (2016). Hydraulic fracturing and seismicity in the Western Canada Sedimentary Basin. *Seismological Research Letters, 87(*3). doi: 10.1785/0220150263
[750] Legere, L. (2016, April 29). State studying link between fracking, Lawrence County earthquakes. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/companies/2016/04/29/State-studying-link-between-fracking-and-Lawrence-County-earthquakes/stories/201604290099

beyond the disposal well and persisting for a decade or more as injected fluids travel underground. In spite of increasing scientific clarity about these mechanisms, regulators have been slow to respond.[751]

- February 1, 2016 – An article in the *Texas Journal of Oil, Gas, and Energy Law* exhaustively reviewed the literature on earthquake activity in areas of six states (Arkansas, Colorado, Kansas, Ohio, Oklahoma, and Texas) where fracking takes place or drilling wastes are disposed underground and concluded that courts should impose strict liability for earthquake damage caused either by fracking itself or by the underground injection of fracking fluids. "Earthquakes sometimes occur when subsurface formations are properly fractured. Likewise, the risk of earthquake damage is not substantially mitigated by the exercise of due care when frack fluids are injected into the ground."[752]

- January 22, 2016 – An international research team investigated a swarm of earthquakes in California's Central Valley that occurred in 2005. Using hydrogeological modeling, the researchers concluded that the underground injection of wastewater from oil drilling operations had contributed to seismicity via changes in localized pressures along an active fault.[753]

- January 12, 2016 – As reported by *CBC News*, a Canadian regulatory agency ordered a drilling and fracking operation in northwestern Alberta to shut down after a magnitude 4.8 earthquake struck nearby. The operator was fracking at the time the earthquake happened.[754]

- November 15, 2015 – A spokesperson for the Oklahoma Corporation Commission, which regulates the oil and gas industry in the state, said that Oklahoma now leads the world in earthquake frequency.[755]

- October 29, 2015 – The Kansas Corporation Commission extended limits on the injection of wastewater from fracking operations after a drop in the frequency of earthquakes that followed an earlier order to limit such injections.[756] Between 2013 and October 2015,

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[751] Kuchment, A. (2016, March 28). Drilling for earthquakes. *Scientific American.* Retrieved from https://www.scientificamerican.com/article/drilling-for-earthquakes/
[752] Watson, B. A. (2016). Fracking and cracking: Strict liability for earthquake damage due to wastewater injection and hydraulic fracturing. *Texas Journal of Oil, Gas and Energy Law, 11*(1). Retrieved from http://ssrn.com/abstract=2735862
[753] Goebel, T. H. W., Hosseini, S. M., Cappa, F., Hauksson, E., Ampuero, J. P., Aminzadeh, F., & Saleeby J. B. (2016). Wastewater disposal and earthquake swarm activity at the southern end of the Central Valley, California. *Geophysical Research Letters, 43*. doi: 10.1002/2015GL066948
[754] *CBC News*. (2016, January 12). Fox Creek fracking operation closed indefinitely after earthquake. Retrieved from http://www.cbc.ca/news/canada/edmonton/fox-creek-fracking-operation-closed-indefinitely-after-earthquake-1.3400605
[755] Miller, J. (2016, November 10). Oklahoma world's no. 1 earthquake area. *Enid News and Eagle.* Retrieved from http://www.enidnews.com/news/local_news/oklahoma-world-s-no-earthquake-area/article_69b145b8-c180-5065-8f99-b2a7ec7ce913.html
[756] Kansas Corporation Commission. (2015, October 29). *Kansas Corporation Commission approves order extending wastewater injection limits.* [Press release.] Retrieved from http://www.kcc.state.ks.us/pi/press/15-13.htm

Kansas recorded more than 200 earthquakes. Before that, the average rate was one earthquake every two years.

- October 23, 2015 – *Bloomberg* explored the national security risks that fracking-induced earthquakes in Oklahoma create for the nation's largest oil storage hub in Cushing, where aboveground tanks hold more than 60 million barrels of crude oil and serve as a way station for oil from North Dakota's Bakken Shale as it heads to Gulf Coast refineries. Earthquake swarms have hit within a few miles of Cushing and may be harbingers of larger quakes in the future. "Now that quakes appear to have migrated closer to Cushing, the issue of what to do about them has morphed from a state issue to one of national security…. Not only is Cushing crucial to the financial side of the oil market, it is integral to the way physical crude flows around the country."[757]

- September 21, 2015 – An international team of geologists investigated possible causes of the Lusi mudflow, which began suddenly in 2006 when mud began erupting from the ground in a volcano-like fashion in an urban area of Java in Indonesia. The ongoing disaster has, as of 2015, displaced 39,700 people and cost nearly $3 billion in damages and disaster management. Looking at data on the emissions of subsurface gases before and after the eruption began, the team concluded that the likely cause was nearby gas drilling that forced fluid into the clay layer via the open well. "We therefore conclude that the Lusi eruption was not triggered naturally but was instead the consequence of drilling operations."[758] In interviews with the *New York Times*, lead author Mark Tinjay said, "We are now 99 percent certain that the drilling hypothesis is valid," while other experts who were not authors of the paper expressed less certainty.[759]

- July 27, 2015 – During a seven-day period in late July, the state of Oklahoma experienced 40 earthquakes. According to the USGS, three registered above magnitude 4.0, one of which was strong enough to be felt by 1.9 million people, including residents of several surrounding states.[760] In response, gas and oil operators voluntarily shut down two nearby wastewater injection wells and reduced operations by half at a third well.[761] According to the Oklahoma Geological Survey, the recent quakes are occurring along a fault line that extends north of Oklahoma City and signal greater potential for a larger earthquake.[762] Ten days before the voluntary shutdowns, the Oklahoma Corporation Commission, which regulates the oil and gas industry, put 211 wastewater disposal wells

[757] Phillips, M. (2015, October 23). Oklahoma earthquakes are a national security threat. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/articles/2015-10-23/oklahoma-earthquakes-are-a-national-security-threat
[758] Tingay, M. R. P., Rudolph, M. L., Manga, M., Davies, R. J., & Wang, C-Y. (2015). Initiation of the Lusi mudflow disaster. *Nature Geoscience, 8*. doi:10.1038/ngeo2472
[759] Nuwer, R. (2015, September 21). Indonesia's 'mud volcano' and nine years of debate about its muck. *The New York Times*. Retrieved from http://www.nytimes.com/2015/09/22/science/9-years-of-muck-mud-and-debate-in-java.html?rref=collection%2Fsectioncollection%2Fscience&_r=0
[760] U.S. Geological Survey, (2015, July 27). M4.5 – 6 km NNE of Crescent, Oklahoma. Retrieved from http://earthquake.usgs.gov/earthquakes/eventpage/us200030gd#impact_pager
[761] Oklahoma Corporation Commission (2015, July 28). Media advisory: new actions taken in response to earthquake activity in the Crescent area. Retrieved from http://www.occeweb.com/News/Crescent%20wells.pdf
[762] Murphy, S. (2015, July 28). 2 injection wells shut down after Oklahoma quakes. *Associated Press.* Retrieved from http://www.santacruzsentinel.com/business/20150728/2-injection-wells-shut-down-after-oklahoma-quakes

under extra review.[763] The next month, Oklahoma regulators, acknowledging that previous efforts have been unsuccessful in reducing seismic activity, asked operators of 23 injection wells to decrease the amount of wastewater injected by 38 percent and signaled that more sweeping regulatory actions may follow.[764]

- July 1, 2015 – Two researchers, from the USGS and the Geological Survey of Canada, offered a summary of the history, basic geology, and engineering of fracking fluid injection and induced seismicity. Noting that since 2001 Oklahoma had experienced two earthquakes of very large magnitude (5.0 and 5.3), the authors called for "a detailed understanding of the physical processes involved in inducing large magnitude events and a detailed understanding of the geology and hydrology at the site of the earthquakes." They also noted that many important parameters are either unknown or not easily constrained, making it "difficult to determine the wells that will induce earthquakes and those that will not."[765]

- June 30, 2015 – The Oklahoma Supreme Court ruled that homeowners who have sustained injuries or property damage that they believe is due to earthquakes caused by oil and gas operations can sue for damages in state trial courts. The number of earthquakes with magnitude 3.0 or higher has skyrocketed in Oklahoma, with 1,100 predicted to occur in 2015. Earlier this year, scientists at the state's geological survey reversed prior views and embraced the conclusion that the majority of the recent earthquakes in central and north-central Oklahoma were "very likely triggered" by underground wastewater disposal. Industry lawyers have complained that liability for such damages will be economically unsustainable. A separate class action lawsuit is planned.[766]

- June 19, 2015 – By compiling a database of 187,570 injection wells in the central and eastern United States, University of Colorado Boulder and USGS researchers were able to test for associations between fracking waste disposal and earthquakes. Results showed far more injection wells were potentially related to earthquakes than had previously been realized, and active disposal-only wells were more than 1.5 times more likely than active oil extraction wells to be associated with an earthquake. In addition, high-rate injection wells, receiving more than 300,000 barrels of fluid per month, were much more likely than lower-rate wells to be associated with an earthquake, while other factors, including wellhead injection pressure, appeared unrelated to increased earthquake activity. The

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[763] Oklahoma Corporation Commission (2015, July 17). *OCC announces next step in continuing response to earthquake concerns, 200-plus more disposal wells added to action list* [Press release]. Retrieved from http://www.occeweb.com/News/DIRECTIVE-2.pdf

[764] Wines, M. (2015, August 4). Oklahoma acts to limit earthquake risk at oil and gas wells. *The New York Times.* Retrieved from http://www.nytimes.com/2015/08/05/us/oklahoma-acts-to-limit-earthquake-risk-at-oil-and-gas-wells.html?_r=0

[765] Rubenstein, J. L., & Mahani, A. B. (2015). Myths and facts on wastewater injection, hydraulic fracturing, enhanced oil recovery, and induced seismicity. *Seismological Research Letters, 86*(4), 1060-1067. doi: 10.1785/0220150067

[766] Oppel Jr., R.A. (2015, June 30). Oklahoma court rules homeowners can sue oil companies over quakes. *The New York Times*. Retrieved from http://www.nytimes.com/2015/07/01/us/oklahoma-court-rules-homeowners-can-sue-oil-companies-over-quakes.html?emc=edit_tnt_20150630&nlid=66402583&tntemail0=y&_r=0

study called for managing injection rates as "a useful tool to minimize the likelihood of induced earthquakes." The researchers did not address the impact of hydrofracturing activities *per se* as a potential confounding variable.[767, 768]

- June 18, 2015 – Close examination of several areas in Oklahoma by Stanford University geophysicists revealed that dramatic increases in recent earthquake activity followed 5- to 10-fold increases in deep-well injection of briny "produced water," the highly salty fluid that rises to the surface from water-bearing oil reserves and requires disposal. The rate of earthquake occurrence, which began to increase in 2009, is now 600 times higher than it was before the onset of widespread fracking in the state. The disposal of this type of waste in Oklahoma mostly occurs via injection into geological formations that appear to be in hydraulic communication with potentially active faults in the crystalline basement. The study proposed that increasing pressure, spreading away from injection wells over time, could eventually trigger slips on critically stressed faults, resulting in earthquake activity. It is likely that, "even if injection from many wells were to stop immediately, seismicity would continue as pressure continues to spread out from past injection."[769]

- June 12, 2015 – Researchers in France uncovered an unexpected mechanism by which subsurface fluid injections, such as those used in high volume hydrofracturing, can cause earthquakes. They found that injection of pressurized water can cause fault lines to "creep" rather than slip suddenly as occurs during earthquakes. Earthquakes did follow this slow movement but took place in a portion of the fault outside the pressurized zone. This research demonstrated that subsurface injection of fluids under pressure can cause primary gradual slippage of fault planes leading to secondary sudden seismic activity.[770, 771]

- June 11, 2015 – As reported by the Vancouver news magazine *The Tyee,* seismic events of magnitude greater than 2.0 (but less than 4.0) in the Fox Creek area were reported in Alberta, Canada since the initiation in February of a novel "traffic light system" for responding to measured seismic activity. The system requires varying responses according to the magnitude of the event, ranging from no action up to ceasing operations and informing the Alberta Energy Regulator for events at magnitudes greater than 4.0. Experts noted that the system does not work well when the largest event in the sequence is the first event. Moreover, once a sequence of earthquakes is initiated, the sequence

[767] Weingarten, M. Ge, S., Godt, J. W., Bekins, B. A., & Rubinstein, J. L. (2015). High-rate injection is associated with the increase in U.S. mid-continent seismicity. *Science, 348*(6241), 1336-1340. doi: 10.1126/science.aab1345
[768] Rosen, J. (2015). Pumped up to rumble: Massive studies of wastewater injection wells show fast pumping raises earthquake risk. *Science, 368*(6241),1299. doi: 10.1126/science.aac6857
[769] Walsh, F. R. III, & Zobakc, M. D. (2015). Oklahoma's recent earthquakes and saltwater disposal. *Science Advances, 1*(5), e1500195. doi: 10.1126/sciadv.1500195
[770] Guglielmi, Y., Cappa, F., Avouac, J.-P., Henry, P., & Elsworth, D. (2015). Seismicity triggered by fluid injection–induced aseismic slip. *Science*, *348*(6240), 1224-1226. doi: 10.1126/science.aab0476
[771] Johnson, S. K. (2015, June 11). Making tiny earthquakes to understand fracking-driven quakes. *arstechnica.* Retrieved from http://arstechnica.com/science/2015/06/making-tiny-earthquakes-to-understand-fracking-driven-quakes/

may continue, sometimes with larger earthquakes, long after potentially causally related drilling or injection activities have ceased.[772]

- June 1, 2015 – In a data-rich presentation, a team of researchers from St. Louis University, Colorado State University, and USGS concluded that "a fundamental change in the earthquake-triggering process has occurred" in central Oklahoma. Using advanced field monitoring and high-performance software, computer models illustrate active earthquake sequences associated with long fault structures "that might be capable of supporting large earthquakes (M 5 to 6)" and possibly cascades of earthquakes, which could occur near population centers and expensive infrastructure associated with the oil and gas industry, such as a large underground crude-oil storage facility.[773]

- May 11, 2015 – A series of directives from the Oklahoma Corporation Commission revealed a slowly evolving approach to the regulation of disposal well operations in that state, and the gradual tightening of a "traffic light system" introduced in 2013 to determine whether disposal wells for fracking waste should be permitted, permitted only with special restrictions and requirements, or not permitted, in light of the now-proven connection between the injection of liquid waste and the soaring frequency of earthquakes in Oklahoma. Since 2013, earthquake activity in Oklahoma has continued to increase in rate and intensity.[774, 775]

- April 23, 2015 – In a first-of-its-kind approach, the USGS is updating its National Seismic Hazard Model to address the rapidly increasing, highly variable, and difficult-to-predict hazards of induced earthquakes.[776] This initial report identified 17 areas within eight states (Alabama, Arkansas, Colorado, Kansas, New Mexico, Ohio, Oklahoma, and Texas) with increased rates of induced seismicity, including many areas experiencing earthquakes of large magnitude.[777] Two days before the release of this report, Oklahoma's state government acknowledged for the first time that wastewater disposal related to oil and gas drilling is "very likely" to blame for the huge surge of earthquakes

[772] Nikiforuk, A. (2015, June 11). More industry linked earthquakes recorded in Alberta. *TheTyee.ca.* Retrieved from http://thetyee.ca/News/2015/06/11/More-Fracking-Earthquakes/

[773] McNamara, D. E., Rubinstein, J. L., Myers, E., Smoczyk, G., Benz, H. M., Williams, R. A., . . . Earle, P. (2015). Efforts to monitor and characterize the recent increasing seismicity in central Oklahoma. *The Leading Edge, 34*(6). doi: 10.1190/tle34060628.1

[774] Oklahoma Corporation Commission, Oil & Gas Conservation Division. (2015, May 11). Media advisory: Ongoing OCC earthquake response. Retrieved from http://www.occeweb.com/News/2015/ADVISORY%20-%20TRAFFIC%20LIGHT.pdf

[775] Oklahoma Corporation Commission. (n.d.) Seismic statement. Retrieved from http://www.occ.state.ok.us/SeismicStatementB.pdf

[776] Petersen, M. D., Mueller, C. S., Moschetti, M. P., Hoover, S. M., Rubinstein, J. L., Llenos, A. L., . . . Anderson, J. G. (2015). Incorporating induced seismicity in the 2014 United States National Seismic Hazard Model—Results of 2014 workshop and sensitivity studies: U.S. Geological Survey Open-File Report 2015–1070. doi: 10.3133/ofr20151070

[777] USGS. (2015, April 23). New insight on ground shaking from man-made earthquakes. *USGS Newsroom.* Retrieved from http://www.usgs.gov/newsroom/article_pf.asp?ID=4202

in many areas of Oklahoma, the *New York Times* reported.[778] Several states have developed protocols to shut down existing wells and halt drilling of new disposal wells following an upsurge in earthquake activity.

- April 21, 2015 – Analyzing the unusual increase of seismicity in north Texas since 2008, researchers from Southern Methodist University, the USGS, and University of Texas at Austin concluded that observed earthquake swarms were associated both with extraction (of gas and brine formation waters) and injection (of fracking wastewater), via significant stress changes at earthquake depths. The research team noted that baseline pressure monitoring data, though easy to obtain and routinely collected by industry at well sites, were currently "neither required nor typically available for analysis." Greater transparency and cooperation in regional seismic monitoring is needed to generate more comprehensive data sets that are necessary for robust earthquake hazard analysis, they asserted.[779, 780]

- April 21, 2015 – In a statement reporting on an increase in earthquakes in Oklahoma of greater than magnitude 3.0 from less than two per year historically to over two per day in 2015, the Oklahoma Geological Society acknowledged that that the primary, suspected source of "triggered seismicity" is the injection and disposal of produced water associated with oil and gas production.[781]

- March 30, 2015 – *Bloomberg Business* reported that Oklahoma state seismologists had received pressure from oil industry representatives to downplay the evidence linking fracking wastewater disposal to the soaring frequency of earthquakes in the state.[782]

- March 6, 2015 – A careful and detailed analysis of historical data coupled with onsite, real-time measurements of seismic activity in central Oklahoma via rapidly deployed seismic sensors revealed that reactivated ancient faults responsible for thousands of earthquakes in Oklahoma are capable of causing larger seismic events. Current hazard maps did not include induced seismicity and therefore underestimate earthquake hazard, the USGS reported. Until new hazard maps become available, providing information about the type, length, and location of these reactivated faults could provide guidance to the oil and gas industry and help inform public policy decisions.[783] In addition, noted lead

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[778] Pérez-Peña, R. (2015, April 23). U.S. maps pinpoint earthquakes linked to quest for oil and gas. *The New York Times.* Retrieved from http://www.nytimes.com/2015/04/24/us/us-maps-areas-of-increased-earthquakes-from-human-activity.html?ref=us&_r=1

[779] Hornbach, M. J., DeShon, H. R., Ellsworth, W. L., Stump, B. W., Hayward, C., Frohlich, C., . . . Luetgert, J.H. (2015). Causal factors for seismicity near Azle, Texas. *Nature Communications, 6*(6728). doi: 10.1038/ncomms7728

[780] Richter, M. (2015, April 21). Small north Texas quakes likely linked to oil, gas operations – study. *Reuters.* Retrieved from http://www.reuters.com/article/2015/04/21/us-usa-texas-earthquake-idUSKBN0NC2DY20150421

[781] Andrews, R.D. & Holland, A. (2015, April 21). Statement on Oklahoma Seismicity. Retrieved from http://wichita.ogs.ou.edu/documents/OGS_Statement-Earthquakes-4-21-15.pdf

[782] Elgin, B., & Phillips, M. (2015, March 30). Big oil pressured scientists over fracking wastewater's link to quakes. *Bloomberg Business.* Retrieved from http://www.bloomberg.com/news/articles/2015-03-30/big-oil-pressured-scientists-over-fracking-wastewater-s-link-to-quakes

[783] McNamara, D. E., Benz, H. M., Herrmann, R. B., Bergman, E. A., Earle, P., Holland, A., . . . Gassner, A. (2015). Earthquake hypocenters and focal mechanisms in central Oklahoma reveal a complex system of reactivated subsurface strike-slip faulting. *Geophysical Research Letters, 42*(8), 2742–2749. doi: 10.1002/2014GL062730

author Dan McNamara, such information can "aid in adapting building codes to ensure that structures can withstand more damaging earthquakes.[784]

- February 20, 2015 – Scientists with the USGS reported in *Science* about grappling with an unexpected increase in injection-related seismic activity across the middle of North America. In 2014, the number of measured earthquakes with magnitude of 3 or greater in Oklahoma exceeded that in California, and observations increasingly suggested that the effects of fluid injection were not confined to the target formation but instead were communicated, sometimes to greater depths, along pre-existing faults. Making hazard modeling more difficult, "most of these faults are only detected when they are imaged by well-located induced earthquakes." Consequently, predicting and controlling such seismic activity may not be possible, leading to a recommendation that injection projects should be sited away from population centers.[785]

- February 5, 2015 – Citing an association between increased water use and fracking-induced seismic activity, a research scientist at the Geological Survey of Canada offered the quantity of water injected underground as his hypothesis for an observed increase in the frequency and magnitude of earthquake activity in areas near fracking wells. Although the Council of Canadian Academies in 2014 called for more monitoring and data collection, there are only ten monitoring stations in British Columbia, overseeing the operations of thousands of fracking wells, reported the *Vancouver Observer*.[786]

- January 29, 2015 – The industry-funded Alberta Energy Regulator confirmed that the location of an earthquake of magnitude 4.4 near Fox Creek, Alberta, was "consistent with being induced by hydraulic fracturing operations," making it the largest felt earthquake yet believed to be related to fracking. Despite claims from industry that tremors related to deep-level fracking could never reach magnitudes that would allow them to be felt on the surface, Gail Atkinson, who holds the Canada Research Chair in Induced Seismicity Hazards at Western University in Ontario, noted, "With fracking, the magnitudes have been increasing every year."[787]

- January 6, 2015 – Using a specialized program, Miami University researchers analyzed data from multiple seismic stations and determined that a cluster of 77 earthquakes in Poland Township, Ohio, which occurred over the course of a little more than a week, was related temporally and spatially to active hydraulic fracturing operations. When the fracturing operations were shut down, the rate of earthquake activity declined to only 6 events in the next 12 hours and only a single event over approximately the next two

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[784] Koontz, H. (2015, March 6). *Reawakened Oklahoma faults could produce larger future events* [Press release]. Retrieved from http://www.usgs.gov/newsroom/article_pf.asp?ID=4144
[785] McGarr, A., Bekins, B., Burkardt, N., Dewey, J., Earle, P., Ellsworth, W., Ge, S., … Sheehan, A. (2015). Coping with earthquakes induced by fluid injection. *Science, 347*(6224), 830-831. doi: 10.1126/science.aaa0494
[786] Leahy, D. (2015, February 5). Fracking-induced earthquake puts B.C. gas bonanza on shaky ground. *Vancouver Observer.* Retrieved from http://www.vancouverobserver.com/news/fracking-induced-earthquake-puts-bc-gas-bonanza-shaky-ground
[787] Nikiforuk, A. (2015, January 29). Did Alberta just break a fracking earthquake world record? *TheTyee.ca.* Retrieved from http://thetyee.ca/News/2015/01/29/Alberta-Fracking-Earthquake/?utm_source=fb-page-editor-post&utm_medium=fb-page&utm_campaign=fb-01-2015

months. Among this cluster of seismic activity, an earthquake of magnitude 3.0 ranks as one of the largest earthquakes in the United States to be induced by hydraulic fracturing. The mechanism for these earthquakes appears to be induction of slip along a pre-existing fault or fracture zone. Because "no known fault or historical seismicity had been [previously] identified in the area," regulations prohibiting fracturing within three miles of a known fault would not have been protective.[788, 789]

- December 18, 2014 – In Canada, an investigation by the British Columbia Oil and Gas Commission found that induced seismicity in the Horn River Basin could be attributed both to wastewater disposal and to hydraulic fracturing operations. The Commission recommended mitigation of induced seismicity from wastewater disposal by "reducing injection rates, limiting the increase in [subsurface] reservoir pressure, and locating distal from faults," among other mitigation techniques.[790, 791]

- October 23, 2014 – Researchers from USGS and the Global Seismological Services in Golden, Colorado, linked a 2011 magnitude 5.3 earthquake in Colorado, which damaged the foundations of several homes, to underground disposal of fracking wastewater. The study determined that the earthquake ruptured an 8-10 kilometer-long segment of normal faults—an unexpectedly long length for a magnitude 5.3 earthquake—suggesting that wastewater disposal may have triggered a low stress drop.[792] Lead author Bill Barnhart, a USGS geophysicist, told *Reuters*, "We saw a big increase in seismicity starting in 2001, including magnitude 5 earthquakes, in many locations in the basin, and that coincided with a surge in gas production and injection of wastewater."[793]

- September 23, 2014 – Youngstown State University geologist Ray Beiersdorfer described increased seismic activity in Youngstown, Ohio in an essay that explores how fracking and fracking-related processes are causing "earthquake epidemics" across the United States.[794]

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[788] Skoumal, R. J., Brudzinski, M. R. & Currie, B. S. (2015). Earthquakes induced by hydraulic fracturing in Poland Township, Ohio. *Bulletin of the Seismological Society of America 105*(1). doi: 10.1785/0120140168
[789] Wines, M. (2015, January 10). New research links scores of earthquakes to fracking wells near a fault in Ohio. *The New York Times.* Retrieved from http://www.nytimes.com/2015/01/08/us/new-research-links-scores-of-earthquakes-to-fracking-wells-near-a-fault-in-ohio.html?hp&action=click&pgtype=Homepage&module=first-column-region&region=top-news&WT.nav=top-news&assetType=nyt_now&_r=0
[790] BC Oil & Gas Commission (2014). *Investigation of observed seismicity in the Montney Trend.* Retrieved from http://www.bcogc.ca/node/12291/download
[791] Nikiforuk, A. (2015, January 10). Fracking industry shakes up Northern BC with 231 tremors. *TheTyee.ca.* Retrieved from http://www.thetyee.ca/News/2015/01/10/Fracking_Industry_Shakes_Up_Northern_BC/
[792] Barnhart, W. D., Benz, H.M., Hayes, G.P., Rubinstein, J.L., & Bergman, E. (2014), Seismological and geodetic constraints on the 2011 Mw5.3 Trinidad, Colorado earthquake and induced deformation in the Raton Basin, *Journal of Geophysical Research: Solid Earth* , *119,* 7923–7933, doi: 10.1002/2014JB011227. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/2014JB011227/abstract
[793] Zuckerman, L. (2014, October 29). Gas wastewater likely triggered 2011 quake in Colorado: USGS. *Reuters*. Retrieved from http://www.reuters.com/article/2014/10/29/us-usa-earthquake-colorado-idUSKBN0II2NP20141029
[794] Beiersdorfer, R. (2014, September 23). View: On fracking, earthquakes and Indian Point. *Journal Online.* Retrieved from http://www.lohud.com/story/opinion/contributors/2014/09/23/view-geologist-warns-fracking-ties-earthquakes/16100755/

- September 15, 2014 – Researchers at the National Energy Technology Laboratory teamed up with researchers from industry and academia to publish data and analysis from a closely watched project that involved field monitoring of the induced fracturing of six horizontal Marcellus Shale gas wells in Greene County, Pennsylvania. Touted in earlier media reports as demonstrating that, during short-term follow-up, fracking chemicals injected into these six wells did not spread to overlying aquifers[795], the study's most notable finding is striking documentation of fractures from three of the six wells extending vertically to reach above an overlying rock layer previously thought to create an impenetrable "frac barrier" (that is, an upper barrier to fracture growth). In one case, a fracture extended vertically 1,900 feet, a surprisingly far distance. No pre-existing fault had been detected at this location, suggesting that small "pre-existing fractures or small-offset (sub-seismic) faults may have focused the energy of hydraulic fractures on certain areas…." Perhaps because of the extremely small sample size and a design focused primarily on monitoring for potential gas and fluid migration, the study's analysis includes no discussion of the seismic relevance of extremely long, vertical induced fractures.[796]

- September 15, 2014 – Scientists from USGS ascribed causality to wastewater injection wells from coal-bed methane production for increases in seismic activity in New Mexico and Colorado and, in particular, for an earthquake that measured magnitude 5.3 in Colorado in 2011—the second largest earthquake to date for which there is clear evidence that the earthquake sequence was induced by fluid injection.[797]

- September 6, 2014 – The Ohio Department of Natural Resources suspended operations at two deep-injection wells for fracking wastewater near Warren in northeastern Ohio after discovering evidence that the operation possibly caused a magnitude 2.1 earthquake. The injection well operator, American Water Management Services, had recently received permission to increase pressures at the site of the wells. In 2012, Governor John Kasich had halted disposal of fracking wastewater surrounding a well site in the same region after a series of earthquakes were tied to a deep-injection well. The company that ran that well has disputed the link. The state placed seismic-monitoring devices in the Warren area under protocols adopted after the series of earthquakes in nearby Youngstown.[798]

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[795] Begos, K. (2014, July 19). DOE study: Fracking chemicals didn't taint water. *Associated Press*. Retrieved from http://bigstory.ap.org/article/ap-study-finds-fracking-chemicals-didnt-spread

[796] Hammack, R., Harbert, W., Sharma, S., Stewart, B. W., Capo, R. C., Wall, A. J., . . . Veloski, G. (2014). An evaluation of fracture growth and gas/fluid migration as horizontal Marcellus Shale gas wells are hydraulically fractured in Greene County, Pennsylvania. *NETL-TRS-3-2014: EPAct Technical Report Series. US Dept of Energy, National Energy Technology Laboratory*: Pittsburgh PA. Retrieved from http://www.netl.doe.gov/File%20Library/Research/onsite%20research/publications/NETL-TRS-3-2014_Greene-County-Site_20140915_1_1.pdf

[797] Rubinstein, J. L., Ellsworth, W. L., McGarr, A., & Benz, H. M. (2014). The 2001-present induced earthquake sequence in the Raton Basin of Northern New Mexico and Southern Colorado [abstract]. *Bulletin of the Seismological Society of America*. Retrieved from http://www.bssaonline.org/content/104/5/2162.abstract?stoc

[798] Smyth, J. C. (2014, September 6). Ohio halts injections at two wells for fracking wastewater after quake. *Associated Press*. Retrieved from http://www.dispatch.com/content/stories/local/2014/09/06/ohio-halts-2-wells-for-fracking-wastewater-after-quake.html

- September 1, 2014 – Explaining the need for increased seismic monitoring, Andrew Beaton, Director of the Alberta Geological Survey, stated that over a long period of time, stresses increase in and around an injection wellbore. Seismic movement can be caused if the rate of injection is too fast or if there is a geological feature, such as a fault or fracture in nearby areas. Although Albertans in rural areas have been reporting for years that they can feel tremors under their feet near oil and gas activity, especially around areas of fracking, the Alberta Energy Regulator noted that deep well injections have been shown to create more of an earthquake hazard than hydraulic fracturing. Alberta experienced 819 earthquakes between 1918 and 2009. In comparison, Saskatchewan recorded 13 in the same time period and British Columbia recorded more than 1,200 earthquakes in 2007 alone. There are currently 24 seismic monitors in Alberta, which are tied into other networks, such as those belonging to Environment Canada, University of Calgary, and University of Alberta.[799]

- August 26, 2014 – In a first-of-its-kind lawsuit, a resident of Prague, Oklahoma, sued two energy companies after rocks fell from her chimney and injured her leg during an earthquake of greater than magnitude 5. The lawsuit claims that underground injection of fracking wastewater conducted by New Dominion LLC and Spess Oil Company has caused shifts in fault lines that have resulted in earthquakes.[800]

- July 31, 2014 – William Ellsworth, a research geophysicist at the USGS Earthquake Science Center, reported that USGS is developing a hazard model that takes induced earthquakes into account. In addition, residents of Oklahoma, where a sharp spike in earthquake activity has been noted over the past decade, are showing an increased interest in obtaining earthquake insurance.[801]

- July 3, 2014 – Using data from the Oklahoma Corporation Commission, a team of researchers led by Cornell University geophysicist Katie Keranen found that a steep rise in earthquakes in Oklahoma can be explained by fluid migration from wastewater disposal wells. Moreover, injected fluids in high volume wells triggered earthquakes over 30 kilometers (over 18 miles) away. All of the wells analyzed were operated in compliance with existing regulations. Similar mechanisms may function in other states with high volumes of underground injection of wastewater from unconventional oil and gas production.[802] Reporting on the study and the increase in earthquakes across the United States and the link to fracking and wastewater disposal, the *Associated Press*

[799] Maclean, R. (2014, September 1). Earthquake hazard linked with deep well injection in Alberta: Deep well disposal of oilfield waste over time leads to increased earthquake risk. *CBC News*. Retrieved from http://www.cbc.ca/news/canada/calgary/earthquake-hazard-linked-with-deep-well-injection-in-alberta-1.2751963

[800] Rangel, L. (2014, August 26). Prague resident files lawsuit against two Okla. energy companies following earthquake injury. *Newschannel 4 (kfor.com)*. Retrieved from http://kfor.com/2014/08/26/prague-resident-files-lawsuit-against-two-okla-energy-companies-following-earthquake-injury/

[801] Eaton, J. (2014, July 31). Oklahoma grapples with earthquake spike—and evidence of industry's role: Spike in seismic activity is linked with oil and gas wastewater disposal. *National Geographic*. Retrieved from http://news.nationalgeographic.com/energy/2014/07/140731-oklahoma-earthquake-spike-wastewater-injection/

[802] Keranen, K. M., Weingarten, M., Abers, G. A., Bekins, B. A., & Ge, S. (2014). Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection. *Science*, *345*(6195), 448-451. doi: 10.1126/science.1255802

noted that some states, including Ohio, Oklahoma, and California, have introduced new rules compelling drillers to measure the volumes and pressures of their injection wells as well as to monitor seismicity during fracking operations.[803]

- July 1, 2014 – Seismologists linked the emergence of a giant sinkhole that formed in August 2012 near Bayou Corne in southeast Louisiana to tremors (earthquakes) caused by high-pressure pulses of either natural gas or water charged with natural gas. The surges of natural gas that caused the explosive tremors (earthquakes) may have weakened an adjacent salt cavern and caused its collapse. Alternatively, part of the salt cavern may have collapsed, causing a nearby gas pocket to give off surges of gas, later followed by the complete collapse of the salt cavern. These findings help illuminate the role of pressurized fluids in triggering seismic events.[804]

- June 24, 2014 – Following two earthquakes within a one-month period, the Colorado Oil and Gas Conservation Commission directed High Sierra Water Services to stop disposing wastewater into one of its Weld County injection wells. Monitoring by a team of seismologists from the University of Colorado had picked up evidence of continuing low-level seismic activity near the injection site, including a magnitude 2.6 event less than a month following a magnitude 3.4 earthquake that shook the Greeley area on May 31, 2014.[805]

- May 2, 2014 – The USGS and Oklahoma Geological Survey (OGS) jointly issued an official earthquake warning for Oklahoma, pointing out that the number of earthquakes in the state has risen 50 percent since just October—when the two agencies had issued a prior warning. The advisory stated that this dramatic increase in the frequency of small earthquakes "significantly increases the chance for a damaging quake in central Oklahoma." Injection wells used for the disposal of liquid fracking waste have been implicated as the presumptive cause of the earthquake swarm. According to the OGS, about 80 percent of the state of Oklahoma is closer than ten miles from an injection well.[806] Since the joint earthquake advisory was released in May, the number of earthquakes in Oklahoma has continued to rise. During the first four months of 2014, Oklahoma had experienced 109 earthquakes of magnitude 3 or higher on the Richter

[803] Schmall, E. & Jouzapavicius, J. (2014, July 14). States with fracking see surge in earthquake activity. *Associated Press*. Retrieved from http://www.huffingtonpost.com/2014/07/14/fracking-earthquake_n_5585892.html
[804] Nayak, A. & Dreger, D. S. (2014). Moment tensor inversion of seismic events associated with the sinkhole at Napoleonville Salt Dome, Louisiana. *Bulletin of Seismological Society of America 104(4),* 1763-1776. doi: 10.1785/0120130260
[805] Tomasic, J. (2014, June 24). Colorado drilling regulators halt injection-well activity in reaction to Greeley quake. *Colorado Independent*. Retrieved from http://www.coloradoindependent.com/147934/colorado-drilling-regulators-halt-injection-well-activity-in-reaction-to-greeley-quake (see also Baker, B. (2014, June 24). Colorado regulators halt fracking wastewater injection operation after earthquake strikes area for second time in a month. *Ecowatch*. Retrieved from http://ecowatch.com/2014/06/24/colorado-wastewater-injection-earthquake/)
[806] Geological Survey Joint Statement. (2014, May 2). Record number of Oklahoma tremors raises possibility of damaging earthquakes. United States Geological Survey. Retrieved from http://earthquake.usgs.gov/regional/ceus/products/newsrelease_05022014.php

scale. By mid-June, the number of earthquakes had topped 200, exceeding the frequency of earthquakes in California.[807]

- May 2, 2014 – At the annual meeting of the Seismological Society of America, leading geologists warned that the risks and impacts of earthquakes from fracking and injection wells are even more significant than previously thought, pointing out that such earthquakes could occur tens of miles away from wells themselves, including quakes greater than magnitude 5.0. Justin Rubinstein, a research geophysicist at the USGS said, "This demonstrates there is a significant hazard. We need to address ongoing seismicity."[808] Seismologist Gail Atkinson reported, "We don't know how to evaluate the likelihood that a [fracking or wastewater] operation will be a seismic source in advance."[809]

- April 11, 2014 – State geologists reported a link between fracking and a spate of earthquakes in Ohio, prompting the Ohio Department of Natural Resources to place a moratorium on drilling in certain areas and to require greater seismic monitoring.[810]

- April 3, 2014 – Researchers linked earthquakes in Mexico to fracking in the Eagle Ford Shale, which extends beneath both southern Texas and northern Mexico. They also noted a statistical correlation between seismic activity and fracking, particularly in the border state of Nuevo Leon, which registered at least 31 quakes between magnitude 3.1 and 4.3.[811]

- April 2014 – Researchers from the University of Alberta and the Alberta Geological Survey published a study in the *Journal of Geophysical Research* that found wastewater injection in Alberta is highly correlated with spikes of seismic activity between October 2006 and March 2012.[812] On November 13, 2014, *CBC News* reported on a more recent increase in earthquakes, which may also be linked to injection wells.[813]

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[807] Branson-Potts, H. (2014, June 17). Oklahoma coming to terms with unprecedented surge in earthquakes. *Los Angeles Times*. Retrieved from http://www.latimes.com/nation/la-na-oklahoma-earthquakes-20140618-story.html#page=1
[808] Walsh, B. (2014, May 1). The seismic link between fracking and earthquakes. *Time*. Retrieved June 9, 2014, from http://time.com/84225/fracking-and-earthquake-link/
[809] Kiger, P. J. (2014, May 2). Scientists warn of quake risk from fracking operations. *National Geographic*. Retrieved from http://news.nationalgeographic.com/news/energy/2014/05/140502-scientists-warn-of-quake-risk-from-fracking-operations/
[810] Dave, P. (2014, April 12). Ohio finds link between fracking and sudden burst of earthquakes. *Los Angeles Times*. Retrieved from http://www.latimes.com/nation/nationnow/la-na-nn-ohio-finds-link-fracking-earthquakes-20140411-story.html#axzz2yrnpHW1h
[811] Godoy, E. (2014, April 3). Fracking, seismic activity grow hand in hand in Mexico. *Inter Press Service*. Retrieved from http://www.ipsnews.net/2014/04/fracking-seismic-activity-grow-hand-hand-mexico/
[812] Schultz, R., Stern, V., & Gu, Y. J. (2014). An investigation of seismicity clustered near the Cordel Field, west central Alberta, and its relation to a nearby disposal well. *Journal of Geophysical Research: Solid Earth, 119,* 3410–3423. doi: 10.1002/2013JB010836
[813] Trynacity, K., & Siekierska, A. (2014, November 13). Fracking linked to Alberta earthquakes, study indicates. *CBC News*. Retrieved from http://www.cbc.ca/news/canada/edmonton/fracking-linked-to-alberta-earthquakes-study-indicates-1.2829484

- March 7, 2014 – USGS researchers published a study confirming that Oklahoma's damaging magnitude 5.7 earthquake in 2011 was caused by fracking wastewater injection.[814] One of the authors of the study, seismologist Elizabeth Cochran, noted, "Even if wastewater injection only directly affects a low-hazard fault, those smaller events could trigger an event on a larger fault nearby."[815]

- January 30, 2014 – A USGS research team linked the rise in earthquakes in Colorado to fracking wastewater injection wells and announced that a study will be published in six to nine months.[816]

- December 12, 2013 – The *New York Times* detailed the growing link between fracking wastewater injection wells and earthquakes, as well as between fracking itself and earthquakes, with a focus on Oklahoma and a recent magnitude 4.5 earthquake there. As the *New York Times* noted, "Oklahoma has never been known as earthquake country, with a yearly average of about 50 tremors, almost all of them minor. But in the past three years, the state has had thousands of quakes. This year has been the most active, with more than 2,600 so far, including 87 last week…. State officials say they are concerned, and residents accustomed to tornadoes and hail are now talking about buying earthquake insurance."[817]

- November 19, 2013 – *Reuters* reported that a series of Oklahoma earthquakes in September of 2013 damaged several homes, and that more scientists in a number of states are concerned about earthquakes related to oil and gas development. Seismologist Austin Holland with the University of Oklahoma said, "This is a dramatic new rate of seismicity."[818]

- July 19, 2013 – A study from the Lamont-Doherty Earth Observatory linked 109 earthquakes in Youngstown, Ohio to fracking wastewater disposal.[819, 820]

- July 11, 2013 – A study in *Science* by Columbia University's Lamont-Doherty Earth Observatory showed that deep-well injection of fracking waste can stress geological

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[814] Sumy, D. F., Cochran, E. S., Keranen, K. M., Wei, M., & Abers, G. A. (2013). Observations of static Coulomb stress triggering of the November 2011 M5.7 Oklahoma earthquake sequence [Abstract]. *Journal of Geophysical Research: Solid Earth, 119*(3), 1904-1923. doi: 10.1002/2013JB010612
[815] Oskin, B. (2014, March 07). Wastewater injection triggered Oklahoma's earthquake cascade. *Live Science*. Retrieved from http://www.livescience.com/43953-wastewater-injection-earthquake-triggering.html
[816] McClurg, L. (2014, January 30). Earthquakes in southern Colorado linked to oil and gas production. *Colorado Public Radio*. Retrieved from http://www.cpr.org/news/story/earthquakes-southern-colorado-linked-oil-and-gas-production#sthash.UVvw0JWe.UQwWtYJS.dpuf
[817] Fountain, H. (2013, December 12). Experts eye oil and gas industry as quakes shake Oklahoma. *The New York Times*. Retrieved from http://www.nytimes.com/2013/12/13/science/earth/as-quakes-shake-oklahoma-scientists-eye-oil-and-gas-industry.html
[818] Gillam, C. (2013, November 19). In Oklahoma, water, fracking - and a swarm of quakes. *Reuters*. Retrieved from http://www.reuters.com/article/2013/11/19/us-usa-earthquakes-fracking-oklahoma-idUSBRE9AI12W20131119
[819] Kim, W. (2013). Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *Journal of Geophysical Research: Solid Earth, 118*(7), 3506-3518. doi: 10.1002/jgrb.50247
[820] Chameides, B. (2013, September 5). Fracking waste wells linked to Ohio earthquakes. *Scientific American*. Retrieved from http://www.scientificamerican.com/article/fracking-waste-wells-linked-to-ohio-earthquakes/

faults in ways that make them vulnerable to slipping. The research shows that distant natural earthquakes triggered swarms of smaller earthquakes on critically stressed faults. The researchers wrote, "The fluids [in wastewater injection wells] are driving the faults to their tipping point…. Areas with suspected anthropogenic earthquakes are more susceptible to earthquake-triggering from natural transient stresses generated by the seismic waves of large remote earthquakes."[821]

- April 2013 – A group of British researchers stated that hydraulic fracturing itself was the likely cause of at least three earthquakes powerful enough to be felt by human beings at the surface. The researchers proposed that increases in the fluid pressure in fault zones were the causal mechanism for these three known instances of "felt seismicity" in the United States, Canada, and the United Kingdom. The largest of these earthquakes was a magnitude 3.8 in the Horn River Basin, Canada.[822]

- March 26, 2013 – Scientists from the University of Oklahoma, Columbia University and USGS linked a 2011 swarm of earthquakes in Oklahoma to fracking waste disposal in that state.[823] This included a magnitude 5.7 earthquake—possibly the largest ever triggered by wastewater injection—that injured two people, destroyed 14 homes, and was felt across 17 states.[824] The research team concluded in a paper in the journal *Geology* that their data called into question the previously predicted maximum size of injection-induced earthquakes.[825, 826]

- December 14, 2012 – At a 2012 American Geophysical Union meeting, scientists presented data and concluded that some U.S. states, including Oklahoma, Texas and Colorado, have experienced a significant rise in seismic activity coinciding with a boom in gas drilling, fracking and wastewater disposal. Scientists further found that Oklahoma has seen a significant increase in earthquakes linked to wastewater injection, that a 5.3 earthquake in New Mexico was linked to wastewater injection, and that earthquakes were increasingly common within two miles of injection wells in the Barnett Shale region of Texas. Art McGarr, a researcher at the USGS Earthquake Science Center, concluded that,

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821 Begley, S. (2013, July 11). Study raises new concern about earthquakes and fracking fluids. *Reuters*. Retrieved from http://www.reuters.com/article/2013/07/11/us-science-fracking-earthquakes-idUSBRE96A0TZ20130711

822 Davies, R., Foulger, G., Bindley, A., & Styles, P. (2013). Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons. *Marine and Petroleum Geology, 45*, 171-185. doi: 10.1016/j.marpetgeo.2013.03.016

823 Drajem, M., & Efstathiou, J., Jr. (2013, March 26). Quake tied to oil-drilling waste adds pressure for rules. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2013-03-26/oklahoma-earthquake-in-2011-tied-to-wastewater-wells-in-fracking.html

824 Behar, M. (2013, March/April). Fracking's latest scandal? Earthquake swarms. *Mother Jones*. Retrieved from http://www.motherjones.com/environment/2013/03/does-fracking-cause-earthquakes-wastewater-dewatering?page=1

825 Keranen, K. M., Savage, H. M., Abers, G. A., & Cochran, E.S. (2013). Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence. *Geology.* doi: 10.1130/G34045.1

826 Diep, F. (2013, March 28). Study: wastewater injection caused Oklahoma's largest-ever earthquake. *Popular Science.* Retrieved from http://www.popsci.com/science/article/2013-03/largest-earthquake-ever-linked-lightly-regulated-wastewater-wells

"The future probably holds a lot more in induced earthquakes as the gas boom expands."[827]

- November 30, 2012, January 11, 2012, December 22, 2009 – In three different sets of comments on proposed fracking guidelines and regulations, citing scientific reports linking oil and gas infrastructure to seismic activity, the New York City Department of Environmental Protection (NYC DEP) raised serious concerns about the impacts of potential seismic activity from fracking-related activities on New York City's water supply infrastructure.[828, 829, 830] The NYC DEP has consistently raised concerns that seismic activity surrounding New York City's aquifers and watershed infrastructure could threaten the city's drinking water supply by triggering microseismic events and small induced earthquakes that, in turn, could threaten the integrity of the aging, 100-mile-long aqueducts that carry drinking water from the Catskill Mountains into the New York City metropolitan area. The agency expressed specific concerns about the ability of hydraulic fracturing fluids to migrate underground and to intercept and reactivate faults miles away.

- September 6, 2012 – The British Columbia Oil and Gas Commission determined that fracking itself causes earthquakes, pointing to the results of a probe into 38 seismic events near fracking operations in the Horn River Basin. The report noted that no quakes had been recorded in the area prior to April 2009, before fracking began. The report recommended that the link between fracking and seismic activity be further examined.[831]

- March 29, 2012 – The USGS found that between 2001 and 2011, there was a six-fold increase in earthquakes greater than magnitude 3.0 in the middle of the United States that "are almost certainly manmade." The agency further reported that the increase appears to be linked to oil and gas production and deep injection of drilling wastewater.[832, 833]

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[827] Leber, J. (2012, December 14). Studies link earthquakes to wastewater from fracking. *MIT Technology Review*. Retrieved from http://www.technologyreview.com/news/508151/studies-link-earthquakes-to-wastewater-from-fracking/

[828] New York City Department of Environmental Protection. (2009, December 22). *New York City comments on: Draft supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program - Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permeability gas reservoirs* (Rep.). Retrieved from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_final_12-22-09.pdf

[829] New York City Department of Environmental Protection. (2012, January 11). *Comments on the revised draft supplemental generic environmental impact statement*. (Rep.). Retrieved from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_on_rdsgeis_for_hvhf_20120111.pdf

[830] New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). Retrieved from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

[831] The Canadian Press. (2012, September 6). Fracking causes minor earthquakes, B.C. regulator says. *CBC News*. Retrieved from http://www.cbc.ca/news/canada/british-columbia/fracking-causes-minor-earthquakes-b-c-regulator-says-1.1209063

[832] Ellsworth, W. (2011, April 18). Are seismicity rate changes in the midcontinent natural or manmade? Retrieved from http://www2.seismosoc.org/FMPro?-db=Abstract_Submission_12&-sortfield=PresDay&-sortorder=ascending&-sortfield=Special+Session+Name+Calc&-sortorder=ascending&-sortfield=PresTimeSort&-

- July 31, 2011 – Numerous earthquakes in Arkansas motivated the Arkansas Oil and Gas Commission to shut down a disposal well and enact a permanent moratorium on future disposal wells in a nearly 1,200 square-mile area of the Fayetteville Shale.[834]

- March 10, 2010 – In Texas, a 2008-2009 swarm of earthquakes in the Dallas-Fort Worth area was linked to produced water disposal wells.[835]

- June 12, 2009 – *The Wall Street Journal* reported that earthquakes shook Cleburne, Texas, a small town at the epicenter of fracking activity. More earthquakes were detected during that period of fracking activity than in the previous 30 years combined.[836]

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833 Soraghan, M. (2012, March 29). 'Remarkable' spate of man-made quakes linked to drilling, USGS team says. *E&E Publishing, LLC*. Retrieved from http://www.eenews.net/stories/1059962190

834 Zilk, C. (2011, July 31). Permanent disposal-well moratorium issued. *Arkansas Online*. Retrieved from http://www.arkansasonline.com/news/2011/jul/31/permanent-disposal-well-moratorium-issued-20110731/

835 Frohlich, C., Hayward, C., Stump, B., & Potter, E. (2011). The Dallas-Fort Worth Earthquake Sequence: October 2008 through May 2009. *Bulletin of the Seismological Society of America, 101*(1), 327-340. doi: 10.1785/0120100131

836 Casselman, B. (2009, June 12). Temblors rattle Texas town. *Wall Street Journal*. Retrieved from http://online.wsj.com/news/articles/SB124476331270108225

Abandoned and active wells as pathways for gas and fluid migration

Most fracking operations take place in oil and gas fields with a long history of conventional drilling and therefore with many abandoned wells. These can serve as potential pathways for contaminants to migrate vertically. Of the estimated 2.6 million oil and gas wells across the United States that are no longer in production, the location and status of the vast majority are not recorded in state databases, and most remain unplugged. Whether plugged or unplugged, abandoned wells are a significant source of methane leakage into the atmosphere and, based on findings from New York and Pennsylvania, may exceed cumulative total leakage from oil and gas wells currently in production. No state or federal agency routinely monitors methane leakage from abandoned wells. Abandoned wells also serve as underground pathways for fluid migration, heightening risks of groundwater contamination. Fluid can migrate upward through vertical channels when fractures from new drilling and fracking operations intersect with old wells. The most probable pathway of contaminant transport takes place outside the well casing. Industry experts, consultants, and government agencies including the U.S. Environmental Protection Agency (EPA), the U.S. Government Accountability Office (GAO), Texas Department of Agriculture, New York State Department of Environmental Conservation (NYS DEC), Pennsylvania Department of Environmental Protection (PA DEP), Illinois Environmental Protection Agency, and the British Columbia Oil and Gas Commission have all warned about problems with abandoned wells due to the potential for pressurized fluids and gases to migrate through inactive and, in some cases, active wells.

- March 11, 2019 – There are roughly 200,000 abandoned oil and gas wells in Pennsylvania left over from more than a century of drilling. Most are not mapped. Alabama-based Diversified Gas & Oil, which now owns about 23,000 gas wells in the state, reached an agreement with the PA DEP to plug 1,400 abandoned wells over the next 15 years—or bring them back into production. The agreement requires the company to submit a $7 million performance bond to cover the costs of plugging. In 2018, the company plugged 41 wells across its entire operating area.[837]

- March 5, 2019 – There are 30,000 abandoned oil wells in California, with 1,850 in Los Angeles County. The state is currently not required to report to the public on toxic air emissions from these wells before, during, or after they are plugged, even when idle wells are located within densely populated residential communities. The process of capping wells can itself release harmful gases. Legislation has been proposed to remediate this oversight.[838]

- February 21, 2019 – While preparing to mine over a natural gas storage field in Greene County, Pennsylvania, a coal company discovered dozens of undisclosed abandoned gas

[837] Legere, L., & Litvak, A. (2019, March 11). Pa. strikes well-plugging deal with largest conventional oil and gas operator in Appalachia. *Pittsburgh Post-Gazette.* Retrieved from https://www.post-gazette.com/business/powersource/2019/03/11/Diversified-Gas-and-Oil-abandoned-wells-plugging-settlement-Pennsylvania-DEP/stories/201903080130

[838] Scauzillo, S. (2019, March 5). What toxins are being emitted from LA County's abandoned oil wells? A lawmaker wants to find out. Retrieved from https://www.sgvtribune.com/tag/california-legislature/

wells at the site, according to a report by the *Pittsburgh Post-Gazette.* "Pennsylvania's history of fossil fuel extraction, combined with modern operations harvesting coal, oil and gas at different depths, makes it a particularly thorny place to work underground."[839]

- January 25, 2019 – Colorado Governor John Hickenlooper signed an executive order to force the "plugging, remediation and reclamation of all medium- and high-priority orphaned wells and orphaned sites." There are roughly 55,000 oil and gas wells in Colorado. At least 260 are orphaned, which means that the well's owner cannot be identified, usually because of bankruptcy. Inactive wells that are orphaned become the responsibility of the state.[840]

- December 21, 2018 – Most fracking operations take place in oil and gas fields with a long history of conventional drilling and therefore with many abandoned wells. The possibility of hydraulic fractures intercepting these old wells and opening a pathway for rapid vertical transport for fluids to the surface or to groundwater aquifers depends on multiple variables. A University of Goettingen-led team used modeling to explore the relevant factors that predict long-term flow and transport of fracking fluids into groundwater aquifers through a leaky, abandoned well. The results showed that wellbore integrity of the abandoned well and its distance from the fracking operation are the two most influential parameters determining the vertical transport of fracking fluid through an abandoned well. The most probable pathway of contaminant transport takes place outside the well casing. Hydraulic fracking fluid tends to spread laterally when sediment layers are permeable, decreasing upward movement of fluid and decreasing contamination distribution in the aquifer. When freshwater aquifers are shallow, the short-term probability of contamination is negligible even in the presence of a leaky, abandoned well. "Model results show that hydraulic fracturing fluid reaches the aquifer three years after production."[841]

- December 15, 2018 – A University of Vermont-led team explored the ability of various predictive models to forecast fluid migration from and through abandoned wells in Alberta, Canada. Although all the models "performed better than random guessing," none of them perfectly predicted which wells would leak in part because of incomplete data. In Alberta, wells that do not leak at the time they are drilled are not retested until they are abandoned. Continuous monitoring of wells in a small area would allow the models to be retrained with more accurate information. Consistent with previous findings, the models

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[839] Legere, L. (2019, February 21). Pa. DEP threatened to shut down a gas storage field fearing risks to approaching coal mine. *Pittsburgh Post-Gazette*. Retrieved from https://www.post-gazette.com/business/powersource/2019/02/21/coal-mine-natural-gas-storage-abandoned-wells-Pennsylvania-Equitrans-Consol/stories/201902200130

[840] Staver, A. (2019, January 25). Hickenlooper signs order to release the locations of orphan wells, sets deadline to cap them. *Denver Post.* Retrieved from https://www.denverpost.com/2018/07/18/hickenlooper-executive-order-orphan-wells/

[841] Taherdangkoo, R., Tatomir, A., Anighoro, T., & Sauter, M. (2019). Modeling fate and transport of hydraulic fracturing fluid in the presence of abandoned wells. *Journal of Contaminant Hydrology, 221*, 58-68. Advance online publication. doi: 10.1016/j.jconhyd.2018.12.003

did show that the most important features in predicting whether an abandoned well will leak is the deviation of the well from vertical and the year the well was constructed.[842]

- November 20, 2018 – An investigation by WPXI, an NBC-affiliated television station in Pittsburgh, reported that Pennsylvania lacks funds to locate, plug, and remediate all potentially dangerous abandoned wells in the state. "Overall the problems could cost the state close to $4 billion, so it is responding to the most critical cases first."[843]

- November 20, 2018 – There are an estimated 12,000 abandoned wells in West Virginia, of which 4,000 are orphaned and have no owners, according to a story in the *Charleston Gazette-Mail* that reported how gas companies are saving money by leaving depleted wells behind instead of plugging them.[844]

- September 5, 2018 – An investigation of abandoned wells on Native American lands in the San Juan Basin found that the Bureau of Land Management (BLM), responsible for monitoring oil and gas wells on most tribal lands, has routinely failed to require operators to file paperwork on abandoned wells, lacks a clear strategy for identifying them, and does not prioritize cleaning up or remediating them.[845]

- May 16, 2018 – The GAO reported to Congress that BLM needs to improve its oversight of abandoned oil and gas wells. Companies are supposed to provide bonds up front to cover the costs of plugging abandoned wells and reclaiming the sites, but if they don't, or if the costs exceed expectations, BLM can be liable and taxpayers can shoulder the clean-up costs. "Reclamation costs and potential liabilities likely increased since 2010, but we couldn't determine how much because BLM does not systematically track the data." The GAO recommended that, among other things, the director of BLM should systematically track the actual costs that the agency incurs when reclaiming orphaned wells, the number of orphaned and abandoned wells over time, and the information needed to determine the agency's potential liabilities. The BLM concurred with the GAO's recommendations. There are roughly 94,000 oil and gas wells on federal lands overseen by BLM.[846]

- Dec 26, 2017 – In 1965, a blowout at a gas well in northeastern Netherlands caused the formation of quicksand, which swallowed up an entire drill rig. Eventually, the area was

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[842] Montague, J. A., Pinder, G. F., & T. L. Watson. (2018). Predicting gas migration through existing oil and gas wells. Environmental Geosciences, 25(4), 121-132. doi: 10.1306/eg.01241817008
[843] WPXI (2018, November 20). Abandoned oil wells hidden under thousands of local properties. Retrieved from https://www.wpxi.com/news/top-stories/abandoned-oil-wells-hidden-under-thousands-of-local-properties/875732284
[844] Mishkin, K. (2018, November 20). Drilling companies avoiding responsibility to plug orphan wells, group says. *Charleston Gazette-Mail.* Retrieved from https://www.wvgazettemail.com/news/drilling-companies-avoiding-responsibility-to-plug-orphan-wells-group-says/article_c423997f-d011-5e8a-a54f-13e54d3c0985.html
[845] Clarren, R. (2018, September 5). Idle oil, gas wells threaten Indian tribes while energy companies, regulators do little. *InvestigateWest.* Retrieved from http://www.invw.org/2018/09/05/idle-oil-gas-wells-threaten-indian-tribes-while-energy-companies-and-regulators-do-little/
[846] U.S. Government Accountability Office. (2018, May 16). *Oil and Gas Wells: Bureau of Land Management Needs to Improve its Data and Oversight of Its Potential Liabilities.* GAO-18-250. Retrieved from https://www.gao.gov/assets/700/691810.pdf

turned into a park. More than 50 years later, a team of researchers discovered that the site is still leaking methane. They found in the groundwater high levels of methane with an isotopic composition that matched that of the gas reservoir. An analysis of groundwater flow conditions showed that this methane is not a remnant of the blowout but the result of ongoing leakage. "Combined, the data reveal the long-term impact that underground gas well blowouts may have on groundwater chemistry, as well as the important role of anaerobic oxidation in controlling the fate of dissolved methane."[847, 848]

- June 28, 2017 – *The Tyee* made public the results of an unreleased 2016 report by the Alberta Energy Regulator (AER) showing that 36 of 335 abandoned oil and gas wells that are located close to occupied buildings in urban areas of Alberta are leaking methane. Six abandoned wells were leaking at levels (10,000 ppm) that pose explosion risks and are considered life-threatening. (Natural background level is about 1.9 ppm.) Based on these findings, the report also estimated that 17,000 of 170,000 abandoned wells in rural Alberta were likely also leaking. The author of the unreleased report said in an interview with *The Tyee* that AER, a corporation that functions in part as a regulatory agency, does not have the capacity to evaluate the potential threat to public health and safety. "The expertise to assess the health risk of abandoned wells really doesn't exist in house."[849, 850]

- March 27, 2017 – In an experimental study, Canadian researchers injected methane gas into a shallow sand aquifer over a 72-day period and monitored methane migration for eight months. After 72 days, they found that half of the methane had vented into the atmosphere and half remained in the groundwater, traveling laterally a greater distance than expected and degrading at a rate less than expected. "Our findings demonstrate that even small-volume releases of methane gas can cause extensive and persistent free phase and solute plumes."[851, 852]

- December 21, 2016 – The *Texas Tribune* investigated abandoned oil wells in Texas where the Texas Railroad Commission, which is charged with regulating the oil and gas industry, has tracked and mapped 6,628 unplugged, orphaned wells. The commission is struggling with a ballooning inventory of inactive, leaking wells and decreasing clean-up funds to deal with them. The most recent oil boom, involving horizontal drilling with fracking, added to the problem as drillers cut corners in the rush to bring oil to market.

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[847] Schout, G., Hartog, N., Hassanizadeh, S. M., & Griffioen, J. (2018). Impact of an historic underground gas well blowout on the current methane chemistry in a shallow groundwater system. *Proceedings of the National Academy of Sciences, 115*(2), 296-301. Advance online publication. doi: 10.1073/pnas.1711472115
[848] Yirka, B. (2017, December 29). Methane still leaking from the ground at site of gas explosion decades ago. *Phys.org.* Retrieved from https://phys.org/news/2017-12-methane-leaking-ground-site-gas.html
[849] Nikiforuk, A. (2017, June 28). Energy industry legacy: Hundreds of abandoned wells leaking methane in Alberta communities. *The Tyee.* Retrieved from https://thetyee.ca/News/2017/06/28/Energy-Industry-Legacy/
[850] Nikiforuk, A. (2017, July 4). Alberta failing on risk from leaking oil and gas wells, says expert. *The Tyee.* Retrieved from https://thetyee.ca/News/2017/07/04/Alberta-Failing-Leaking-Oil-Gas-Wells-Risk/
[851] Cahill, A. G., Steelman, C. M., Forde, O., Kuloyo, O., Ruff, S. E., Mayer, B., . . . Parker, B. L. (2017). Mobility and persistence of methane in groundwater in a controlled-release field experiment. *Nature Geoscience, 10,* 289–294. doi: 10.1038/ngeo2919
[852] Nikiforuk, A. (2017, April 11). Methane leaks from energy wells affects groundwater, travels great distances, study confirms. *The Tyee.* Retrieved from https://thetyee.ca/News/2017/04/11/Methane-Leaks-from-Energy-Wells-Affects-Groundwater/

"Just drill the well as fast as possible, because they were under such pressure to get cash flow going," according to a geoscientist interviewed for the story who had recently retired as a groundwater advisor for the Railroad Commission.[853]

- November 14, 2016 – Methane emissions from abandoned wells vary widely, with a few high emitters responsible for a disproportionately large share of the problem. Using new field measurement and data mining techniques, a Stanford University-led team investigated gas leaks at 88 inactive wells in Pennsylvania in an attempt to identify the characteristics of these "super-emitters." Their results showed that unplugged gas wells and wells located in coal areas had the highest methane flow rates. Well plugging does not always reduce methane emission, especially when the wells are vented. In many areas with extensive coal layers, decommissioning requirements for wells included mandatory venting. Using comprehensive databases, the team also estimated the number of abandoned wells in Pennsylvania to be between 470,000 and 750,000, considerably more than previous estimates of 300,000 to 500,000. The research team calculated that, all together, Pennsylvania's abandoned wells contribute 5-8 percent of the state's annual greenhouse gas emissions.[854, 855]

- June 20, 2016 – Pennsylvania's attorney general began reviewing regulations requiring drillers to document abandoned oil and gas wells within 1,000 feet of a new fracking site. According to a *Bloomberg* investigation, "This puts Pennsylvania among states such as California, Texas, Ohio, Wyoming and Colorado confronting the environmentally catastrophic legacy of booms as fracking and home development expand over former drilling sites. As the number of fracked wells increases, so does the chance they might interact with lost wells." As noted by *Bloomberg,* state databases document only about 10 percent of the nation's 2.6 million abandoned oil and gas wells; the whereabouts of the vast majority are unknown. Current efforts in Pennsylvania to increase documentation on the location and status of inactive wells rely on "citizen scientists" equipped with GPS and methane sniffers, as well as home and farm-owners living on top of abandoned wells. Over a period of three decades, PA DEP has located and plugged only about 3,000 abandoned wells.[856]

- May 30, 2016 – New developments of houses, schools, and shopping centers are being built over abandoned oil and gas wells, according to a report by Wyoming Public Media. In most states there is no requirement for homeowners to be notified about abandoned

[853] Malewitz, J. (2016, December 21). Abandoned Texas oil wells seen as "ticking time bombs" of contamination. *Texas Tribune.* Retrieved from https://www.texastribune.org/2016/12/21/texas-abandoned-oil-wells-seen-ticking-time-bombs-/
[854] Kang, M., Christian, S., Celia, M. A., Mauzerall, D. L., Bill, M., Miller, A. R., . . . Jackson, R. B. (2016). Identification and characterization of high methane-emitting abandoned oil and gas wells. *Proceedings of the National Academy of Sciences, 113*(48), 13636-13641. doi: 10.1073/pnas.1605913113
[855] Than, K. (2016, November 14). Stanford study of abandoned oil and gas wells reveals new ways of identifying and fixing the worst methane emitters. *Stanford News.* Retrieved from https://news.stanford.edu/2016/11/14/study-abandoned-oil-gas-wells-reveals-new-ways-fixing-worst-methane-emitters/
[856] Oldham, J. (2016, June 20). In the birthplace of U.S. oil, methane gas is leaking everywhere. *Bloomberg.* Retrieved from http://www.bloomberg.com/news/articles/2016-06-20/in-the-birthplace-of-u-s-oil-methane-gas-is-leaking-everywhere

wells on their properties, and these wells are not systematically monitored for leaks, nor are their locations well mapped. A builder who worked in the oil and gas industry for decades and suffered cardiac arrest when methane from an abandoned well he was inadvertently working atop exploded, said that there were "no signs" that a well was there.[857]

- January 26, 2016 – Researchers tested soil methane levels at 102 United Kingdom decommissioned oil and gas wells between 8 and 79 years old. Thirty percent of the wells had methane at the soil surface that was significantly higher than their control samples in nearby fields. Thirty-nine percent of well sites had significantly lower surface soil methane than their respective controls. Researchers suggested several explanations for the latter results, including replaced soils.[858]

- October 20, 2015 – Abandoned oil and gas wells near fracking sites can be conduits for methane escape that is not currently being measured, according to University of Vermont researchers. Fractures in the surrounding rock may connect to existing unused oil and gas wells in the area during fracking processes, thus providing a pathway for methane to migrate to the surface. The study used a mathematical model based on the large part of southern New York State underlain by the Marcellus Shale, incorporating "the depth of a new fracturing well, the vertical growth of induced fractures, and the depths and locations of existing nearby wells." The researchers concluded the probability that new fracking-induced fractures would connect to a pre-existing well to be .03 percent to 3 percent. Density of nearby abandoned wells was the largest factor, and researchers pointed out the continuing problem of undocumented abandoned wells.[859] As noted in an accompanying press release, probabilities are likely much higher: "Industry-sponsored information made public since the paper was published vastly increased assumptions about the area impacted by a set of six to eight fracking wells known as a well pad – to two square miles – increasing the probabilities cited in the paper by a factor of 10 or more."[860]

- July 9, 2015 – As part of an extensive, peer-reviewed assessment of fracking in California, the California Council on Science and Technology identified leakage through failed, inactive wells as a known mechanism for fracking-related water contamination in other states, including Texas and Ohio, and said that it is not known whether abandoned wells in California likewise function as conduits for groundwater contamination and gas leakage. In California, there are more inactive than active wells. Of the state's nearly one-quarter million oil and gas wells, more than half (116,000) have been plugged and abandoned, while another 1,800 inactive wells are "buried" with only an approximate

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[857] Editor. (2016, May 30). Danger below? New properties hide abandoned oil and gas wells. *Wyoming Public Media.* Retrieved from http://wyomingpublicmedia.org/post/hidden-abandoned-dangerous-old-gas-and-oil-wells-neighborhoods
[858] Boothroyd, I. M., Almond, S., Qassim, S. M., Worrall, F., & Davies, R. J. (2016). Fugitive emissions of methane from abandoned, decommissioned oil and gas wells. *Science of the Total Environment, 547,* 461-469. doi: 10.1016/j.scitotenv.2015.12.096
[859] Montague, J. A., & Pinder, J. F. (2015). Potential of hydraulically induced fractures to communicate with existing wellbores. *Water Resources Research*, *51*, 8303–8315. doi: 10.1002/2014WR016771
[860] Newswise. (2015, October 20). Dirty pipeline: Methane from fracking sites can flow to abandoned wells, new study shows. *Newswise.* Retrieved from http://www.newswise.com/articles/view/641581/

location known. The locations of another 338 old wells are entirely unknown. California also has 110 orphaned wells, that is, abandoned wells with no owners. Most of California's abandoned wells (53 percent) are located in Kern County.[861]

- May 11, 2015 – *CBC News* reported that falling gas and oil prices have prompted many smaller companies to abandon their operations in Alberta, Canada, leaving the provincial government to close down and dismantle their wells. In the past year alone, the number of orphaned wells in Alberta increased from 162 to 702. At the current rate of work, deconstructing the inventory of wells abandoned just in the past year alone will be a 20-year task.[862]

- April 27, 2015 – In a peer-reviewed study, researchers with the U.S. Fish and Wildlife Service documented 5,002 wells located on National Wildlife Refuge System units, in addition to 1,339 miles of pipeline. Almost half of the wells were inactive, while one-third were active and the remainder either plugged and abandoned or with status unknown. Highlighting the impacts of leaks, spills, and routine operation and maintenance on wildlife conservation efforts, the authors called for regular on-site ecological assessments, improved efforts to plug inactive wells and restore inactive well sites, and a "consolidated and robust regulatory framework" to protect the public's interests.[863]

- March 24, 2015 – Analyzing data from 42 abandoned oil and gas wells in western Pennsylvania, a Princeton and Stanford team documented a wide range of leakage potentials. As a group, gas wells have higher permeability than oil wells. Among gas wells, methane flow rates are positively correlated with permeability. Subterranean temperatures and temperatures, along with well depth, are all variables that can influence leakage potentials of abandoned wells. The leakage potential of wells drilled prior to 1960 is moderate to high, and plugged wells, as well as unplugged wells, can leak. The authors note that cement plugs are imperfect barriers that can develop defects that allow fluids to flow through gaps between the plug and surrounding hole, through pores or fissures within the plug itself, or directly through cracks in the well casing.[864]

- December 8, 2014 – A Princeton University team found that abandoned oil and gas wells in Pennsylvania, left over from prior decades of conventional drilling, leak significantly more methane than previously thought. Between 300,000 and 500,000 abandoned oil and gas wells are located in Pennsylvania, and many go unchecked and unmonitored for

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[861] Stringfellow, W. T., Cooley H., Varadharajan, C., Heberger, M., Reagan, M. T., Domen, J.K., . . . Houseworth, J. E. (2015, July 9). Volume II, Chapter 2: Impacts of well stimulation on water resources. In: *An Independent Scientific Assessment of Well Stimulation in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from http://ccst.us/publications/2015/vol-II-chapter-2.pdf
[862] Johnson, T. (2015, May 11). Alberta sees huge spike in abandoned oil and gas wells. *CBC News.* Retrieved from http://www.cbc.ca/news/canada/calgary/alberta-sees-huge-spike-in-abandoned-oil-and-gas-wells-1.3032434
[863] Ramirez Jr., P., & Mosley, S. B. (2015). Oil and gas wells and pipelines on U.S. wildlife refuges: Challenges for managers. *PLoS ONE, 10*(4). doi: 10.1371/journal.pone.0124085
[864] Kang, M., Baik, E., Miller, A. R., Bandilla, K. W., & Celia, M. A. (2015). Effective permeabilities of abandoned oil and gas wells: analysis of data from Pennsylvania. *Environmental Science & Technology, 49*(7). doi: 10.1021/acs.est.5b00132

leaks. Nearly three-quarters are unplugged. Based on direct measurements of methane flow from 19 such wells, most of which were a half century old or older, the researchers estimated that the methane leaks from abandoned wells alone could account for between 4 and 7 percent of human-caused methane emissions in the state. Based on these measurements of positive methane flow from decades-old wells, the authors concluded that cumulative emissions from these abandoned wells "may be significantly larger than the cumulative leakage associated with oil and gas production, which has a shorter lifetime of operation." Further, methane flow rates from plugged wells measured in this study were not consistently lower than unplugged wells and indeed were sometimes higher, even though wells are plugged for the precise purpose of limiting the escape of gases. The authors noted that an estimated three million abandoned oil and gas wells are scattered across the United States and likely represent "the second largest potential contribution to total US methane emissions above US Environmental Protection Agency estimates." In the United States, no regulatory requirements for monitoring methane leaks from abandoned wells exist.[865, 866]

- December 1, 2013 – An analysis of reports from the NYS DEC found that three-quarters of the state's abandoned oil and gas wells were never plugged. New York State has approximately 48,000 such wells; many of their locations remain unknown.[867]

- Aug. 4, 2011 – A report from the EPA to Congress in 1987—and discovered by the *New York Times*—concluded that abandoned natural gas wells may have served as a pathway for hydraulic fracturing fluids to migrate underground from a shale gas well to a water well in West Virginia. In noting that the water well was polluted due to hydraulic fracturing and that such contamination was "illustrative" of contamination from oil and natural gas drilling, the report suggested that additional cases of groundwater contamination from hydraulic fracturing may exist.[868]

- April 4, 2011 – *ProPublica* reported that abandoned wells have caused problems across the nation including contamination of drinking water in Colorado, Kentucky, Michigan, New York, Texas, and other states. *ProPublica* also found that a draft report from the Pennsylvania DEP described a 2008 incident in Pennsylvania in which a person died in an explosion triggered by lighting a candle in a bathroom after natural gas had seeped into a septic system from an abandoned well. The same draft report documented at least two dozen additional cases in which gas leaked from old wells, and three in which gas

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[865] Kang, M., Kanno, C. M., Reid, M. C., Zhang, X., Mauzerall, D. L., Celia, M. A., . . . Onstott, T. C. (2014). Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania. *Proceedings of the Natural Academy of Sciences*. Advance online publication. doi: 10.1073/pnas.1408315111

[866] Magill, B. (2014, June 19). Derelict oil wells may be major methane emitters. *Climate Central.* Retrieved from http://www.climatecentral.org/news/abandoned-oil-wells-methane-emissions-17575

[867] Bishop, R. E. (2014). Historical analysis of oil and gas well plugging in New York: Is the regulatory system working? *New Solutions: A Journal of Environmental and Occupational Health Policy*, *21*, 103-116. Retrieved from http://baywood.metapress.com/media/16ut607yqg1yrw9ydad3/contributions/b/0/4/7/b047j34r87552325.pdf

[868] Urbina, I. (2011, August 4). A tainted water well, and concern there may be more. *The New York Times.* Retrieved from http://www.nytimes.com/2011/08/04/us/04natgas.html

from new wells migrated into old wells, seeping into water supplies and requiring the evacuation of homes.[869]

- May 20, 2010 – The British Columbia Oil and Gas Commission issued a safety advisory after hydraulic fracturing caused a large "kick," or unintentional entry of fluid or gas, into a nearby gas well. The commission reported that it knew of 18 incidents in British Columbia and one in Western Alberta in which hydraulic fractures had entered nearby gas wells. "Large kicks resulted in volumes up to 80 cubic meters [about 100 cubic yards] of fluids produced to surface. Invading fluids have included water, carbon dioxide, nitrogen, sand, drilling mud, other stimulation fluids and small amounts of gas." These cases occurred in horizontal wells with a distance between wellbores of up to 2,300 feet. The Commission wrote, "It is recommended that operators cooperate through notifications and monitoring of all drilling and completion operations where fracturing takes place within 1000m [3,280 feet] of well bores existing or currently being drilled." Such communication between active wells raises the potential that similar communication can occur between active wells and abandoned wells.[870]

- 2010 – The NYS DEC cautioned that "abandoned wells can leak oil, gas and/or brine; underground leaks may go undiscovered for years. These fluids can contaminate ground and surface water, kill vegetation, and cause public safety and health problems." As the agency reported, "DEC has at least partial records on 40,000 wells, but estimates that over 75,000 oil and gas wells have been drilled in the State since the 1820s. Most of the wells date from before New York established a regulatory program. Many of these old wells were never properly plugged or were plugged using older techniques that were less reliable and long-lasting than modern methods."[871] The agency published similar comments in 2008 and 2009.

- January 2009 – In a presentation before the Society of Petroleum Engineers, industry consultant Michael C. Vincent reported on evidence that fractures from hydraulically fractured wells can communicate with nearby oil and gas wells. In spite of numerous examples of fractures intersecting with adjacent wellbores, the industry is reluctant to publish reports documenting these cases because "such information could unnecessarily alarm regulators or adjacent leaseholders." Vincent added, "Although computing tools have improved, as an industry we remain incapable of fully describing the complexity of the fracture, reservoir, and fluid flow regimes." These findings raise the possibility that there could be similar communications between existing fracked wells that are fractured and abandoned wells and that operators cannot accurately predict how these will interact.[872]

[869] Kusnetz, N. (2011, April 4). Danger in honeycomb of old wells. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/nation/2011/04/04/Danger-in-honeycomb-of-old-wells/stories/201104040149
[870] British Columbia Oil & Gas Commission. (2010, May 20). Safety advisory: Communication during fracture stimulation. Retrieved from https://www.bcogc.ca/node/5806/download
[871] New York State Department of Environmental Conservation. (2010). New York oil, gas and mineral resources 2010. Retrieved from http://www.dec.ny.gov/docs/materials_minerals_pdf/10anrpt1.pdf
[872] Vincent, M. C. (2009, January 19). Examining our assumptions – Have oversimplifications jeopardized our ability to design optimal fracture treatments? Lecture presented at Society of Petroleum Engineers hydraulic

- 2005 – M.K. Fisher, Vice President of Business Management at Pinnacle, a service of Halliburton that specializes in hydraulic fracturing, reported in an article published by the Society of Petroleum Engineers that a single fracture produced during a fracking operation in the Texas Barnett Shale had unexpectedly spread 2,500 feet laterally in two directions. He also described fractures in the Barnett Shale as "extremely complex."[873] These findings raise the possibility that well communication over very large distances could occur due to fractures that spread "unexpectedly."

- October 1999 – The U.S. Department of Energy reported that there were approximately 2.5 million abandoned oil and gas wells in the U.S.[874]

- Early 1990s – An underground waste disposal well in McKean County, Pennsylvania, contaminated groundwater when the wastewater traveled up a nearby abandoned, unmapped, and unplugged oil well. Owners of private water wells that were contaminated by the incident eventually had to be connected to a public water system.[875]

- July 1989 – In the past, the investigative agency for Congress, the U.S. General Accounting Office (now the Government Accountability Office—GAO) studied oil and natural gas underground injection disposal wells and found serious cases of contamination. The agency reported that, in several cases, wastewater from oil and natural gas operations had migrated up into abandoned oil and natural gas wells, contaminating underground water supplies. The GAO found that "if these abandoned wells are not properly plugged—that is, sealed off —and have cracked casings, they can serve as pathways for injected brines [waste fluids from natural gas and oil drilling] to enter drinking water…. Because groundwater moves very slowly, any contaminants that enter it will remain concentrated for long periods of time, and cleanup, if it is technically feasible, can be prohibitively costly."[876]

- December 1987 – The EPA submitted a report to Congress on oil and natural gas wastes in which the agency cautioned that abandoned wells must be plugged with cement in order to avoid "degradation" of ground and surface waters as a result of pressurized brine or injected waste from wastewater disposal wells migrating into to aquifers, rivers, or

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fracturing technology conference in The Woodlands, Texas. Retrieved from http://www.spe.org/dl/docs/2010/MikeVincent.pdf

[873] Fisher, M., Wright, C., Davidson, B., Steinsberger, N., Buckler, W., Goodwin, A., & Fielder, E. (2005). Integrating fracture-mapping technologies to improve stimulations in the Barnett Shale. *SPE Production & Facilities, 20*(2). doi: 10.2118/77441-PA

[874] United States Department of Energy, Office of Fossil Energy. (1999, October 5). *Environmental benefits of advanced oil and gas exploration and production technology*. (Rep.). Retrieved from http://www.netl.doe.gov/kmd/cds/disk25/oilandgas.pdf

[875] Hopey, D. (2012, January 3). Wastewater disposal wells under scrutiny following Irvin leak. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/news/environment/2012/01/03/Wastewater-disposal-wells-under-scrutiny-following-Irvin-leak.html

[876] United States Government Accountability Office. (1989, July 5). Drinking water: Safeguards are not preventing contamination from injected oil and gas wastes. Retrieved from http://www.gao.gov/products/RCED-89-97. (2, 4, Rep.).

streams.[877] While the EPA did not address the potential for contamination through abandoned wells as a result of hydraulic fracturing, both hydraulic fracturing and underground injection disposal wells require underground injection of fluid under pressure, raising the potential that there is a similar risk of groundwater contamination when hydraulic fracturing occurs near abandoned wells.

- 1985 – In an investigation of 4,658 complaints due to oil and natural gas production, the Texas Department of Agriculture found that "when a water well is experiencing an oilfield pollution problem (typically, high chlorides), the pollution source is often difficult to track down. The source could be a leak in the casing of a disposal well, leakage behind the casing due to poor cement bond, old saltwater evaporation pits, or, most often, transport of contaminants through an *improperly plugged abandoned well*" (emphasis in original). The agency found more than a dozen confirmed or suspected cases in which pollutants had migrated up abandoned wells and contaminated groundwater. In one case, drilling wastewater migrated up an abandoned well a half mile away from where the wastewater was injected underground for disposal.[878]

- November 1978 – In a report later cited by the EPA in its 1987 report to Congress (cited above), the state of Illinois Environmental Protection Agency found that oil and natural gas wastes injected underground could migrate through abandoned oil and natural gas wells and contaminate groundwater. The agency wrote, "In old production areas, abandoned wells may pose a serious threat to ground water quality. Unplugged or improperly plugged wells provide possible vertical communication between saline and fresh water aquifers."[879]

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[877] U.S. Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (III-47, Rep.). Retrieved from http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20012D4P.pdf

[878] Texas Department of Agriculture, Department of Natural Resources. (1985). *Agricultural land and water contamination: From injection wells, disposal pits, and abandoned wells used in oil and gas production* (pp. 5, 12-15). Austin, TX: Dept. of Agriculture, Office of Natural Resources.

[879] Illinois Environmental Protection Agency, Water Quality Management Planning. (1978). *Illinois oil field brine disposal assessment* (pp. 44-45, Rep.).

Flood risks

Fracking exacerbates flood risks in two ways. First, massive land clearing and forest fragmentation that necessarily accompany well site preparation increase erosion, run-off, and risks for catastrophic flooding. The construction of access roads, easements for pipelines, and build-out of other related infrastructure further contribute to the problem. Compared to an acre of forest or meadow, an acre of land subject to fracking construction activity releases 1,000-2,000 times more sediment during rainstorms. In addition, in some cases, operators choose to site well pads on flood-prone areas in order to have easy access to water for fracking, to abide by setback requirements intended to keep well pads away from inhabited buildings, or to avoid productive agricultural areas.

Second, the vulnerability of fracking sites to flooding increases the known dangers of unconventional gas extraction, heightening the risks of contamination of soils and water supplies, the overflow or breaching of containment ponds, and the escape of chemicals and hazardous materials. During Hurricane Harvey flooding in Texas in 2017, Eagle Ford operators reported 31 spills at oil and gas wells, storage tanks, and pipelines. Rising sea levels, more powerful hurricanes, and increased storm surges in coastal areas, a consequence of climate change, are expected to represent an increasing threat to oil and gas infrastructure, especially along the Gulf coast. According to a 2018 study, natural gas processing plants in U.S. coastal areas are among the most vulnerable energy infrastructure to inundation by sea level rise.

- March 5, 2019 – In the aftermath of Hurricane Harvey, which brought record rainfall and widespread flooding to Houston and Galveston, the state of Texas and the U.S. Environmental Protection Agency (EPA) prohibited a National Aeronautics and Space Administration (NASA) plane "equipped with the world's most sophisticated air samplers" to fly over chemical spills, fires, flooded storage tanks, damaged plants, and flooded Superfund sites. Instead, a single-prop plane was used by the EPA to gather information on about two dozen air pollutants, whereas the NASA jet could have analyzed more than 450. At the same time, the Texas governor began a seven-month suspension of state air pollution emissions rules. A subsequent investigation by the Associated Press and the *Houston Chronicle* showed there was "widespread, unreported pollution and environmental damage in the region. The team identified more than 100 storm-related toxic releases, including a cloud of hydrochloric acid that leaked from a damaged pipeline and a gasoline spill from an oil terminal that formed 'a vapor cloud.'"[880]

- November 30, 2018 – According to the *Miami Herald*, a new Florida Power & Light gas plant, replacing an existing one, will be raised 11.5 feet "to protect from sea level rise, a growing threat caused by emissions from fossil fuel plants." The region is expected to see 14 to 34 inches of sea level rise by 2062. Testimony at a public hearing, following an

[880] Rust, S., & Sahagun, L. (2018, March 5). Post-Hurricane Harvey, NASA tried to fly a pollution-spotting plane over Houston. The EPA said no. *Los Angeles Times*. Retrieved from https://www.latimes.com/local/california/la-me-nasa-jet-epa-hurricane-harvey-20190305-story.html

outpouring of public opposition to the project, included objections to further investments in fossil fuel projects. "What will you tell residents when the last of their personal possessions wash out to sea and the plant that fuels that tide stands above them?"[881]

- November 29, 2018 – Storm protections will not be coming nearly as quickly as the planned tens of billions of dollars in new natural gas processing and chemical facilities along the Texas gulf, explained a collaborative investigative article in the *Texas Tribune*. "Many of the proposed, under-construction or recently built facilities along the Texas Gulf are in areas that felt [Hurricane] Harvey's bite." Harvey dropped more rain than any storm on U.S. record and led to chemical spills, contaminant releases to the air, and explosions at oil, gas, and chemical facilities. "Extensive storm modeling by top Texas scientists has shown that if a hurricane hit near the southern end of Galveston Island outside Houston… storm surge would pour into the Port of Houston, dislodging thousands of storage tanks full of crude oil and hazardous chemicals."[882]

- September 14, 2018 – In Beaver County, Pennsylvania, a landslide following heavy rains and flooding caused an explosion of a new section of Energy Transfer Partners' Revolution Pipeline one week after it was operational, according to an investigative piece in *Environmental Health News*. The explosion destroyed a house, other structures, and vehicles, and forced evacuations. A few months earlier, a TransCanada natural gas pipeline in Marshall County, West Virginia exploded due to landslide. In its recent permit application, Shell Pipeline Company identified 25 locations prone to landslides along the route of its proposed Falcon Ethane Pipeline through Pennsylvania, Ohio, and West Virginia.[883]

- September 11, 2018 – Pipeline construction guidelines are based on standards that do not account for recent changes in weather patterns, and flood risks are particularly exacerbated along the Mountain Valley Pipeline route, which passes through extraordinarily rugged terrain. In a mountainous area of Virginia, pipeline construction workers were compelled to rush preparations for catastrophic rain from Hurricane Florence in summer 2018 as the abnormally wet summer overcame efforts to prevent runoff and erosion.[884]

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[881] Harris, A., & Gross, S. J. (2018, November 30). FPL to build new fossil fuel plant — and elevate it 11 feet to protect from sea rise. *Miami Herald.* Retrieved from https://www.miamiherald.com/news/local/community/broward/article222435610.html?fbclid=IwAR3mbqV7WBYvpGOzmLpbz1R6q1gxZQJzwXQ84fmx0RBocfyaG93M6bsZGws

[882] Hopkins, J. S., & Collier, K. (2018, November 29). Surge of oil and gas flowing to Texas coastline triggers building boom, tensions. *Texas Tribune.* Retrieved from https://www.texastribune.org/2018/11/29/oil-and-gas-surge-texas-coastline-triggers-building-boom-tensions/

[883] Marusic, K. (2018, September 14). 25 zones along the proposed Shell Falcon Pipeline are at risk of explosions due to landslides. *Environmental Health News.* Retrieved from https://www.ehn.org/here-are-the-25-zones-along-the-proposed-shell-falcon-pipeline-at-risk-of-explosions-due-to-landslides-2604629860.html

[884] Schneider, G. S. (2018, September 11). Hurricane could devastate Virginia pipeline project that is already struggling with changing weather. *Washington Post*. Retrieved from https://www.washingtonpost.com/local/virginia-politics/hurricane-could-devastate-virginia-pipeline-project-that-is-already-struggling-with-changing-weather/2018/09/11/572d0ef8-b5cf-11e8-94eb-3bd52dfe917b_story.html?noredirect=on&utm_term=.194bc781a7df&wpisrc=nl_buzz&wpmm=1

- August 22, 2018 –The state of Texas sought at least $12 billion, nearly all of it coming from public funds, to build a nearly 60-mile "spine" of concrete seawalls, earthen barriers, floating gates, and steel levees on the Texas Gulf Coast. This region is home to one of the world's largest concentrations of petrochemical facilities, including most of Texas' 30 refineries. Facilities that would be protected by this project include those owned by the Saudi-controlled Motiva, Chevron, DuPont, and others. Scaled back from earlier proposals, the current one focused on refineries, according to the Associated Press.[885]

- April 28, 2018 – In their assessment of coastal energy infrastructure at risk along the Gulf Coast, scholars at Louisiana State University concluded that natural gas processing plants in the United States are particularly vulnerable to inundation by sea level rise compared to other energy infrastructure, with up to eight percent of natural gas processing capacity at risk. Tidal flooding is known to be an ancillary effect of sea level rise. Hence, apart from sea level rise itself, "storm surges and flooding from extreme weather-related events often increase the current exposure of these facilities to near-term damage."[886] Fifteen natural gas processing plants were in the potential inundation zones of the study's various sea level rise scenarios, with nine plants projected to be inundated under all three scenarios.

- December 29, 2017 – Flooding was a central theme in an internationally focused review of energy critical infrastructures at risk from climate change. Potential flood impacts on oil and gas infrastructure take many forms: storm surge flooding damaging aboveground fuel storage tanks; flood-related soil erosion exposing buried underground oil and gas pipelines; and inundation of oil refineries. The authors noted that as climate change "leads to an increase in atmospheric moisture content, the likelihood of extreme precipitation and the risk of flooding increase with associated physical impacts" on infrastructure such as power plants and gas pipelines.[887]

- September 15, 2017 – Hurricane Harvey and its resulting flooding affected various parts of metropolitan Houston's vast oil and gas operations, as well as the Eagle Ford shale region of South Texas. *Reuters* reviewed company reports to the U.S. Coast Guard on the various releases of petrochemicals around the time of Harvey's hit and subsequent flooding. In addition to more than 22,000 barrels of crude oil, gasoline, diesel, drilling wastewater, and petrochemicals spilled from refineries, storage terminals, and other facilities in the days after the storm, 27 million cubic feet (765,000 cubic meters) of natural gas was released.[888] Pipeline operators are required to report oil and gas, but not

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[885] Weissert, W. (2018, August 22). Big oil asks government to protect it from climate change. *Associated Press.* Retrieved from https://apnews.com/4adc5a2a2e6b45df953ebcba6b63d171
[886] Dismukes, D.E., & Narra, S. (2018) Sea-level rise and coastal inundation: A case study of the Gulf Coast energy infrastructure. *Natural Resources, 9,* 150-174. doi: 10.4236/nr.2018.94010
[887] Mikellidou, C. V., Shakou, L. M., Boustras, G., & Dimopoulos, C. (2018). Energy critical infrastructures at risk from climate change: A state of the art review. *Safety Science, 110,* 110-120. Advance online publication. doi: 10.1016/j.ssci.2017.12.022
[888] Flitter, E., & Valdmanis, R. (2017, September 15). Oil and chemical spills from Hurricane Harvey big, but dwarfed by Katrina. *Reuters.com.* Retrieved from https://www.reuters.com/article/us-storm-harvey-spills/oil-and-chemical-spills-from-hurricane-harvey-big-but-dwarfed-by-katrina-idUSKCN1BQ1E8

drilling wastewater, spills to the Texas Railroad Commission. An environmental organization retrieved and listed this data, finding 31 spills at oil and gas wells, storage tanks, and pipelines during the hurricane's flooding. The group notes that though the data contains many "produced water" spills, they are likely underreported since they are not mandatory.[889] More than half the fracking rigs running in the region were estimated to have shut down. "Given that much of oil and gas activity occurs in areas only accessible via dirt roads, the heavy rainfall usually makes the movement of trucks and supplies much more difficult…The trucking and rail of sand, chemicals, and personnel to the well site will all take more time given the likely nasty condition of many Eagle Ford access roads," according to an energy analyst.[890]

- May 25, 2016 – The removal of photos of flood-related oil spills on a Texas state-run website appears to be an effort to hide visuals that "don't portray the energy business in a flattering light," according to the *El Paso Times* Editorial Board. The photos revealed potential environmental damage caused by flooding at fracking sites.[891] As earlier reported by the *El Paso Times*, many of the photos shot during Texas' recent floods "show swamped wastewater ponds at fracking sites, presumably allowing wastewater to escape into the environment—and potentially into drinking-water supplies."[892]

- May 1, 2016 – Spring floods across Texas inundated oil wells and fracking sites, tipped over storage tanks, and flushed crude oil and fracking chemicals into rivers, as documented in an Associated Press story that referenced dozens of aerial photographs showing flooded production sites along the Sabine River on the Texas-Louisiana border. (The photographs were later removed from direct public access; see above.) Past president of the American Public Health Association Walter Tsou, MD, called the situation "a potential disaster."[893]

- June 12, 2015 – At the beginning of 2015, after a month of record-breaking rainfall, Fish and Wildlife Service officials at the Hagerman National Wildlife Refuge in Texas found that floodwaters flowing through oil production well pads in the refuge had inundated dozens of jackpumps, pipelines, and other oil and gas infrastructure, leaving bubbling, oily water and a gassy stench. In 1989, the U.S. Government Accountability Office (GAO) called for "bold action" to address fossil fuel production activities incompatible

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[889] Environment Texas. (2017, September 12). *Report: Environmental and health concerns about oil and gas spills after Hurricane Harvey.* Retrieved from https://environmenttexas.org/sites/environment/files/reports/Harvey%20Oil%20Gas%20Spills%20-%20Env%20TX%20-%209.22.17.pdf

[890] Wethe, D. (2017, August 31). Harvey's floods could delay 10% of U.S. fracking: Analyst. *Bloomberg L.P.* Retrieved from https://www.bloomberg.com/news/articles/2017-08-31/harvey-s-floods-could-delay-10-percent-of-u-s-fracking-analyst

[891] *El Paso Times* Editorial Board. (2016, May 25). Editorial: Hiding bad news from Texans. *El Paso Times.* Retrieved from http://www.elpasotimes.com/story/opinion/editorials/2016/05/25/editorial-hiding-bad-news-texans/84937054/

[892] Schladen, M. (2016, April 30). Flooding sweeps oil, chemicals into rivers. *El Paso Times.* Retrieved from http://www.elpasotimes.com/story/news/2016/04/30/flooding-sweeps-oil-chemicals-into-rivers/83671348/

[893] Siron, C. (2016, May 1). Texas floods washing fracking chemicals, crude oil into rivers. *Dallas Morning News.* Retrieved from http://thescoopblog.dallasnews.com/2016/05/texas-floods-washing-fracking-chemicals-crude-oil-into-rivers.html/

with the mission of the refuge system. Subsequent reforms have been exceedingly slow, according to a report from *Greenwire*. In most cases, the Fish and Wildlife Service does not know how much fossil fuel is produced or spilled on refuges, and remediation efforts are inadequate. Severe weather events are expected to increase in frequency and severity as climate change progresses, amplifying flood related concerns.[894]

- June 20, 2014 – The *Coloradoan* reported that Noble Energy storage tanks damaged by spring flooding in Colorado dumped 7,500 gallons of crude oil, fracking chemicals, and fracking wastewater into the Cache la Poudre River, which is both a National Heritage area and a habitat for Colorado's only self-sustaining population of wild trout. Recent high river flows had undercut the bank where the oil tank was located, which caused the tank to drop and break a valve.[895]

- March 2014 – An extraordinary flood that struck the Front Range of Colorado killed ten people, forced the evacuation of 18,000 more, destroyed more than 1,850 homes, and damaged roads, bridges, and farmland throughout the state. More than 2,650 oil and gas wells and associated facilities were also affected, with 1,614 wells lying directly within the flood impact zone. Many of these storm-damaged facilities and storage tanks leaked uncontrollably. In a later accounting, Matt Lepore, Director of the Colorado Oil and Gas Conservation Commission, estimated the flooding had resulted in the release to the environment of 48,250 gallons of oil or condensate and 43,479 gallons of fracking wastewater from 50 different spill sites across the state. In Colorado, more than 20,850 oil and gas wells lie within 500 feet of a river, stream, or other drainage. According to Director Lepore, setback requirements that keep drilling and fracking operations away from residential areas inadvertently encourage operators to drill in unoccupied floodplains. At the same time, oil and gas operators prefer locations close to supplies of water for use in fracking. These twin factors result in a clustering of drilling and fracking operations in low-lying areas prone to catastrophic flooding.[896]

- 2004-2013 – In at least six of the last ten years (2004, 2005, 2006, 2009, 2011, and 2013), several counties targeted for shale gas drilling in New York State have experienced serious flooding. These include the counties of Albany, Broome, Cattaraugus, Chautauqua, Chenango, Delaware, Erie, Greene, Madison, Orange, Otsego, Schoharie, Sullivan and Ulster. In at least five of the past 10 years (2004, 2005, 2006, 2009 and 20011), floods have exceeded 100-year levels in at least some of the counties.[897, 898, 899, 900, 901, 902, 903]

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894 Hiar, C. (2015, June 12). Wildlife refuges: Floods expose weakness in FWS's oil and gas oversight. *E&E Publishing.* Retrieved from http://www.eenews.net/stories/1060020169
895 Handy, R. (2014, June 20). Crude oil spills into Poudre near Windsor. *Coloradoan.* Retrieved from http://www.coloradoan.com/story/news/local/2014/06/20/crude-oil-spills-poudre-near-windsor/11161379/
896 Lepore, M. (2014, March). "Lessons Learned" in the front range flood of September 2013: a staff report to the commissioners of the Colorado Oil and Gas Conservation Commission. Retrieved from http://cogcc.state.co.us/Announcements/Hot_Topics/Flood2013/FinalStaffReportLessonsLearned20140314.pdf
897 Brooks, L. T. (2005). *Flood of September 18-19, 2004 in the upper Delaware River basin, New York* (Rep.). United States Geological Survey. Retrieved from http://ny.water.usgs.gov/pubs/of/of051166/
898 Suro, T. P., & Firda, G. D. (2006). *Flood of April 2–3, 2005, Neversink River basin, New York* (Rep.). United States Geological Survey. Retrieved from http://pubs.usgs.gov/of/2006/1319/

- February 7, 2013 – In its 2012 annual report to investors, oil and gas drilling company Noble Energy stated, "Our operations are subject to hazards and risks inherent in the drilling, production and transportation of crude oil and natural gas, including … flooding which could affect our operations in low-lying areas such as the Marcellus Shale."[904]

- September 7, 2011 – The New York State Department of Environmental Conservation's (NYS DEC) draft shale gas drilling plan recommended that drilling be prohibited within 100-year floodplains but acknowledged that many areas in the Delaware and Susquehanna River basins that were affected by flooding in 2004 and 2006 were located outside of officially designated flood zones.[905] In 2004, 2005, 2006, 2009, and 2011, flooding in New York exceeded 100-year levels in at least some of the counties where drilling and fracking may occur.

- 1992 – In its Generic Environmental Impact Statement (GEIS) for oil and natural gas drilling, which was predicated on conventional drilling, the NYS DEC raised concerns that storage tanks holding drilling wastewater, spent hydraulic fracturing fluid, or other contaminants could be damaged by flooding and leak. At the time, the GEIS called for at least some of these tanks to be properly secured.[906] Shale gas extraction via horizontal fracking would require many more storage tanks for fracking fluids and wastewater than conventional drilling operations anticipated in 1992 when the agency estimated that oil and gas wells in the state would each require 20,000-80,000 gallons of fracking fluid.[907] As of 2011, the agency anticipated that high volume, horizontally fracked shale gas wells

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[899] Suro, T. P., Firda, G. D., & Szabo, C. O. (2009). *Flood of June 26–29, 2006, Mohawk, Delaware and Susquehanna River basins, New York* (Rep.). United States Geological Survey. Retrieved from http://pubs.usgs.gov/of/2009/1063/pdf/ofr2009-1063.pdf

[900] Szabo, C. O., Coon, W. F., & Niziol, T. A. (2010). *Flash floods of August 10, 2009, in the villages of Gowanda and Silver Creek, New York* (Rep.). United States Geological Survey. Retrieved from http://pubs.usgs.gov/sir/2010/5259/pdf/SIR%202010-5259.pdf

[901] Szabo, L. (2011, September 8). *Remnants of Tropical Storm Lee cause record flooding in the Susquehanna River basin* (Rep.). United States Geological Survey. Retrieved from http://ny.water.usgs.gov/leeindex.html

[902] Giordano, S. (2013, January 29). Several eastern counties in central New York under water after heavy flooding. *Syracuse Post-Standard*. Retrieved from http://www.syracuse.com/news/index.ssf/2013/06/several_eastern_counties_in_ce.html

[903] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (2-32, 33, Rep.).

[904] Noble Energy, Annual Report (Form 10-K) (Feb. 7, 2013) at 42.

[905] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (ES-22, 2-32, 33, Rep.).

[906] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (8-42, 8-43, 9-35, Rep.).

[907] New York State Department of Environmental Conservation. (1992). *Generic environmental impact statement on the oil, gas and solution mining regulatory program* (Rep.). (9-26, Rep.).Retrieved from http://www.dec.ny.gov/docs/materials_minerals_pdf/dgeisv1ch8.pdf

in New York State would each require 2.4-7.8 million gallons of fluid—roughly 100 times the 1992 estimate.[908]

[908] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (ES-8, Rep.).

Threats to agriculture, soil quality, and forests

Drilling and fracking operations pose risks to farming, soil, and forests. In California, fracking wastewater illegally injected into aquifers threatens crucial irrigation supplies to farmers in a time of severe drought. Fracking wastewater reused for irrigation and livestock watering in California's San Joaquin Valley may contain at least ten known or suspected chemical carcinogens, as well as over a dozen chemicals with no available toxicological data and many unidentified compounds currently classified as "trade secrets." Agricultural uses of wastewater, as well as flowback water spills, raise questions about direct exposure of affected soils, contamination of food crops via bioabsorption through plant roots, and impacts on livestock due to ingestion. Studies and case reports from across the country have highlighted instances of deaths, neurological disorders, aborted pregnancies, and stillbirths in farm animals that have come into contact with wastewater. Additionally, farmers have expressed concern that nearby fracking operations can hurt the perception of agricultural quality and invalidate value-added organic certification. Land use changes and transport of invasive species by drilling and fracking operations have led to documented ecological and monetary harm to soils, forests, and natural areas. In forested areas of Pennsylvania, drilling and fracking operations have greatly reduced canopy covers and thereby diminished the carbon storage capacity of photosynthesizing forest trees. Soil compaction in cleared areas is detrimental to new plant growth and encourages the growth of invasive species.

- September 15, 2018 – Drilling and fracking operations and their associated infrastructure removed a large volume forest canopy in the upper Susquehanna River basin of New York and Pennsylvania from 2006 to 2013. This loss can be considered permanent, according to U.S. Geological Survey (USGS) scientists. Using "lidar" (light detection and ranging) remote sensing technology, the research team assessed three-dimensional volumetric change of forest loss, as opposed to two-dimensional areal loss. Because trees capture carbon dioxide on the surfaces of their canopy leaves during photosynthesis, three-dimensional measurements allow for the assessment of the carbon storage capacity that is sacrificed to gas development via tree removal. The researchers found that a total of 991,326,760m^3 of forest canopy was removed by oil and gas activities in the upper Susquehanna River watershed area studied. New York's loss was "relatively low" because of the state's fracking moratorium during the study period. The largest losses in forest volumes took place in the Pennsylvania counties of Lycoming, Tioga, Sullivan, Bradford, Wyoming, and Susquehanna. Although timber operations removed more canopy overall, that loss was concentrated in a smaller area.[909]

- September 7, 2018 – Cleared areas around fracking well pads in Pennsylvania state forests are subjected to soil compaction equivalent to that in parking lot construction, according to researchers quoted in a *StateImpact* article. Although not used once the well is in production, these cleared areas are not typically repaired or replanted. Further, this

[909] Young, J., Maloney, K. O., Slonecker, E. T., & Milheim, L. E., & Siripoonsup, D. (2018). Canopy volume removal from oil and gas development activity in the upper Susquehanna River basin in Pennsylvania and New York (USA): An assessment using lidar data. *Journal of Environmental Management, 222,* 66-75. doi: 10.1016/j.jenvman.2018.05.041

level of compaction is detrimental to new plant growth as the soil has fewer pores to store water or gases needed for plant survival. Experimenting with repair for these areas, Penn State University soil scientist Patrick Drohan said, “A lot of our native species, especially the grasses, are very deeply rooted. So if they can get down through 20 inches of loosened soil they’re going to be able to develop really deep, nice root systems.” Though involved with these experiments and resulting step-by-step repair directions, the Pennsylvania Department of Conservation and Natural Resources is “not proposing to make any of these methods mandatory.”[910]

- July 18, 2018 – A USGS study on the Colorado Plateau investigated vegetation cover at inactive well sites. Researchers found that on half of plugged and abandoned oil and gas well sites, the median vegetation cover after five years was 26 percent, while sites with high vegetation cover were dominated by invasive, non-native species. Using satellite-based Landsat time series analysis, the scientists looked at three to six years of vegetation regrowth at 365 well sites in Utah, Colorado, and New Mexico, drilled in 1985 or after and abandoned in 1997 or after. Vegetation recovery generally slowed over time and was related to moisture conditions year to year. Recovery was lower on abandoned well sites in shrublands or evergreen woodlands, which produced only about half the regrowth of well sites in grasslands. The grassland recovery, however, was dominated by invasive annuals such as cheatgrass and Russian thistle. There are currently over 26,000 abandoned and 63,000 active well pads on the Colorado Plateau.[911]

- July 17, 2018 – A simulation study that applied actual fracking wastewater to local soils in the Denver area investigated how fracking spills might affect the growth of crops. Spills of fracking wastewater resulted in metal contamination at environmentally relevant concentrations as well as a dramatic decrease in water infiltration rate in ways that could have “severe impact on crop production.”[912] Many of the metals studied, including copper, lead, and iron, “met or approached water quality standards and could have important environmental and human health impacts.”

- April 13, 2018 – Grasslands and row crop habitats were most affected in a predictive modeling study of vegetation conversion and landscape fragmentation that would result from future drilling and associated well pad construction in the Eagle Ford Shale. The study, which used “energy production outlook” predictions, found that these impacts increased in spatial extent and magnitude as oil prices increased. The study anticipated that up to 83,000 wells would be drilled through the year 2045 and include as many as 45,500 well pads. In this scenario, between 26,485 and 70,623 hectares (65,446 to 174,513 acres) would undergo vegetative conversion. These results are consistent with findings from related studies. The authors cautioned that their model did not include

[910] Frazier, R. (2018, September 7). Bringing the forest back after shale gas. *StateImpact.* Retrieved from https://stateimpact.npr.org/pennsylvania/2018/09/07/bringing-the-forest-back-after-shale-gas/

[911] Waller, E. K., Villarreal, M. L., Poitras, T. B., Nauman, T. W., & Duniway, M. C. (2018). Landsat time series analysis of fractional plant cover changes on abandoned energy development sites. *International Journal of Applied Earth Observation and Geoinformation, 73,* 407-419. doi: 10.1016/j.jag.2018.07.008

[912] Oetjen, K., Blotevogel, J., Borch, T., Ranville, J. F., & Higgins, C. P. (2018). Simulation of a hydraulic fracturing wastewater surface spill on agricultural soil. *Science of the Total Environment, 645,* 229-234. doi: 10.1016/j.scitotenv.2018.07.043

future locations of associated infrastructure, such as surface water impoundments and compressor stations. If they were included, "doubling land-change results of this study… would result in a reasonable estimate of overall footprint of all hydrocarbon extractive infrastructure."[913]

- July 20, 2017 – Penn State Unversity researchers identified a direct correlation between the spread of invasive, non-native plants in Pennsylvania's northern forests and specific aspects of fracking operations. Researchers surveyed 127 Marcellus Shale gas well pads and adjacent access roads in seven state forest districts in the Allegheny National Forest. The study "found that within less than a decade invasive non-native plants have spread to over half of the 127 well pads in our survey, and for the 85% of the pads that were less than 4 years old it occurred in a much shorter period of time." Gravel shipments and mud on the tires and undercarriages of trucks carry and deposit seeds and propagules of invasive plants. "Given the fact that on average 1235 one-way truck trips delivering fracturing fluid and proppant are required to complete an unconventional well, the potential to transport invasive plant propagules is significant."[914] "The spread of invasive non-native plants could have long-term negative consequences for the forest ecosystem in a region where the ubiquitous woods provide timbering revenue, wildlife habitat, and ecotourism, warns team member David Mortensen, professor of weed and applied plant ecology."[915]

- May 15, 2017 – By 2015, the annual ecological cost of fracking in the United States reached over $272 million per year, according to a team of biologists from Hendrix College in Arkansas. They reached this value by estimating the impact of land-use changes on "ecosystem services," the benefits that natural habitats provide to humans, such as carbon sequestration, flood mitigation, food security, ecotourism revenue, and genetic diversity. Authors considered this estimate to be conservative. In addition, they wrote, "[d]epending on future well-drilling rates, cumulative ecosystem services costs projected to the year 2040 range from US$9.4 billion to US$31.9 billion." Their results showed, "that temperate grassland and deciduous forest are being disproportionately impacted by unconventional oil and gas development. Temperate grasslands are some of the most imperiled ecosystems in North America." They found "considerable variation in ecosystem services costs between different plays, with Haynesville, Bakken/Three Forks, and Fayetteville showing the highest annual costs."[916]

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[913] Wolaver, B. D., Pierre, J. P., Ikonnikova, S. A., Andrews, J. R., McDaid, G., Ryberg, W. A., . . . LaDuc, T. J. (2018). An improved approach for forecasting ecological impacts from future drilling in unconventional shale oil and gas plays. *Environmental Management, 62*(2), 323-333. doi: 10.1007/s00267-018-1042-5

[914] Barlow, K. M., Mortensen, D. A., Drohan, P. J., & Averill, K. M. (2017). Unconventional gas development facilitates plant invasions. *Journal of Environmental Management, 202*, 208e216. doi: 10.1016/j.jenvman.2017.07.005

[915] Mulhollem, J. (2017, July 20). Shale gas development spurring spread of invasive plants in Pa. forests. *PennState News.* Retrieved from http://news.psu.edu/story/475225/2017/07/20/research/shale-gas-development-spurring-spread-invasive-plants-pa-forests

[916] Moran, M. D., Taylor, N. T., Mullins, T. F., Sardar, S. S., & McClung, M. R. (2017). Land-use and ecosystem services costs of unconventional US oil and gas development. *Frontiers in Ecology and the Environment, 15*(5), 237–242. doi: 10.1002/fee.1492

- April 2, 2017 – Nearly four percent of “core forest” was lost within six years of shale gas development in Lycoming County, Pennsylvania, from 2010 to 2016. Pipelines were the largest contributor to the industry's spatial footprint and were identified as the major fragmenting feature. “Linear infrastructure” (pipelines and roads) led to 3.2 percent loss of core forest, whereas well pad infrastructure (well pad, water impoundment, compressor station, etc.) resulted in 0.9 percent loss of core forests. “Limiting loss of core forest and fragmentation is of particular importance in Pennsylvania and central Appalachia due to potential impacts to area sensitive species.”[917]

- November 29, 2016 – A study by engineers and environmental scientists from China, the U.K., and the Republic of Korea investigated the impact of contaminated fracking flowback water on soil health, using soils from representative shale gas areas in China. They also performed a preliminary human health risk assessment of exposure to the arsenic found in such soils. The solutions they tested were representative of flowback water from various stages following a fracked well’s establishment, and their study found that the temporal change in the composition of these wastewaters “leads to different environmental implications.” They tested heavy metal mobility and bioaccessibility, finding that even though mobility was reduced by high ionic strength of flowback water, the metals maintained relatively high bioaccessibility. Soil toxicity moderately increased after a month “aging” with the flowback water treatment. Arensic, one of the metals included in the testing, is a known human carcinogen and therefore the focus of the human health risk assessment. Results indicated “a low level of cancer risk through exposure via ingestion.”[918]

- October 4, 2016 – A research team from Lawrence Berkeley National Laboratory, University of California Berkeley, and University of the Pacific released preliminary results from a first-ever hazard assessment of chemicals used in California oil drilling operations that reuse wastewater for livestock watering and other agricultural purposes in the San Joaquin Valley. This evaluation, compiled as a technical report by PSE Healthy Energy and Lawrence Berkeley National Laboratory, revealed that more than one-third of the 173 chemicals used are classified as trade secret and their identities are therefore unknown. Of the remainder, ten are classified as either carcinogenic or possibly carcinogenic in humans, 22 are classified by the state of California as toxic air contaminants, and 14 had no ecotoxicity or mammalian toxicity data available. “It is difficult or impossible to estimate risks to consumers, farmworkers or the environment,” the authors concluded, “when identification of chemical additives remains in trade secret form and/or lacks toxicity and environmental profile information.”[919]

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[917] Langlois, L. A., Drohan, P. J., & Brittingham, M. C. (2017). Linear infrastructure drives habitat conversion and forest fragmentation associated with Marcellus shale gas development in a forested landscape. *Journal of Environmental Management, 197*, 167-176. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301479717302608?via%3Dihub

[918] Chen, S. S., Suna Y., Tsang, D. C. W., Grahamc, N. J. D., Ok, Y. S., Feng, Y., & Li, X.-D. (2016). Potential impact of flowback water from hydraulic fracturing on agricultural soil quality: Metal/metalloid bioaccessibility, Microtox bioassay, and enzyme activities. *Science of the Total Environment, 579,* 1419–1426. doi: 10.1016/j.scitotenv.2016.11.141

[919] Shonkoff, S. B. C., Stringfellow, W. T., & Domen, J. K. (2016, September). *Hazard assessment of chemicals additives used in oil field that reuse produced water for agricultural irrigation, livestock watering, and groundwater*

- June 1, 2016 – "Co-contaminant interaction effects" can occur when multiple chemicals are involved in spills of oil and gas wastewater on agricultural soils, according to a study by a Colorado State University research team. Through simulations, researchers analyzed how degradation was affected when combinations of three fracking-related organic chemicals spilled, alone or together: polyethylene glycol, a commonly used surfactant; glutaraldehyde, a biocide to prevent pipe corrosion from microbial activity; and polyacrylamide, a friction reducer. In addition to interactions between the chemicals, they analyzed the role of naturally occurring salts. Results showed that polyethylene glycol surfactants alone can break down in topsoil within 42−71 days, but, in the presence of the biocide glutaraldehyde or salt concentrations typical of fracking wastewater, their biodegradation was impeded or halted altogether. Authors emphasized that the interactions they studied account for only a fraction of the hundreds of fracking chemicals in use, but that their results "show a complex picture of co-contaminant fate and toxicity" that has, so far, been ignored.in the regulatory process.[920]

- December 12, 2015 – A research team at the University of Aberdeen found high levels of selenium, molybdenum, and arsenic in rock samples collected from a region in northern England that has been targeted for fracking. The finding is important due to the possible risk that these toxic elements will be released into groundwater during shale gas operations. Selenium poisoning has occurred among Irish horses confined to pastures underlain by black shale. While small amounts of selenium are essential for metabolism, high levels (which, in the case of human consumption, is above 400 μg/day) are toxic. Possible consequences include neurotoxicity, cancer and diabetes."[921]

- November 23, 2015 – Gas-related impacts on Pennsylvania farmers may include pipelines criss-crossing fields and forests, as well as jeopardization of organic certification, according to a report covering a State Agriculture Department spokesman's presentation, on the Potter County government website. The spokesman said, "steps should be taken to steer this development in ways that diminish impact on soil quality and fragmentation." "With trees and other vegetation being cleared from pipeline rights-of-way, he noted, it's important for the acreage to be replanted with plant species that are beneficial to agriculture—pollinating plants, as an example."[922]

- October 24, 2015 – More than 180 million gallons of wastewater from oil and gas operations spilled from 2009 to 2014, according to an Associated Press analysis of data

recharge in the San Joaquin Valley of California: Preliminary results. Retrieved from https://www.psehealthyenergy.org/wp-content/uploads/2017/04/Preliminary_Results_13267_Disclosures_FINAL-1.pdf

[920] McLaughlin, M. C., Borch, T., & Blotevogel, J. (2016). Spills of hydraulic fracturing chemicals on agricultural topsoil: biodegradation, sorption, and co-contaminant interactions. *Environmental Science & Technology, 50*(11). doi: 10.1021/acs.est.6b00240

[921] Parnell, J., Brolly, C., Spinks, S., & Bowden, S. (2015). Selenium enrichment in Carboniferous Shales, Britain and Ireland: Problem or opportunity for shale gas extraction? *Applied Geochemistry, 66,* 82-87. doi: 10.1016/j.apgeochem.2015.12.008

[922] *Potter County Today.* (2015, November 23). Shale gas impact on agriculture 'profound.' Retrieved from http://today.pottercountypa.net/shale-gas-impact-on-agriculture-profound/

from leading oil- and gas-producing states (Texas, North Dakota, California, Alaska, Colorado, New Mexico, Oklahoma, Wyoming, Kansas, Utah and Montana). A *Dallas Morning News* report focused on how the resulting contamination of groundwater and soils has affected agricultural and ranching. In one case, wastewater from pits seeped beneath a cotton and nut farm near Bakersfield, California and forced the grower to remove 2,000 acres from production. In western Texas, pipeline failures and illegal dumping of frack waste contaminated ranches and pastures.[923]

- May 2, 2015 – The *Los Angeles Times* reported that farmers in Kern County, California purchased over 21 million gallons per day of treated oil field wastewater to use for crop irrigation. The article identified lingering questions about chemicals remaining after treatment and their potential impact both on the crops and those who consume them. Independent testing identified chemicals including acetone and methylene chloride, along with oil, in the treated irrigation water.[924] Acetone and methylene chloride are powerful industrial solvents that are highly toxic to humans, and samples of the wastewater contained concentrations of both that were higher than those seen at oil spill disaster sites. (Chevron's own report confirmed the presence of acetone, benzene, and xylene, though in lesser concentrations; Chevron did not appear to test for methylene chloride.[925]) Broader testing requirements involving chemicals covered under California's new fracking disclosure regulations went into effect June 15, 2015.[926]

- April 24, 2015 – Unconventional technologies in gas and oil extraction facilitated the drilling of an average of 50,000 new fractured wells per year in North America over the past 15 years. An interdisciplinary study published in *Science* demonstrated that the accumulating land degradation has resulted in continent-wide impacts, as measured by the reduced amount of carbon absorbed by plants and accumulated as biomass. This is a robust metric of essential ecosystem services, such as food production, biodiversity, and wildlife habitat, and its loss "is likely long-lasting and potentially permanent." The land area occupied by well pads, roads, and storage facilities built during this period is approximately three million hectares, roughly the land area of three Yellowstone National Parks. The authors concluded that new approaches to land use planning and policy are "necessary to achieve energy policies that minimize ecosystem service losses."[927]

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[923] Flesher, J. (2015, October 24). Fatal flow: Brine from oil, gas drilling fouls land, kills wildlife at alarming rate. *Dallas Morning News.* Retrieved from http://www.dallasnews.com/news/local-news/20151024-fatal-flow-brine-from-oil-gas-drilling-fouls-land-kills-wildlife-at-alarming-rate.ece

[924] Cart, J. (2015, May 2). Central Valley's growing concern: Crops raised with oil field water. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-drought-oil-water-20150503-story.html#page=1

[925] Amec Foster Wheeler Environment & Infrastructure, Inc. (2015, June 15). Technical report: Reclaimed water impoundments sampling, Cawelo Water District Ponds, Kern River Oil Field, Kern County, California, Prepared for Chevron U.S.A. Inc. Retrieved from https://drive.google.com/file/d/0B1ccgD60cwq7dWE5Y0c2ZDh5WnM/view

[926] Ross, D. (2015, June 19). Has our food been contaminated by Chevron's wastewater? *Truthout.* Retrieved from http://www.truth-out.org/news/item/31470-has-our-food-been-contaminated-by-chevron-s-wastewater

[927] Allred, B. W., Kolby Smith, W., Tridwell, D., Haggerty, J. H., Running, S. W., Naugle, D. E., & Fuhlendorf, S. D. (2015). Ecosystem services lost to oil and gas in North America. *Science, 348* (6233), 401-402. doi: 10.1126/science.aaa4785

- January 26, 2015 – Two Colorado scientists performed a detailed analysis of vegetative patterns—followed chronologically—over a selected group of well pads in Colorado managed by the U.S. Bureau of Land Management, including two undisturbed reference sites. They documented the disturbance of plant and soil systems linked to contemporary oil and gas well pad construction, and found that none of the oil and gas well pads included in the study returned to pre-drilling condition, even after 20-50 years. Full restoration may require decades of intensive effort.[928]

- October 14, 2014 – State documents obtained by the Center for Biological Diversity show that almost three billion gallons of fracking wastewater have been illegally dumped into central California aquifers that supply drinking water and farming irrigation. The California Water Board confirmed that several oil companies used at least nine of 11 injection wells that connect with high-quality water sources for disposal of fracking wastewater, which included high levels of arsenic, thallium, and nitrates. The California Division of Oil, Gas and Geothermal Resources has shut down 11 oil field injection wells and is scrutinizing almost 100 others for posing a "danger to life, health, property, and natural resources." At least one farming company has sued oil producers in part for contaminating groundwater that farms use for irrigation.[929]

- September 6, 2014 – *Al Jazeera America* examined the challenges that North Dakota farmers are facing in light of wastewater spills from oil and gas development. Notably, in heavily drilled Bottineau County, some levels of chloride, from sites where an estimated 16,800-25,200 gallons of wastewater had seeped into the ground, were so high that they exceeded the levels measurable with the North Dakota Department of Health's test strips. State records, testimonies from oil workers and various residents, and the decades-long failure of contaminated fields to produce crops indicate that wastewater spills are a significant hazard in the current fracking boom.[930]

- August 6, 2014 – The Pennsylvania Department of Environmental Protection (PA DEP) found that leaks of fracking wastewater from three impoundments contaminated soil and groundwater. The findings prompted the state to issue a violation and increase testing.[931]

- August 5, 2014 – Michelle Bamberger, a veterinarian and researcher, and Robert Oswald, a professor of molecular medicine at Cornell University, published a book that describes their research into the impacts of drilling and fracking on agriculture and animal health. They detail results of 24 case studies from six gas drilling states, including follow-up on

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928 Minnick, T. J., & Alward, R. D. (2015). Plant–soil feedbacks and the partial recovery of soil spatial patterns on abandoned well pads in a sagebrush shrubland. *Ecological Applications, 25*(1), 3-10. doi: 10.1890/13-1698.1
929 Dechert, S. (2014, October 14). Fracking wastewater spoils California drinking, farm supplies. *Clean Technica*. Retrieved from http://cleantechnica.com/2014/10/14/fracking-wastewater-spoils-california-drinking-farm-supplies/
930 Gottesdiener, L. (2014, September 6). In shadow of oil boom, North Dakota farmers fight contamination. *Al Jazeera America*. Retrieved from http://america.aljazeera.com/articles/2014/9/6/north-dakota-wastewaterlegacy.html
931 Hopey, D. (2014, August 6). State: Fracking waste tainted groundwater, soil at three Washington County sites. *Pittsburgh Post-Gazette.* Retrieved from http://www.post-gazette.com/local/washington/2014/08/06/Pa-finds-tainted-water-soil-at-three-Washington-County-shale-sites/stories/201408050198

cases they previously published in the peer-reviewed literature, raising concerns about the effects of drilling and fracking on agriculture and the health of animals.[932]

- August 1, 2014 – At least 19,000 gallons of hydrochloric acid spilled during completion of a fracking well on an alfalfa farm in Kingfisher County, Oklahoma. The Oklahoma Corporation Commission reported concerns about rain pushing chemical runoff into a nearby creek that flows into the town of Hennessey's water system. The responsible company, Blake Production, planned to pay for the alfalfa crop for six years. The landowner and a neighbor were pursuing litigation.[933]

- May 4, 2014 – In an analysis of state data from Colorado, the *Denver Post* reported that fracking related to oil and gas drilling is putting soil quality and farmlands at risk due to significant amounts of toxic fluids penetrating the soil. According to report, 578 spills were reported in 2013, which means that, on average in the state, a gallon of toxic liquid penetrates the ground every eight minutes. Colorado State University soil scientist Eugene Kelly, said that the overall impact of the oil and gas boom "is like a death sentence for soil."[934]

- November 28, 2012 – In conjunction with the Food & Environment Reporting Network, *The Nation* reported that serious risks to agriculture caused by fracking are increasing across the country and linked these concerns to risks to human health.[935]

- January 2012 – A study of gas drilling's impacts on human and animal health concluded that the drilling process may lead to health problems. The study reported and analyzed a number of case studies, including dead and sick animals in several states that had been exposed to drilling or hydraulic fracturing fluids, wastewater, or contaminated ground or surface water.[936] The researchers cited 24 cases in six states where animals and their owners were potentially affected by gas drilling. In one case, a farmer separated 96 head of cattle into three areas, one along a creek where fracking wastewater was allegedly dumped and the remainder in fields without access to the contaminated creek; the farmer found that, of the 60 head exposed to the creek, 21 died and 16 failed to produce, whereas the unexposed cattle experienced no unusual health problems. In another case, a farmer reported that of 140 head of cattle exposed to fracking wastewater, about 70 died, and there was a high incidence of stillborn and stunted calves in the remaining cattle.[937]

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[932] Bamberger, M., & Oswald, R. (2014). The real cost of fracking: How America's shale gas boom is threatening our families, pets, and food. Boston: Beacon Press.
[933] Passoth, K. (2014, August 1). Major oil field spill in Kingfisher Co. *KOCO.com Oklahoma City*. Retrieved from http://www.koco.com/news/major-oil-field-spill-in-kingfisher-county/27236612
[934] Finley, B. (2014, May 4). Colorado faces oil boom "death sentence" for soil, eyes microbe fix. *Denver Post*. Retrieved from http://www.denverpost.com/environment/ci_25692049/colorado-faces-oil-boom-death-sentence-soil-eyes
[935] Royte, E. (2012, November 28). Fracking our food supply. *The Nation*. Retrieved from http://www.thenation.com/article/171504/fracking-our-food-supply
[936] Bamberger, M., & Oswald, R. E. (2012). Impacts of gas drilling on human and animal health. *New Solutions: A Journal of Environmental and Occupational Health Policy, 22*(1), 51-77. doi: 10.2190/NS.22.1.e
[937] Ramanujan, K. (2012, March 7). Study suggests hydrofracking is killing farm animals, pets. *Cornell Chronicle*. Retrieved from http://www.news.cornell.edu/stories/2012/03/reproductive-problems-death-animals-exposed-fracking

- January 2011 – U.S. Forest Service researchers reported dramatic negative effects on vegetation caused by the drilling and fracking of a natural gas well in an experimental forest in northeastern West Virginia. In June 2008, the researchers found browning of foliage near the well pad, a lack of ground foliage, and that many trees nearby had dropped their foliage. They attributed these impacts to the loss of control of the wellbore on May 29, 2008, which caused an aerial release of materials from the well. Trees showed no apparent symptoms the following summer. However, the researchers also found "dramatic impacts on vegetation" where drilling and fracking wastewater had been sprayed on the land as a disposal technique following completion of the well. Just after the spraying of approximately 60,000 gallons of wastewater at the first disposal site, the Forest Service researchers found 115 damaged trees and other evidence of harm. This figure grew to 147 trees almost a year later. At a second site, where about 20,000 gallons of wastewater was sprayed, the damage was less dramatic, yet the researchers still found "considerable leaf browning and mortality of young northern red oak seedlings." The researchers concluded that the spraying of the drilling fluids resulted in an "extreme" dose of chlorides to the forest.[938]

- May 2010 – Pennsylvania's Department of Agriculture quarantined 28 cows in Tioga County after the animals wandered through a spill of drilling wastewater and may have ingested some of it. The Department was concerned that beef eventually produced from the cows could be contaminated as a result of any exposure. In May 2011, only ten yearlings were still quarantined, but the farmer who owned the cows, Carol Johnson, told National Public Radio that of 17 calves born to the quarantined cows in the spring of 2011, only six survived, and many of the calves that were lost were stillborn. "They were born dead or extremely weak. It's highly unusual," she said, continuing, "I might lose one or two calves a year, but I don't lose eight out of eleven."[939]

- March 2010 – A Pennsylvania State Extension analysis of dairy farms in the state found a decline in the number of dairy cows in areas where fracking was prevalent. Pennsylvania counties that had both more than 10,000 dairy cows and more than 150 Marcellus Shale wells experienced a 16-percent decline in dairy cows between 2007 and 2010.[940]

- April 28, 2009 – Seventeen cows in Caddo Parish, Louisiana died within one hour after apparently ingesting hydraulic fracturing fluids spilled at a well that was being fractured. "It seemed obvious the cattle had died acutely from an ingested toxin that had drained

[938] Adams, M. B., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest*. United States Department of Agriculture, Forest Service. General Technical Report NRS-76. Retrieved from http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf

[939] Phillips, S. (2011, September 27). Burning questions: Quarantined cows give birth to dead calves. *StateImpact*. Retrieved from http://stateimpact.npr.org/pennsylvania/2011/09/27/burning-questions-quarantined-cows-give-birth-to-dead-calves/

[940] Penn State Extension. (2010, March). *Pennsylvania dairy farms and Marcellus shale, 2007–2010* (Rep.). Retrieved from http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PA%20Dairy%20Farms%20and%20Marcellus%202007%20to%202010.pdf

from the ‘fracking’ operation going on at the property,” Mike Barrington, a state veterinarian said in a document obtained from the state Department of Environmental Quality by the *Times-Picayune*.[941, 942]

- August 1977 – A paper in the *Journal of Arboriculture* described how natural gas leaks in soil can damage plants and crops. The paper notes that vegetation dies in the vicinity of natural gas leaks. Due to the oxidation of methane by methane-consuming bacteria, gas leaks drive down the oxygen concentration to extremely low levels and cause carbon dioxide concentration to rise. The resulting low oxygen concentration is the greatest contributing factor in the death of trees and other vegetation near natural gas leaks.[943]

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941 Schleifstein, M. (2011, March 27). Haynesville natural gas field is the most productive in the U.S. *The Times-Picayune*. Retrieved from http://www.nola.com/politics/index.ssf/2011/03/haynesville_natural_gas_field.html
942 KSLA. (2009, April 28). Cows in Caddo Parish fall dead near gas well. *KSLA News*. Retrieved from http://www.ksla.com/Global/story.asp?S=10268585
943 Davis, S. H., Jr. (1977). The effect of natural gas on trees and other vegetation. *Journal of Arboriculture, 3*(8), 153-154.

Threats to the climate system

Natural gas is not a climate-friendly fuel. Methane, which escapes from all parts of the natural gas extraction and distribution system, is a powerful greenhouse gas that traps 86 times more heat than carbon dioxide over a 20-year time frame. According to the best available evidence, fuel-switching that replaces coal with natural gas to generate electricity offers no clear climate benefits and likely represents a step backwards. As is now documented in many studies, fugitive methane emissions from U.S. drilling and fracking operations, storage, and ancillary infrastructure are higher than previously supposed. A significant proportion of these leaks are not preventable through engineering fixes. Indeed, some represent intentional venting during routine maintenance or during attempts to control pressure and prevent explosions during malfunctions. Venting takes place at all points along the supply chain, from well pads, pipelines, and compressor stations to liquefied natural gas (LNG) export terminals. A 2018 analysis of methane emissions from the U.S. oil and gas supply chain that used a combination of measurement methodologies found leakage rates 60 percent higher than reported by the U.S. Environmental Protection Agency (EPA) and concluded that natural gas is just as damaging as coal for the climate over a 20-year time frame. Collectively, a range of studies disprove the claim that natural gas is a transitional "bridge" fuel that can lower greenhouse gas emissions while renewable energy solutions are developed.

A sharp rise in global atmospheric methane concentrations began in 2007 and has accelerated since 2014. The causes for this spike are not yet fully understood and likely include both biogenic sources (livestock, agriculture, wetlands, landfills, forest fires) and fossil fuel sources. As both satellite and ground measurements reveal, U.S. methane emissions are responsible for 30-60 percent of the recent upsurge in global atmospheric methane concentrations. Most of this excess methane appears to represent fugitive emissions from U.S. oil and gas operations.

Many lines of evidence point to the important role of unconventional oil and gas extraction in driving greenhouse gas emissions upward. These include the atmospheric pattern of increased methane concentrations directly over intensively fracked areas of the United States; sharp upticks in global methane and co-occurring ethane levels that correspond to the advent of the U.S. fracking boom; and documentation of large pulses of methane released from storage facilities and other "super-emitting" sites. A major study from the National Aeronautics and Space Administration (NASA) in 2017 found that methane from biomass sources, such as fires, decreased over the time period 2001-2016 while fossil fuel sources of methane increased. Further, the widely touted claim that the U.S. fracking boom has contributed to recent declines in carbon dioxide emissions in the United States has been invalidated by research showing that almost all of the reductions in CO_2 emissions between 2007 and 2009 were the result of economic recession rather than coal-to-gas fuel switching. Other lines of research show that expanded use of natural gas impedes rather than encourages investments in, and deployment of, renewable energy infrastructure. In sum, fracking, as a major driver of rising methane emissions, is incompatible with climate stability and the goal of rapid decarbonization that it requires.

- March 12, 2019 – Using aircraft, a team of researchers from multiple universities and institutions estimated emissions from both coal mines and shale gas wells in southwestern Pennsylvania. For coal, their results largely aligned with EPA estimates. However, for natural gas wells, emissions were five times higher than EPA figures. Because the volume of gas extracted per well is higher than in other shale basins, production-scaled methane emissions were still comparatively low, with carbon dioxide emissions from combustion remaining the dominant source of greenhouse gas emissions.[944]

- March 7, 2019 – Methane is a very strong greenhouse gas, with 120 times the power to trap heat than an equivalent amount of carbon dioxide. However, methane persists in the atmosphere for an average of only 12.4 years whereas carbon dioxide can linger for a century or more. Using a combination of approaches, a London team assessed the contribution of natural gas extraction to future greenhouse gas emissions in the United States, taking into account timing as well as magnitude of emissions and changing prices. They found that methane emitted further into the future—and therefore closer to the year where climate stabilization needs to take place—has a disproportionately large bearing on the overall climate impact of drilling and fracking activities, with long-lived gas fields having the most effect. "A key finding of this study is that the environmental and economic consequences of emissions are likely to rise with the age of a field, thus exposing long-lived assets to the greatest potential losses….Overall, our results suggest that future cumulative greenhouse gas emissions from existing US [gas] fields have a significant short-medium climate impact." The authors recommend carbon pricing as a strategy to shorten the lifetime of long-lived gas fields. They also report that 40 percent of carbon dioxide output from natural gas is directly related to drilling activities.[945]

- February 28, 2019 – Australia's LNG export industry contributed significantly to rising carbon emissions from that country in the 12 months prior to September 2018, according to Australia's National Greenhouse Gas Inventory. Emissions from power plants fell during this same time period as the result of a 31 percent jump in renewable energy serving eastern Australia. These declines, however, were more than offset by soaring increases in industrial and fugitive emissions from Australia's LNG plants.[946] LNG exports rose by one fifth in 2018.[947] This jump represents the third consecutive year of

[944] Barkley, Z. R., Lauvaux, T., Davis, K. J., Deng, A., Fried, A., Weibring, P., . . . Dickerson, R. R. (2018). Estimating methane emissions from underground coal and natural gas production in southwestern Pennsylvania. *Geophysical Research Letters, 46*, 4531-4540. doi: 10.1029/2019GL082131

[945] Crow, D. J. G., Balcombe, P., Brandon, N., & Hawkes, A. D. (2019). Assessing the impact of future greenhouse gas emissions from natural gas production. *Science of the Total Environment, 668*, 1242-1258. doi: 10.1016/j.scitotenv.2019.03.048

[946] Commonwealth of Australia Department of Environment and Energy. (2018). *Quarterly update of Australia's National Greenhouse Gas Inventory: September 2018*. Retrieved from https://www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications/quarterly-update-australias-national-greenhouse-gas-inventory-sept-2018

[947] Hannam, P. (2019, February 28). Annual emissions keep rising as gas jump counters power sector drop. *Sydney Morning Herald.* Retrieved from https://www.smh.com.au/environment/climate-change/annual-emissions-keep-rising-as-gas-jump-counters-power-sector-drop-20190228-p510wu.html

rising greenhouse gas emissions from Australia. The expansion in LNG production and export was identified as the major contributor to this trend.[948]

- February 27, 2019 – An international team investigated the climate and the public health harms attributable to fossil fuel combustion. Their global model estimated an avoidable excess mortality rate of 3.61 million deaths per year from air pollution alone. Air pollution also chemically reacts with dust to create aerosols that disrupt the hydrologic cycle and impede rainfall patterns. If fossil fuel burning ended, not only would deaths due to air pollution be avoided but additional lives would be saved as water and food security improved in densely populated areas of India, northern China, and central America. In sum, "a rapid phaseout of fossil fuel-related emissions and major reductions of other anthropogenic sources are needed to save millions of lives, restore aerosol-perturbed rainfall patterns, and limit global warming to 2 C^{o}."[949]

- February 12, 2019 – In southeastern Saskatchewan, Canada, conventional gas and oil drilling takes place side by side with unconventional drilling via fracking. In a first study of its kind, a St. Francis Xavier University research team directly compared methane emissions from both types of co-located wells. By conducting truck-based air sampling downwind from 645 conventional wells and 289 unconventional wells, the team found that 28 percent of conventional wells leaked methane compared to 32 percent of fracked wells. The bigger difference was in measures of mean emission intensities from the wells that were leaking. Leaking fracked wells emitted nearly three times as much methane (59 cubic meters of methane per day) as leaking conventional wells (20 cubic meters of methane per day). "Our results showed that unconventional sites in southeastern Saskatchewan emit about as often as nearby conventional sites, but with somewhat greater severity."[950]

- February 5, 2019 – A team led by University of Maryland researchers conducted aircraft sampling in 2015 to assess leakage from drilling and fracking operations in the southwestern Marcellus Shale. Coalbeds were the likely source of more than 70 percent of the emitted methane. Of the methane that likely arose from shale gas wells, the estimated mean emission rate was 1.1 percent of the total natural gas extraction. These results were consistent with (but at the low end of) estimates determined by previous observational studies in this region. They indicate that the climate impact of natural gas combustion falls below that of coal. Nevertheless, the full range includes values up to 3.5

[948] Cox, L., (2018, May 14). Gas boom fuels Australia's third straight year of rising emissions. *Guardian*. Retrieved from https://www.theguardian.com/environment/2018/may/14/gas-fuels-australias-third-straight-year-of-rising-emissions

[949] Lelieveld, J., Klingmüller, K., Pozzer, A., Burnett, R. T., Haines, A., & Ramanathan, V. (2019). Effects of fossil fuel and total anthropogenic emission removal on public health and climate. *Proceedings of the National Academy of Sciences, 116*(15), 7192-7197. doi: 10.1073/pnas.1819989116

[950] Baillie, J., Risk, D., Atherton, E., O'Connell, E., Fougère, C., Bourlon, E., & MacKay, K. (2019). Methane emissions from conventional and unconventional oil and gas production sites in southeastern Saskatchewan, Canada. *Environmental Research Communications, 1*(1), 01003. doi: 1088/2515-7620/ab01f2

percent, which falls above the break-even point with coal over a 20-year time span.[951]

- February 5, 2019 – Sampling air from remote locations all over the world, an international team of atmospheric scientists confirmed a sharp rise in global atmospheric methane. This spike began in 2007 and has accelerated since 2014. The causes for the increase are not fully understood. The research team also documented, over the same time period, a shift in the carbon isotope ratio, which may signal a shift in the relative proportions of emissions from different sources. (These various methane sources include, for example, gas leaks, microbes, livestock, landfills, biomass burning.) Alternatively—or additionally—it may signal a decline in the oxidative capacity of the atmosphere, which breaks apart methane molecules. A change in the rate of methane destruction can also change the carbon isotope ratio. Either way, a sharp, ongoing increase in global methane concentrations was not predicted by the future greenhouse gas scenarios that were incorporated into the targets of the Paris Agreement. If the current increase continues, the goals of that treaty could be out of reach. "There is now urgent need to reduce methane emissions, especially from the fossil fuel industry… anthropogenic methane emissions are relatively very large and thus offer attractive targets for rapid reduction, which are essential if the Paris Agreement aims are to be attained."[952]

- February 4, 2019 – Permafrost is soil that remains frozen year-round. If it thaws, microbes turn the carbon contained in the soil into carbon dioxide and methane. Because such a vast amount of carbon is held in permafrost, warming Arctic temperatures may release a large pulse of climate-destabilizing methane and so trigger an uncontrolled positive feedback loop. A study by an international team looked at the fate of permafrost under different scenarios of greenhouse gas mitigation, including some in which no progress is made toward decreasing fossil fuel-based emissions and others in which the targets of the Paris Agreement are met. In their analysis, the team determined the highest level of natural methane emissions that can be released from the Arctic by 2100. This level is considerably lower than likely anthropogenic methane emission levels over the same time period, which indicates that human-made emissions can be reduced sufficiently to limit methane-causing climate warming by 2100 even if the permafrost undergoes an uncontrolled emission feedback—but only if a committed, global effort to reduce fossil fuel use takes place very soon.[953] In a press release about this research, one of the authors of the study, Lena Högland-Isaksson, said, "It is important to put the two estimates alongside each other to point out how important it is to urgently address methane emissions from human activities, in particular through a phase out of fossil fuels. It is important for everyone concerned about global warming to know that humans are the main source of methane emissions and that if we can control humans' release of

[951] Ren, X., Hall, D. L., Vinciguerra, T., Benish, S. E., Stratton, P. R., Ahn, D., . . . Dickerson, R. R. (2019). Methane emissions from the Marcellus Shale in Southwestern Pennsylvania and Northern West Virginia based on airborne measures. *Journal of Geophysical Research Atmospheres, 124*, 1862-1878. doi: 10.1029/2018JD029690
[952] Nisbet, E. G., Manning, M. R., Dlugokencky, E. J., Fisher, R. E., Lowry, D., Michel, S. E., . . . White, J. W. C. (2019). Very strong atmospheric methane growth in the four years 2014-2017: Implications for the Paris Agreement. *Global Biochemical Cycles, 33*(3), 318-342. doi: 10.1029/2018GB006009
[953] Christensen, T. R., Arora, V. K., Gauss, M., Höglund-Isaksson, L., & Parmentier, F.-J. W. (2019). Tracing the climate signal: Mitigation of anthropogenic methane emissions can outweigh a large Arctic natural emission increase. *Scientific Reports, 9*, 1146. doi: 10.1038/s41598-018-37719-9

methane, the problem of methane release from the thawing Arctic tundra is likely to remain manageable."[954]

- December 4, 2018 – Research firm Rystad Energy reported that gas flaring in the west Texas Permian Basin has doubled since 2017. Oil wells in the region pump out large volumes of associated natural gas. Without pipelines to bring the gas to burner tips, and in order to maintain the rapid pace of oil drilling, operators simply waste the gas—worth more than $1 million per day—by burning it off in flare stacks. Flaring permits are limited to 45 days but are now routinely extended for up to six continuous months.[955]

- November 23, 2018 – In a report commissioned by the Obama administration in 2016, the U.S. Geological Survey (USGS) provided estimates on greenhouse gas emissions associated with the extraction and combustion of fossil fuels produced from federal lands. Between 2005 and 2014, fully one-quarter of all U.S. carbon emissions come from fossil fuels that were extracted from public lands. The report found that forests on federal lands can offset some of these emissions but only by 15 percent. Fossil fuels are extracted from public lands in 28 states with more than half the total carbon emissions coming from Wyoming.[956, 957]

- October 29, 2018 – The Basin Methane Reconciliation Study was a large-scale field investigation that brought together more than 80 scientists from multiple institutions. They examined why different methods of accounting for methane emissions from natural gas drilling sites vary so widely across the United States. The study took place in 2015 in Arkansas' Arkoma Basin and utilized both bottom-up and top-down approaches, which is to say, measurements were taken on the ground at selected facilities as well as in the atmosphere over the region, via aircraft. This type of concurrent dual analysis had never been attempted before. The study revealed spikes of high emissions that occur during daytime maintenance operations, as when, for example, liquids are being removed from a well and natural gas is freely vented into the air for the duration of that process. The high temporal variability and episodic nature of methane emissions likely explain the persistent gap between the two accounting methods and mean that researchers who attempt to determine how much methane is escaping from drilling and fracking operations require "detailed activity data, unfettered and unbiased site access, and time-resolved operations data." This type of study necessarily requires cooperation with

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954 International Institute for Applied Systems Analysis. (2019, February 6). Diffusing the methane bomb: We can still make a difference [Press release]. Retrieved from https://www.sciencedaily.com/releases/2019/02/190206104538.htm

955 Blum, J. (2018, December 4). Permian Basin gas flaring has nearly doubled in a year. *Houston Chronicle.* Retrieved from https://www.houstonchronicle.com/business/energy/article/Record-Permian-gas-flaring-has-nearly-doubled-in-13443024.php

956 Merrill, M. D., Sleeter, B. M., Freeman, P. A., Liu, J., Warwick, P. D., & Reed, B. C. (2018). Federal lands greenhouse gas emissions and sequestration in the United States—Estimates for 2005–14. *U.S. Geological Survey Scientific Investigations Report 2018–5131*. doi: 10.3133/sir20185131

957 Aton, A. (2018, November 27). Fossil fuel extraction on public lands produces one quarter of U.S. emissions. *E&E News.* Retrieved from https://www.scientificamerican.com/article/fossil-fuel-extraction-on-public-lands-produces-one-quarter-of-u-s-emissions/

industry employees.[958]

- August 1, 2018 – The Groningen natural gas field in the northern Netherlands is one of Europe's major gas fields where extraction, gas processing, and gas storage all take place. It is also a region with intensive agriculture and cattle operations. An international research team investigated methane emissions there with the intent of distinguishing between methane from fossil fuel sources and methane arising from livestock, wetlands, and agriculture. Using both ground and aircraft measurements, the researchers determined that emissions from oil and gas operations account for 20 percent of regional methane, with the remainder from biogenic sources. That figure for fossil fuel sources is, nevertheless, ten times higher than the 1.9 percent that was estimated by previous inventories. Ground-based measurements at extraction, processing, and storage sites found low emission rates compared to gas production facilities in the United States. Production volume was a poor predictor of emission rates. Even wells with no production still had emissions.[959]

- August 1, 2018 – California's climate goals call for an 80 percent reduction in emissions by 2050. With this goal in mind, a Lawrence Berkeley National Laboratory team set out to estimate what fraction of California's greenhouse gas emissions represent methane emissions from residential homes, including leakage from gas pipes, stovetops, combustion appliance pilot lights, and forced air furnaces. Total methane emissions from California homes represent 15 percent of the total emissions from the natural gas sector in California and represent two percent of the state's total methane emissions, as calculated in the 2015 state inventory. The team also found that emissions from pilot lights constitute a significant fraction as do flames in domestic hot water heaters. "While methane emissions from houses are small compared to most sources, California's ambitious goals…suggest value in testing and repairing obvious leaks in residential gas lines, modernizing combustion appliances to move away from pilot lights, and gradually increasing the use of non-fossil fuel energy sources for residential space and hot water heating and cooking."[960]

- July 10, 2018 – In 2015, as part of a follow-up study, a research team used helicopters to measure methane emission patterns at 353 well pads in North Dakota's Bakken Shale that had been surveyed in the same way in 2014. In the interim, 21 newly producing well pads were added to the sampling area. They found that the individual well pads that emitted methane in 2014 were far more likely to be still emitting in 2015 than would be expected by chance alone. The reasons for this persistent leaking were not identified but potentially

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[958] Vaughn, T. L., Bell, C. S., Pickering, C.K., Schwietzke, S., Heath, G. A., Pétron, G., … & Nummedal, D. (2018). Temporal variability largely explains top-down/bottom-up difference in methane emission estimates from a natural gas production region. *Proceedings of the National Academy of Sciences, 115(*46), 11712-11717. doi: 10.1073/pnas.1805687115

[959] Yacovitch, T. I., Neininger, B., Herndon, S. C., Denier van der Gon, H., Jonkers, S., Hulskotte, J., . . . Zavala-Araiza, D. (2018). Methane emissions in the Netherlands: The Groningen field. *Elementa: Science of the Anthropocene, 6*(57). doi: 10.1525/elementa.308

[960] Fischer, M. L., Chan, W. R., Jeong. S., & Zhu, Z. (2018). *Natural gas methane emissions from California homes*. California Energy Commission, CEC-500-2018-021. Retrieved from https://www.energy.ca.gov/2018publications/CEC-500-2018-021/CEC-500-2018-021.pdf

include tanks without vapor recovery systems, overpressurization, undersized flaring systems, stuck or clogged valves, and "poorly designed equipment." Altogether, researchers quantified 33 plumes of methane and ethane arising from these well pads.[961]

- June 21, 2018 – An analysis of methane leaks from the U.S. oil and gas supply chain found that natural gas is just as damaging as coal for the climate over a 20-year time frame. This study combined on-the-ground measurements of leaks at selected facilities (bottom-up methods) with data collected from the atmosphere via aircraft (top-down methods). Based on the results, the authors estimated that roughly 2.3 percent of all the natural gas extracted in the United States escapes into the air. This estimated level of leakage was 60 percent higher than the EPA's estimate of 1.4 percent. The authors believe their emissions estimate is the more accurate because they used helicopters to capture episodic releases of large plumes of methane caused by "abnormal operating conditions" and "failure-prone systems" that were likely missed by the sampling methods used for EPA's greenhouse gas inventory. Liquid storage tank hatches and vents were the source of most of acute incidents.[962]

- December 20, 2017 – A major study led by NASA researchers concluded. that fossil fuel sources are driving the sharp uptick in global atmospheric concentrations of methane since 2006. Using satellite measurements and isotopic analysis, the team showed that methane from biomass sources, such as fires, decreased over the time period 2001-2016 while fossil fuel sources of methane increased. These findings helped reconcile conflicting results from other previous studies.[963]

- October 17, 2017 – Using planes, an international team of researchers measured regional airborne methane and ethane emission rates from the Alberta oil and gas fields in Canada. They compared these results to emissions reported by the industries themselves, as part of an accounting system that requires operators to report flaring and venting volumes, and found large discrepancies. Based on the amounts of methane and ethane detected in the atmosphere above the oil and gas fields, the reported industry emissions in this region should be 2.5 ± 0.5 times higher. Such large discrepancies between actual methane emissions and industry-provided data represent a "reporting gap" and present a critical challenge when determining policy. Proposed regulations in Canada currently call for reducing methane emissions from Canadian fracking operations by 45 percent. However, these data indicate that most of the methane emissions from these operations arise from

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[961] Englander, J. G., Brandt, A. R., Conley, S., Lyon, D. R., & Jackson, R. B. (2018). Aerial interyear comparison and quantification of methane emission persistence in the Bakken Formation of North Dakota, USA. *Environmental Science & Technology, 52*(15), 8946-8953. doi: 10.1021/acs.est.8b01665

[962] Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., . . . Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science, 361*(6398): 186-188. doi: 10.1126/science.aar7204

[963] Worden, J. R., Bloom, A. A., Pandey, S., Jiang, Z., Worden, H. M., Walker, T. W., . . . Röckmann, R. (2017). Reduced biomass burning emissions reconcile conflicting estimates of the post-2006 atmospheric methane budget. *Nature Communications, 2227.* doi: 10.1038/s41467-017-02246-0

fugitive leaks that are not being measured at all and/or from episodes of unreported venting.[964]

- July 18, 2017 – A team of 15 climate scientists led by James Hansen at Columbia University conducted a study on the growth rate of greenhouse gas climate forcing, which has accelerated by 20 percent in the past decade. (Climate forcing is the difference between the amount of the sun's energy that is absorbed by the Earth and amount that radiates back into space.) The authors note that methane ($CH_{4)}$ is the largest climate-forcing gas after carbon dioxide. With an atmospheric lifetime of only about ten years, "there is potential to reduce climate forcing rapidly if CH_4 sources are reduced." However, "there is a danger of increased leakage with expanded shale gas extraction." Noting that the speed of ice sheet melting and sea level rise are difficult to predict, the authors assert that targets for limiting global warming should aim to keep global temperatures close to the preindustrial Holocene range rather than allow them to rise to those found during the prior Eemian period, when sea levels were 6-9 meters higher than today. Such targets require immediate phase-out of fossil fuel emissions, along with profound changes in farming and forestry practices. A delay in taking these measures to minimize irreversible climate impacts means that the next generation will be required to undertake risky, expensive, large-scale CO_2 extraction practices, such as carbon capture. "If high fossil fuel emissions continue, a great burden will be placed on the young. . . . Continued high fossil fuel emissions unarguably sentences young people to either a massive, implausible cleanup or growing deleterious climate impacts or both."[965]

- July 8, 2017 – An investigative report from the Inter Press Service News Agency examined the climate impacts of methane emissions from Mexico, which is sixth among the world's nations in technically recoverable shale gas reserves (after China, Argentina, Algeria, the United States, and Canada). Mexico's current energy policy, introduced in 2014, emphasizes the exploitation of shale gas using fracking. Using data from the state-owned energy company Petroleos Mexicanos (PEMEX), the Inter Press Service story documents that as of 2017, more than 900 wells, located in six of Mexico's 32 states, have been drilled and fracked. High volumes of methane are emitted during venting, and methane emissions have been increasing sharply. In 2016, the total methane emissions from Mexico's PEMEX Exploration and Production operations were 641,517 metric tons, 38 percent higher than the previous year. According to researcher Ramón Torres, of the National Autonomous University of Mexico, who is quoted in the story, "Current regulations are based on best practices, but the philosophy of environmental protection has been abandoned. Exploitation is deepening inequities in a negative way, such as environmental impact. It is irresponsible to auction reserves without a proper evaluation of environmental and social impacts."[966]

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[964] Johnson, M. R., Tyner D. R., Conley, S., Schwietzke, S., & Zavala-Araiza, D. (2017). Comparisons of airborne measurements and inventory estimates of methane emissions in the Alberta upstream oil and gas sector. *Environmental Science & Technology*. *51*(21), 13008–13017. doi: 10.1021/acs.est.7b03525

[965] Hansen, J., Sato, M., Kharecha, P., von Schuckmann, K., Beerling, D. J., Cao, J. . . . Ruedy, R. (2017). Young people's burden: Requirement of negative CO2 emissions. *Earth System Dynamics, 8,* 577-616. doi: 10.5194/esd-8-577-2017

[966] Godoy, E. (2017, July 8). Mexico's methane emissions threaten the environment. *Inter Press Service News Agency.* Retrieved from http://www.ipsnews.net/2017/07/mexicos-methane-emissions-threaten-environment/

- June 19, 2017 – A study that measured methane emissions from various components of drilling and fracking equipment on well pads located in four different shale basins in Colorado, Utah, Arkansas, and Wyoming found widely varying results. In Colorado and Utah, a small percentage of well pads leaked the vast majority of methane, whereas leakage was more equitably distributed among wells in Wyoming. The research team also found variations that were dependent on oil/gas/water content as well as on the numbers of wells per well pad. In sum, emissions from well pads contributed significantly to basin-wide methane emissions but varied depending on location. [Note: the authors identify XTO Energy as a cost share partner in this study.][967]

- April 18, 2017 – San Juan Basin in the four-corner region of Utah, Arizona, New Mexico, and Colorado, is one of the largest coal-bed methane producing regions in North America. Between 2003 and 2015, natural gas production declined, and yet, as revealed by atmospheric sampling from aircraft flying over the basin, methane emissions did not decrease during this same time period. These results confirm earlier findings from a satellite study that also showed no declines in regional methane concentrations in spite of significant declines in natural gas production. According to the authors, the likely explanation for the region's persistent, elevated methane levels is increased oil drilling in the basin.[968]

- February 9, 2017 – Using ground-based monitoring methods, a team led by Drexel University researchers monitored a range of emissions, including methane, in two intensively drilled regions of the Marcellus Shale basin in Pennsylvania. The goal was to understand the concentrations and sources of relevant air pollutants that had previously been reported as impacts of drilling and fracking operations. Airborne methane concentrations were higher in southwestern Pennsylvania as compared to northeastern Pennsylvania. The authors conclude that urban-like levels of air pollutants in rural Pennsylvania are likely due to emissions from oil and gas operations in the Marcellus Shale basin.[969]

- January 9, 2017 – A modeling study found that short-lived greenhouses gases, such as methane, contribute to thermal expansion of the ocean over much longer time scales than their brief atmospheric lifetimes might otherwise predict. "Actions taken to reduce

[967] Robertson, A. M., Edie, R., Snare, D., Soltis, J., Field, R. A., Burkhart, M. D., … Murphy, S. M. (2017). Variation in methane emission rates from well pads in four oil and gas basins with contrasting production volumes and compositions. *Environmental Science & Technology*, *51*(15), 8832–8840. doi: 10.1021/acs.est.7b00571
[968] Smith, M. L., Gvakharia, A., Kort, E. A., Sweeney, C., Conley, S. A., Faloona, I., … Wolter, S. (2017). Airborne quantification of methane emissions over the four corners region. *Environmental Science & Technology*, *51*(10), 5832−5837. doi: 10.1021/acs.est.6b06107
[969] Goetz, J. D., Avery, A., Werden, B., Floerchinger, C., Fortner, E. C., Wormhoudt, J., . . . DeCarlo, P. F. (2017) Analysis of local-scale background concentrations of methane and other gas-phase species in the Marcellus Shale.. *Elementa: Science of the Anthropocene,5*(1). doi: https://doi.org/10.1525/ elementa.182

emissions of short-lived gases could mitigate centuries of additional future sea-level rise."[970]

- December 12, 2016 – As part of the interdisciplinary Global Carbon Project, a consortium of scientists undertook a meta-analysis that synthesizes many hundreds of individual studies in order to better understand the global methane cycle. Integrating atmospheric measurements with ground-based data, the researchers found more uncertainty in the emissions from natural sources than from human activities. For the 2003–2012 decade, global methane emissions were 558 teragrams per year (range of 540–568), with 60 percent of global methane emissions attributed to anthropogenic sources of all kinds and with a significant contribution (likely at least 39 percent) from oil and gas production operations.[971]

- December 12, 2016 – An editorial published in *Environmental Research Letters* by an international team of scientists urges immediate attention to quantify and reduce methane emissions. "Unlike CO2, atmospheric methane concentrations are rising faster than at any time in the past two decades and, since 2014, are now approaching the most greenhouse-gas-intensive scenarios." The authors present methods of evaluating anthropogenic and biogenic sources of methane, as from agricultural practices and project future methane emissions.[972]

- November 8, 2016 – The government of Scotland released a report confirming that the pursuit of unconventional oil and gas extraction would make more difficult the nation's goal of meeting its climate targets on greenhouse gas emissions.[973]

- November 1, 2016 – A life cycle analysis of greenhouse gas emissions from fracking operations in the Marcellus Shale region found that upstream activities associated with the use and transportation of chemicals, water, and sand mining contributed relatively lower emissions than downstream phases of the fracking process, which include gas combustion, methane leakage, venting, and flaring.[974]

- October 5, 2016 – A new inventory of worldwide methane emissions from various sources finds that methane emissions from the fossil fuel industry are 20-60 percent

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[970] Zickfeld, K., Solomon, S., & Gilford, D. M. (2017) Centuries of thermal sea-level rise due to anthropogenic emissions of short-lived greenhouse gases. *Proceedings of the National Academy of Sciences, 114*(4), 657-662. doi: 10.1073/pnas.1612066114

[971] Saunois, M., Bousquet, P., Poulter, B., Peregon, A., Ciais, P., Canadell, J. G., … Zhu, Q. (2016). The global methane budget 2000–2012. *Earth System Science Data, 8,* 697–751. doi: 10.5194/essd-8-697-2016

[972] Saunois, M., Jackson, R. B., Bousquet, P., Poulter, B., & Canadell, J.G. (2016). The growing role of methane in anthropogenic climate change. *Environmental Research Letters, 11,* 120207. doi: 10.1088/1748-9326/11/12/120207

[973] Committee on Climate Change. (2016, November 8). Scottish unconventional oil and gas: Compatibility with Scottish greenhouse gas emissions targets. Retrieved from http://www.gov.scot/Resource/0050/00509324.pdf

[974] Sibrizzi, C., & LaPuma, P. (2016). An assessment of life cycle greenhouse gas emissions associated with the use of water, sand, and chemicals in shale gas production of the Pennsylvania Marcellus Shale. *Journal of Environmental Health, 79*(4), 8-15. Retrieved from https://www.neha.org/node/58673

higher than previously thought.[975] This discovery, based on isotopic fingerprinting of methane sources, has prompted researchers to call for revisions to current climate prediction models and for a renewed emphasis on reducing methane emissions as a necessary tool for combating climate change.[976]

- September 26, 2016 – In ratifying the Paris Climate Agreement, the United States pledged to reduce its greenhouse gas emissions 26-28 percent by 2025 as compared to 2005 levels. A research team from Lawrence Berkeley National Laboratory found that the United States is on track to miss this target, in large part because of soaring methane emissions.[977, 978]

- September 12, 2016 – Using isotopic analysis and archived air samples collected from 1977 to 1998, as well as more contemporary data, a team of researchers from Oregon presented "strong evidence" that methane emissions from fossil fuel sectors were approximately constant in the 1980s and 1990s but then increased significantly between 2000 and 2009. Over the same time period, methane emissions from biomass burning, rice cultivation, and wetlands decreased. These results contradict the findings of earlier studies that used atmospheric ethane as a marker for methane and had concluded that fugitive fossil fuel emissions fell during much of that period. (More recent studies show that ethane emissions are increasing again.)[979, 980, 981]

- July 11, 2016 – A group of 130 environmental and health organizations signed a formal complaint with the Inspector General of the U.S. Environmental Protection Agency (EPA) about a pivotal 2013 study that was published in the *Proceedings of the National Academies of Sciences* and which was led by University of Texas chemist David T. Allen. The letter accused Allen of "systemic fraud, waste, and abuse" for his reliance on an inaccurate measurement device that was known to underestimate methane levels.

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[975] Schwietzke, S., Sherwood, O. A., Bruhwiler, L. M. P., Miller, J. B., Etiope, G., Dlugokencky E. J., . . . Tans, P. P. (2016). Upward revision of global fossil fuel methane emissions based on isotope database. *Nature, 538*. 88-91. doi: 10.1038/nature19797

[976] Vaughan, A. (2016, October 5). Fossil fuel industry's methane emissions far higher than thought. *The Guardian.* Retrieved from https://www.theguardian.com/environment/2016/oct/05/fossil-fuel-industrys-methane-emissions-far-higher-than-thought

[977] Greenblatt, J. R., & Wei, M. (2016). Assessment of the climate commitments and additional mitigation policies of the United States. *Nature Climate Change, 6,* 1090-93. doi: 10.1038/nclimate3125

[978] Mooney, C. (2016, September 26). The U.S. is on course to miss its emissions goals, and one reason is methane. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2016/09/26/the-u-s-is-on-course-to-miss-its-emissions-goals-and-one-reason-is-methane/?utm_term=.80df24676a21

[979] Rice, A. L., Butenhoff, C. L., Teama, D. G., Röger, F. H., Khalil, M. A. K., & Rasmussen, R. A. (2016). Atmospheric methane isotopic record favors fossil sources flat in 1980s and 1990s with recent increase. *Proceedings of the National Academy of Sciences,113*(39). 10791–10796. doi: 10.1073/pnas.1522923113

[980] Harvey, C. (2016, September 13). Scientists may have solved a key mystery about the world's methane emissions. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2016/09/13/the-answer-to-the-global-methane-mystery-fossil-fuels-a-study-finds/?utm_term=.64a94b9abf4e

[981] von Kaenel, C. (2016, September 13). Debate rises over real source of higher methane emissions. *Scientific American.* Retrieved from https://www.scientificamerican.com/article/debate-rises-over-real-source-of-higher-methane-emissions/

Partially funded by the oil industry, Allen's study reported very low methane emission rates as part of a large survey of 190 drilling and fracking sites across the nation. That flawed study was influential, said complainants, in preventing EPA from recognizing the magnitude of methane leakage from drilling and fracking operations.[982] (See also the entry below for March 24, 2015.)

- June 17, 2016 – A comparative assessment of emerging methods for measuring methane emissions from different sources recommends combining analytic methods with chemical mass balance (CMB) methods. The CMB system is currently used in the Barnett Shale oil and gas production region in Texas as an approach to tracing methane emissions back to their sources.[983]

- May 25, 2016 – As part of the first field study to directly measure methane emissions from the heavily drilled Bakken Shale formation in northwestern North Dakota, a team led by atmospheric chemist Jeff Peischl at NOAA flew research aircraft over the region in May 2014. The researchers derived a methane emission rate of 275,000 tons of methane per year, which is similar to the rate of methane leakage in the Front Range area of Colorado but significantly lower than previous studies of the Bakken area that relied on satellite remote sensing data during an earlier time period (2006-2011). Analyzing the chemical composition of air samples, the NOAA team determined that almost all of the methane originated with oil and gas operations, rather than with natural or agricultural sources, and estimated a leakage rate of 4.2-8.4 percent.[984] Scaled to production, this emission rate is slightly lower than that estimated by EPA in its recently revised inventory.[985, 986] (See April 15, 2016 entry below.)

- April 15, 2016 – In its 21st annual greenhouse gas inventory, which includes 2014 data, the EPA increased its leakage assessment from oil and gas operations by 34 percent. For oil production alone, the EPA more than doubled its estimates of methane emissions. Further, in an admission that the agency had been historically underestimating methane leaks, the EPA also retroactively increased estimates of past emissions from the fossil

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[982] Johnson, J. (2016, July 11). Pivotal study on methane leaks from U.S. oil and natural gas wells under fire. *Chemical & Engineering News.* Retrieved from http://cen.acs.org/articles/94/i28/Pivotal-study-methane-leaks-US.html

[983] Allen, D. (2016). Attributing atmospheric methane to anthropogenic emission sources. *Accounts of Chemical Research, 49,* 1344−1350. doi: 10.1021/acs.accounts.6b00081

[984] Peischl, J., Karion, A., Sweeney, C., Kort, E. A., Smith, M. L., Brandt, A. R., . . . Ryerson, T. B. (2016). Quantifying atmospheric methane emissions from oil and natural gas production in the Bakken shale region of North Dakota. *Journal of Geophysical Research: Atmospheres, 121*. doi: 10.1002/2015JD024631

[985] National Oceanic and Atmospheric Administration. (2016, May 16). *North Dakota's Bakken oil and gas field leaking 275,000 tons of methane per year* [Press release]. Retrieved from http://www.noaa.gov/news/north-dakota-s-bakken-oil-and-gas-field-leaking-275000-tons-of-methane-year

[986] MacPherson, J. (2016, May 11). A new study says the oil-producing region of North Dakota and Montana leaks 275,000 tons of methane annually. *U.S. News & World Report.* Retrieved from http://www.usnews.com/news/science/articles/2016-05-11/study-bakken-oil-field-leaks-275-000-tons-of-methane-yearly

fuel sector as expressed in prior inventories.[987, 988] In an accompanying news release, the agency said, "Data on oil and gas show that methane emissions from the sector are higher than previously estimated. The oil and gas sector is the largest emitting-sector for methane and accounts for a third of total U.S. methane emissions."[989] Past EPA inventories had identified livestock as the number one source of U.S. methane. These annual inventories fulfill the EPA's obligations under the United Nations Framework Convention on Climate Change, signed and ratified by the United States in 1992, and attempt to identify and quantify U.S. anthropogenic sources and sinks of greenhouse gases for the time period 1990 and forward. The upward revision in both past and current inventories is a reflection of changing methodologies for measuring methane leaks.[990] Older methods included the incorporation of "bottom-up" data supplied by the oil and gas industry, without attention to high-emitting or super-emitting sources or possible sources of error introduced by flawed measuring equipment. In addition, the use of a Global Warming Potential multiplier of 25 for methane, which is based on a 100-year time horizon, rather than 86 for a 20-year time horizon, has come under sustained criticism given the urgency of the climate crisis.[991, 992]

- April 7, 2016 – Since 2009, corresponding to the advent of the U.S. shale gas boom, North American ethane emissions have increased by 5 percent per year. This trend represents a reversal of a previous multi-decade decline (mid-1980s until the end of the 2000s) in the abundance of atmospheric ethane that had been attributed to the reduction of fugitive emissions from fossil fuel sources. These are the findings of an international research team, which analyzed remote sensing data gathered by the Network for the Detection of Atmospheric Composition Change at globally distributed ground-based sites. Ethane is a volatile organic compound (VOC) that readily reacts with nitrogen oxides in the presence of sunlight to create ground-level ozone (smog). Also a potent greenhouse gas, ethane is co-released along with methane from drilling and fracking sites. The source of two-thirds of the ethane in Earth's atmosphere is leakage from natural gas wells and pipelines. Because ethane is co-emitted with methane and can serve as a marker for it, this documentation of a sharp, recent uptick in atmospheric ethane is part of a larger body of evidence suggesting that U.S. drilling and fracking operations are

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987 U.S. Environmental Protection Agency. (2016, April 15). *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2014.* Retrieved from https://www.epa.gov/sites/production/files/2016-04/documents/us-ghg-inventory-2016-main-text.pdf

988 Johnson, J. (2016, April 25). Oil, natural gas operations now top U.S. methane emitters. *Chemical & Engineering News.* Retrieved from http://cen.acs.org/articles/94/i17/Oil-natural-gas-operations-top.html?type=paidArticleContent

989 U.S. Environmental Protection Agency. (2016, April 15). EPA publishes 21st annual U.S. greenhouse gas inventory [Press release]. Retrieved from https://www.epa.gov/newsreleases/epa-publishes-21st-annual-us-greenhouse-gas-inventory

990 Mooney, C. (2016, April 15). The U.S. has been emitting a lot more methane than we thought, says EPA. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2016/04/15/epa-issues-large-upward-revision-to-u-s-methane-emissions/?utm_term=.eca9c599ff09

991 Sumner, T. (2016, April 14). EPA underestimates methane emissions. *ScienceNews.* Retrieved from https://www.sciencenews.org/article/epa-underestimates-methane-emissions

992 Profeta, T. (2016, March 3). Study, EPA spotlight methane emissions from oil and gas industry. *National Geographic.* Retrieved from http://voices.nationalgeographic.com/2016/03/03/study-epa-spotlight-methane-emissions-from-oil-and-gas-industry/

driving up global methane levels.[993] (See also entry dated June 13, 2016 in Air Pollution section].)

- April 5, 2016 – A research team using infrared cameras and helicopters demonstrated that between 1 and 14 percent of oil and gas well pads surveyed were high emitters of hydrocarbons and VOCs, with the greatest number observed in oil producing areas and in areas with horizontal drilling.[994] While some emissions were intentional or part of routine maintenance operations, fugitive, unplanned releases (as from malfunctioning equipment) were also common, as were combustion emissions (as from flares and compressor engine exhaust). Tank vents and hatches were the origin of the vast majority (>90 percent) of detected large emission sources, deeply undercutting the assumption in the EPA's Oil & Gas Emission Estimation Tool of 100 percent capture efficiency by tank control systems. While emissions tended to be higher during the first few months of well production, predicting which wells or other sources would become high emitters was not possible. The lead author, speaking to *InsideClimate News*, concluded that the work "really demonstrates the importance of things like continuous detection or frequent monitoring to find these high emission sites."[995]

- March 10, 2016 – Attempting to explain a methane plateau between 1999 and 2006 within otherwise almost continuously increasing levels of atmospheric methane since the dawn of the industrial revolution, an international team of atmospheric scientists reconstructed the global history of methane and used isotopic carbon fingerprinting to parse the sources of its emission. Thermogenic emissions were assumed to result from fossil-fuel sources, while biogenic sources were assumed to arise from wetlands and agricultural operations. Based on a geographic distribution of methane revealed by remote sensing, the authors concluded that agricultural emissions, especially increases in livestock inventories and rice cultivation, were the most likely drivers of observed global methane increases from 2006 to 2014.[996] These results stand in contrast to other contemporaneous and recent studies that have supplied evidence for the role of oil and gas extraction in the recent upsurge in atmospheric methane.[997] (See entry for February 16, 2016 below.)

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[993] Franco, B., Mahieu, E., Emmons, L. K., Tzompa-Sosa, Z. A., Fischer, E. V., Sudo, K., . . . Walker, K. A. (2016). Evaluating ethane and methane emissions associated with the development of oil and natural gas extraction in North America. *Environmental Research Letters, 11*. doi: 10.1088/1748-9326/11/4/044010

[994] Lyon, D. R., Alvarez, R. A., Zavala-Araiza, D., Brandt, A. R., Jackson, R. B., & Hamburg, S. P. (2016). Aerial surveys of elevated hydrocarbon emissions from oil and gas production sites. *Environmental Science & Technology, 50,* 4877–4886. doi: 10.1021/acs.est.6b00705

[995] McKenna, P. (2016, April 8). Researchers find no shortcuts for spotting wells that leak the most methane. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/07042016/big-methane-leaks-superemitters-oil-gas-production-climate-change-edf

[996] Schaefer, H., Fletcher, S. E. M., Veidt, C., Lassey, K. R., Brailsford, G. W., Bromley, T. M., . . . White, J. W. C. (2016, March 10). A 21st century shift from fossil-fuel to biogenic methane emissions indicated by $^{13}CH_4$. *Science.* doi: 10.1126/science.aad2705

[997] McKenna, P. (2016, March 10). The mystery of the global methane rise: Asian agriculture or U.S. fracking? *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/10032016/mysterious-global-methane-rise-asian-agriculture-or-us-fracking

- February 16, 2016 – A Harvard-led team used both satellite retrievals and surface observations to estimate that methane emissions in the United States increased by more than 30 percent over the past twelve years. These findings, which contradict the 10 percent decline reported by the EPA, suggest that the United States could be responsible for 30-60 percent of the recent global spike in atmospheric methane.[998, 999] Since 2015, research on atmospheric methane has frequently relied on an "inverse method" to optimize emission estimates by combining "bottom-up" and "top-down" data, yet data from different sources have not yielded consistent estimates of methane emissions and levels. Three major sources (Wecht et al. [2014], Miller et al. [2013], and Turner et al. [2015]) all found maximum emissions in the South Central United States, with spatial overlaps that made separating livestock sources from oil and gas sources difficult. Taking into account the time period investigated by differing studies reveals an increasing trend in methane emissions, with an increase of 38 percent from 2004 to 2011, a period of greatly increasing drilling activity. This trend is confirmed by analyzing temporal trends in satellite data. While this account still differs from the EPA's inventory in 2014 showing a 3 percent decrease in oil and gas emissions over that same time period, the EPA's data presumed better control of measured leaks, which may not correlate with better control of overall emissions.

- January 29, 2016 – Working in the Marcellus Shale Basin, a Carnegie Mellon research team compared methane emissions from older conventional gas wells (those that were vertically drilled) and newer, unconventional gas wells (those that combined fracking with horizontal drilling). Measured by facility, the mean emission rate for unconventional wells was 23 times higher than that of conventional wells. This difference, in part, was attributed to the larger size of unconventional well pads, which, typically, have multiple wells per pad, more ancillary equipment, and produce more gas. When corrected for production, the conventional wells leaked more—that is to say, they lost a comparably larger fraction of methane per unit of production—likely due to "unresolved equipment maintenance issues." All together, the authors concluded, these new emissions data show that the recently instituted Pennsylvania Department of Environmental Protection's (PA DEP) methane emissions inventory substantially underestimates facility-level methane emissions. Five unconventional well sites included in this study leaked 10-37 times more methane than estimated in the state inventory.[1000]

- January 25, 2016 – Cornell University scientists introduced an innovative methodology for assessing potential climate impacts of alternative choices and used it to demonstrate that emissions of the two most important greenhouse gases (carbon dioxide and methane), calculated as time-integrated radiative forcing, are lower with heat pump water heaters than any other means of heating water. Further, their calculations showed that

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[998] Turner, A. J., Jacob, D. J., Benmergui, J., Wofsy, S. C., Maasakkers, J. D., Butz, A., . . . Biraud, S. C. (2016). A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations. *Geophysical Research Letters, 43.* doi: 10.1002/2016GL067987

[999] Magill, B. (2016, February, 16). Study ties U.S. to spike in global methane emissions. *Climate Central.* Retrieved from http://www.climatecentral.org/news/us-60-percent-of-global-methane-growth-20037

[1000] Omara, M., Sullivan, M. R., Li, X., Subramanian, R., Robinson, A. L., & Presto, A. A. (2016). Methane emissions from conventional and unconventional natural gas production sites in the Marcellus Shale Basin. *Environmental Science & Technology, 50*. doi: 10.1021/acs.est.5b05503 heat pump water heaters powered by coal-generated electricity achieve greater net climatic benefit than heaters powered by natural gas, while even greater benefits may be achieved by combining heat pump water heaters with electricity generated by renewable sources. The authors proposed and justified a methane emission rate of 3.8 percent for conventional shale gas, which is therefore offered as a lower bound for future, tightly controlled methane emissions from unconventional gas activities. The authors also made their web-based tool for evaluating the greenhouse gas footprint of reference and alternative technologies and its source code available to the public (at http://www.eeb.cornell.edu/howarth/methane/tool.htm).[1001]

- December 22, 2015 – To reconcile troubling divergences in published estimates of methane emissions, in which "top-down" estimates, based on atmospheric or satellite sampling, often exceed "bottom-up" estimates, based on ground-level sampling or individual source reports, researchers used a combination of repeated mass balance measurements plus ethane fingerprinting to improve top-down estimates and incorporated a more complete and detailed count of facilities to improve bottom-up estimates.[1002] The results, as demonstrated in the Barnett Shale oil and gas-producing region of Texas, revealed a convergence of estimates to within 10 percent for fossil methane and 0.1 percent for total methane, with predicted methane emissions 90 percent larger than those estimated by the EPA's Greenhouse Gas Inventory. Exclusion of additional problematic studies might have resulted in even greater convergence and higher estimates.[1003] The agreement between top-down and bottom-up estimates demonstrates that well-designed surveys using either approach can be useful, with spatially resolved bottom-up estimates pointing toward production sites as the source of 53 percent of emissions, compressor stations 31 percent of emissions, and processing plants 13 percent of emissions. The Barnett shale emission rate of 1.5 percent calculated in this study is low enough (less than 3 percent) to suggest that gas fired electricity production in this region causes less climate forcing than coal-fired electricity, but it is high enough (greater than 1 percent) to argue against the conversion of diesel powered freight trucks to compressed natural gas. Gas production practices and heavier activity in other basins may lead to higher emission rates, as may the storage and long-distance or very long-distance transmission of natural gas.

- December 22, 2015 – Writing for *Environment & Energy Publishing*, journalist Gayathri Valdyanathan reported on efforts by climate scientists to convince the United Nations to stop expressing the heat-trapping potential of methane over a 100-year time frame and instead use a twenty-year time frame when generating global warming potential, the conversion factor that allows policymakers to compare methane's ability to trap heat with that of carbon dioxide. Methane is a far more potent heat-trapping gas than is carbon

[1001] Hong, B., & Howarth, R. W. (2016). Greenhouse gas emissions from domestic hot water: Heat pumps compared to most commonly used systems. *Energy Science & Engineering, 4*(2), 123-133. doi: 10.1002/ese3.112
[1002] Zavala-Araiza, D., Lyon, D. R., Alvarez, R. A., Davis, K. J., Harriss, R. Herndon, S. C., . . . Hamburg, S. P. (2015). Reconciling divergent estimates of oil and gas methane emissions. *Proceedings of the National Academies of Science, 112*(51), 15597-15602. doi: 10.1073/pnas.1522126112
[1003] Song, L. (2015, December 7). Texas fracking zone emits 90% more methane than EPA estimated. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/07122015/methane-emissions-texas-fracking-zone-90-higher-epa-estimate

dioxide, but it is also shorter lived. By convention, policymakers have used a 100-year time frame when calculating global warming potentials. However, there is no scientific reason to do so, and many scientific critics argue that choosing this time scale veils the true climate impacts of natural gas and "makes the gas appear more benign than it is."[1004]

- November 25, 2015 – Using reports from countries and companies with proved reserves of recoverable oil, natural gas, and coal, an analysis published in *Global Environmental Change* shows that full production of these resources would use up 160 percent of the world's estimated remaining carbon budget (designed to restrict anthropogenic climate change to equal to or less than 2^{o} C). While 76 percent of reserves are owned by states or state entities, the relatively smaller amount of reserves owned by investors poses the greater immediate threat, since those companies are more likely poised to produce, refine, and deliver fossil fuels to global markets in the near term. However, exploitation of existing proved reserves controlled by the private sector alone does not lead to warming above the 2^{o} limit, if it is not accompanied by exploration for and development of new reserves. Future considerations of fossil fuel use should focus not only on reducing private sector contributions but also on reducing contributions from countries that have historically dominated or currently dominate emissions, and especially nation-states with large undeveloped reserves.[1005]

- November 9, 2015 – Including data available through 2014, the World Meteorological Organization (WMO) reported that globally averaged levels of carbon dioxide, methane, and nitrous oxide reached new highs in 2014, with values, respectively, "143%, 254% and 121% of pre-industrial (1750) levels." [1006, 1007] While the atmospheric increase in carbon dioxide has slowed, methane and nitrous oxide levels continue to increase. Measurements from the WMO's Global Watch Programme point to wetlands in the tropics and anthropogenic sources at mid-latitudes of the northern hemisphere as the sources of increased methane over the past decade.

- October 8, 2015 – As a foundation for policy recommendations, Cornell University biogeochemist Robert Howarth summarized and analyzed the evidence documenting the magnitude of methane emissions related to oil and gas development in the United States since 2007. With estimated emission rates ranging from 3.8-12 percent, the high radiative forcing of methane over a twenty-year period prevents natural gas from serving as a bridge fuel. Instead of further investments in natural gas, Howarth proposes a rapid transition to electric powered vehicles for transportation, high-efficiency heat pumps for space and water heating, and imposition of a methane tax that is roughly 86 times higher

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1004 Vaidyanathan, G. (2015, December 22). Recalculation of leaking methane impacts may affect natural gas market. *E&E Publishing, LLC.* Retrieved from http://www.eenews.net/stories/1060029873

1005 Heede, R., & Oreskes, N. (2015). Potential emissions of CO_2 and methane from proved reserves of fossil fuels: An alternative analysis. *Global Environmental Change, 36.* Advance online publication. Retrieved from http://dx.doi.org/10.1016/j.gloenvcha.2015.10.005

1006 World Meterological Organization. (2015, November 9). The state of greenhouse gases in the atmosphere based on global observations through 2014. *Greenhouse Gas Bulletin, 11.* Retrieved from http://scifun.chem.wisc.edu/news/ghg-bulletin_2015.pdf?id=8495

1007 Miles, T. (2015, November 9). CO_2 levels hit record high for 30th year in a row. *Scientific American.* Retrieved from https://www.scientificamerican.com/article/co2-levels-hit-record-high-for-30th-year-in-a-row/

than currently proposed carbon taxes, which typical address only carbon dioxide.[1008] Howarth also noted that the EPA "has seriously underestimated the importance of methane emissions in general—and from shale gas in particular."[1009]

- August 4, 2015 – A developer of high flow sampling technology determined that a commonly used instrument to quantify methane leakage has unreliable sensors and malfunctions in ways that vastly underreport emissions by factors of three to five. More than 40 percent of the compiled national methane inventory may be affected by this measurement failure, according to the author of this study.[1010] The implications of this discovery for our understanding of system-wide methane leakage rates from drilling and fracking operations are not known, but they do call into question the results of at least one major study of methane emissions that relied on this device for collecting data. This is the second of two studies that finds that the primary tool approved by the EPA for measuring and reporting emissions of methane fails to function properly when used as directed by the manufacturer. (See also entry below dated March 24, 2015.)

- July 21, 2015 – An international team of researchers investigated the claim that the fracking boom, which has dramatically increased supplies of natural gas in the United States, is the main driver of the modest decline in carbon dioxide emissions since 2007. Conventional wisdom, as expressed by the Third National Climate Assessment of the U.S. Global Change Research Program, attributes the drop in emissions to a shift away from carbon dioxide-intensive coal and toward natural gas in power plants. But this team analyzed the sources of change in carbon dioxide emissions and, using a tool called input-output structural decomposition analysis, documented that the economic downturn, not fuel switching in the power sector, was the explanation for declining carbon dioxide emissions since 2007. The single biggest impact on U.S. emissions was changes in the volume of goods and services consumed. Between 2007 and 2013, driven by a huge drop in the volume of capital investment, emissions associated with capital formation decreased by almost 25 percent. During the same period, emissions related to household consumption decreased by 11 percent.[1011]

- July 7, 2015 – A scientific opinion piece by Environmental Defense Fund researchers involved in a group of 11 studies on methane emissions in Texas' Barnett Shale provided an overview and orientation to new research that either measured or estimated methane emissions from oil and gas operations. Research from both top-down estimates (based on measuring atmospheric methane or related compounds at regional or larger scales) and bottom-up measurements (made directly from components or at ground level near

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[1008] Howarth, R. W. (2015). Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy. *Energy and Emission Control Technologies, 3,* 45-54. doi: https://dx.doi.org/10.2147/EECT.S61539

[1009] Hauser, A. (2015, October 21). Two studies highlight risks of fracking-released methane. *Weather.com.* Retrieved from https://weather.com/science/environment/news/studies-highlight-risks-of-methane-from-fracking

[1010] Howard, T. (2015). University of Texas study underestimates national methane emissions at natural gas production sites due to instrument sensor failure. *Energy Science & Engineering.* Advance online publication. doi: 10.1002/ese3.81

[1011] Feng, K., Davis, S. J., Sun, L., & Hubacek, K. (2015). Drivers of the US CO_2 emissions 1997-2013. *Nature Communications, 6.* doi: 10.1038/ncomms8714 studied sites) demonstrated that methane emissions from oil and gas operations in the Barnett Shale region exceeded the emissions expected from the EPA's greenhouse gas inventory, which relies on industry self-reporting and excludes many compressor stations. The new research detailed the importance of addressing high-emitting landfills and natural gas facilities ("super-emitters") and malfunctioning equipment in efforts to control ongoing methane emissions.[1012]

- May 28, 2015 – A comprehensive working paper from the New Climate Economy initiative of the Global Commission on the Economy and Climate at Stockholm Environment Institute found that the experience in the United States of substituting natural gas for oil was unlikely to be replicated around the globe and probably will not provide climate benefits unless coupled with strict controls on methane leakage, limits on total energy use, and policies to prevent the displacement of non-fossil fuel energy by methane. Citing multiple studies of the net climate impact of "more abundant, cheaper natural gas supplies," the Commission concluded that "both globally and for the United States, the increase in emissions from the scale effect [from increased energy consumption boosted by cheap natural gas and loss of potentially more expensive lower carbon approaches] fully offsets the emission benefits from the substitution effect, net of methane leakage."[1013, 1014]

- March 24, 2015 – A University of Cincinnati researcher and independent engineers documented that the Bacharach Hi-Flow Sampler (BHFS)—one of the only tools approved by the EPA for measuring and reporting emissions of methane from natural gas transmission, storage, and processing facilities—failed to function properly when used as indicated by the manufacturer. The BHFS, unless recalibrated daily and running revised software (or taking measurements in a nearly pure methane environment, which is exceedingly rare in the field), misreported high levels of natural gas by as much as an order of magnitude lower than actual concentration. A reanalysis of 2011 results from the City of Fort Worth Air Quality Study revealed at least seven instances for which the BHFS indicated sample concentrations at or below 5 percent when more reliable canister methane readings indicated concentrations that ranged from 6.1 percent to 90.4 percent. Inaccurate measurements like these can contribute to the discrepancy between "top-down" and "bottom-up" measurements of methane, with ground-level measurements from the BHFS potentially producing reports of falsely low emissions.[1015] This study was followed by another that further documented malfunctions in the BHFS device and called

[1012] Harriss, R., Alvarez, R.A., Lyon, D., Zavala-Araiza, D., Nelson, D., & Hamburg, S.P. (2015). Using multi-scale measurements to improve methane emission estimates from oil and gas operations in the Barnett Shale Region, Texas. *Environmental Science & Technology, 49*, 7524-7526. doi: 10.1021/acs.est.5b02305

[1013] Lazarus, M., Tempest, K., Klevnäs, P., & Korsbakken, J. I. (2015) Natural gas: Guardrails for a potential climate bridge. Stockholm Environment Institute. Retrieved from http://www.sei-international.org/mediamanager/documents/Publications/Climate/NCE-SEI-2015-Natural-gas-guardrails-climate-bridge.pdf

[1014] Evans, S. (2015, June 2). The climate benefits of a gas bridge are unlikely to be significant. *Climate Spectator.* Retrieved from http://www.businessspectator.com.au/article/2015/6/2/policy-politics/climate-benefits-gas-bridge-are-unlikely-be-significant

[1015] Howard, T., Ferrara, T., & Townsend-Small, A. (2015). Sensor transition failure in the high flow sampler: Implications for methane emission inventories of natural gas infrastructure. *Journal of the Air & Waste Management Association, 65*(7), 856-862. doi: 10.1080/10962247.2015.1025925 into question the results of a landmark 2013 survey of methane emissions at 190 drilling and fracking sites across the United States. That 2013 survey, from the University of Texas, relied on the BHFS device for collecting data and found very low leakage rates.[1016] (See also entry above dated August 4, 2015.)

- March 20, 2015 – A team led by Bruno Franco from the University of Liege in Belgium discovered an abrupt uptick in ethane levels at a mountaintop station in the Swiss Alps that is far removed from local pollution sources.[1017] In a later comment about this discovery, Franco said, "Since 2009, we observed increases of 5% per year here—it was completely unexpected."[1018] The team attributed the trend reversal to the natural gas boom in North America. Ethane is released together with methane from drilling and fracking operations and serves as a proxy for it. (See also the entry above for April 7, 2016.)

- March 9, 2015 – With specialized equipment in a mobile van, University of Colorado, NOAA, Environmental Defense Fund, and independent researchers continuously measured methane and ethane from public roads at sites downwind of potential emission sources, such as natural gas production wellheads, processing plants, and compressor stations. The sampling method and modeling allowed capture of multiple "accidental" plumes, acquired during long drives across the study region between planned measurements near large facilities. Sampling was not random but documented a large number of facilities with low methane emission rates (equal to or less than 10 kg/hr), with a smaller yet important number of facilities showing much higher emissions. Although the largest measured emission in this study (1,360 kg/hr) corresponded to approximately $1.2 million in lost revenue per year, the authors noted that, in this industry, the "leak fraction" or "proportional loss" levels they documented would generally translate into only a small proportion of lost revenue, probably not sufficient to prompt strong energy-sector self-regulation.[1019]

- March 1, 2015 – Using a simulation model, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, writing for Germany's Federal Environmental Agency, found that shale gas was not a cheap option to reduce global greenhouse gas emissions. Multiple comparison simulations found that shale gas availability, especially in the short-term, tends to lead to higher emissions due to lower energy prices inducing higher use. The net result is higher costs to achieve compliance

[1016] Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D.W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. *Proceedings of the National Academy of Sciences,* 110,17768–17773. doi: 10.1073/pnas.1304880110

[1017] Franco, B., Bader, W., Toon, G. C., Bray, C., Perrin, A., Fischer, E. V., . . . Mahieu, E. (2015). Retrieval of ethane from ground-based FTIR solar spectra using improved spectroscopy: recent burden increase above Jungfraujoch. *Journal of Quantitative Spectroscopy and Radiative Transfer, 160*, 36-49. http://dx.doi.org/10.1016/j.jqsrt.2015.03.017

[1018] Environmental Research Web. (2016, May 23). Ethane emissions back on the rise. Retrieved from http://environmentalresearchweb.org/cws/article/news/65093

[1019] Yacovitch, T. I., Herndon, S. C., Pétron, G., Kofler, J., Lyon, D., Zahniser, M. S., & Kolb, C. E. (2015). Mobile laboratory observations of methane emissions in the Barnett Shale Region. *Environmental Science & Technology, 49,* 7889–7895. doi: 10.1021/es506352j with climate targets. In this model, shale gas was also found to compete in an unhelpful way with renewable energy sources, resulting in reduced use of renewable energy sources and reduced investment in energy efficiency measures.[1020]

- January 8, 2015 – Using a single integrated modeling program that incorporates detailed estimates of the world's reserves of oil, gas, and coal and is consistent with a wide variety of prior modeling approaches, University College London researchers demonstrated that, around the world, "a third of oil reserves, half of gas reserves and over 80 per cent of current coal reserves should remain unused from 2010 to 2050" in order to meet a target of less than or equal to a 2 degree Celsius rise in global temperature. In addition, "development of resources in the Arctic and any increase in unconventional oil production are incommensurate with efforts to limit average global warming" below the 2 degree threshold. Calling for a "stark transformation" of our understanding of fossil fuel availability, the authors noted that, in a climate-constrained world, fears of scarcity of fossil fuels must be superseded by a commitment to preventing overuse of existing resources and reserves.[1021]

- November 26, 2014 – Stanford University and independent researchers compared coal and natural gas for power generation and concluded that the question of "whether natural gas plants are better than coal plants cannot be answered in the general case." During the period of plant operation, "natural gas plants can produce greater near-term warming than coal plants, with the same power output." They found that over time, natural gas plants can produce some reduction in near-term warming, but only if life cycle methane leakage rates are low and power plant efficiency is high. Relative to coal, there is the potential that "deployment of natural gas power plants could both produce excess near-term warming (if methane leakage rates are high) and produce excess long-term warming (if the deployment of natural gas plants today delays the transition to near-zero emission technologies)."[1022]

- October 23, 2014 – Adding to the debate about natural gas and climate change, a multi-center, international research team used a sophisticated, integrated approach to the global energy-economy-climate systems question and found no climate benefit to natural gas over other fossil fuels. As summarized by the editor of *Nature*,

  > The development of hydraulic fracturing technologies has led to rapid growth in the use of natural gas as an energy source. Some evidence has suggested that this growing adoption of natural gas might lead a reduced greenhouse gas burden and consequent mitigation of climate change. This collaboration between five energy–

[1020] Kersting, J., Duscha, V., Schleich, J., & Keramidas, K. (2015). The impact of shale gas on the costs of climate policy. Environmental Research of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. Retrieved from https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/climate_change_03_2015_the_impact_of_shale_gas_1.pdf

[1021] McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature, 517,* 187-190. doi: 10.1038/nature14016

[1022] Zhang, X., Myhrvold, N. P., & Calideira, K. (2014). Key factors for assessing climate benefits of natural gas versus coal electricity generation. *Environmental Research Letters, 9.* doi: 10.1088/1748-9326/9/11/114022 climate modelling teams show that instead—under a scenario of abundant natural gas availability—increased consumption will have little or no impact on climate change." The authors concluded, "although market penetration of globally abundant gas may substantially change the future energy system, it is not necessarily an effective substitute for climate change mitigation policy.[1023]

- October 6, 2014 – Utilizing satellite data for the Bakken and Eagle Ford formations, scientists from Germany, the United Kingdom, and the University of Maryland confirmed that higher "top-down" estimates of fugitive methane leaks from oil and gas fields (which are obtained via tall tower flask samples, aircraft measurements, and road surveys) are more accurate than lower "bottom-up" estimates (which are obtained by summing emissions from different types of known sources at sites provided by participating utility companies). According to "bottom-up" estimates, the average U.S. leakage rate ranges from 1.2-2.0 percent. But satellite data show much higher leakage rates: 10.1 percent (± 7.3 percent) and 9.1 percent (± 6.2 percent), for the Bakken and Eagle Ford formations, respectively. These higher estimates indicate that current inventories likely underestimate fugitive emissions and call into question any immediate climate benefit from switching from coal to natural gas. Similar results were seen for the Marcellus shale region, but as a result of technical and geographical limitations, the authors declined to quantify their results, pending future studies with enhanced equipment.[1024]

- September 24, 2014 – According to a paper published by scientists from the University of California and Stanford University, "… without strong limits on [greenhouse gas] emissions or policies that explicitly encourage renewable electricity, abundant natural gas may actually slow the process of decarbonization, primarily by delaying deployment of renewable energy technologies." The study builds on previous research by examining natural gas in a range of supply curves, with a tested economic model, and across three different types and levels of climate policy. Researchers found that abundant natural gas, even with low rates of methane leakage, does little to reduce—and may increase—greenhouse gases. They conclude that delaying deployment of renewable energy technologies "may actually exacerbate the climate change problem in the long term."[1025]

- September 2, 2014 – Analyzing the level of greenhouse gas emissions attributable to electricity from natural-gas-fired power plants and coal-fired power plants, economist Chris Busch and physicist Eric Gimon conclude that, over short time frames and at high rates of leakage, natural gas offers little benefit compared to coal and could exacerbate global warming. Although Busch and Gimon acknowledge that natural gas offers some reductions in greenhouse gas emissions over longer time frames, they point out that such

[1023] McJeon, H., Edmonds, J., Bauer, N., Clarke, L., Fisher, B., Flannery, B., . . . Tavoni, M. (2013). Limited impact on decadal-scale climate change from increased use of natural gas. *Nature, 514,* 482–485. doi: 10.1038/nature13837
[1024] Schneising, O., Burrows, J. P., Dickerson, R. R., Buchwitz, M., Reuter, M., & Bovensmann, H. (2014). Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations. *Earth's Future, 2*(10), 548–558. doi: 10.1002/2014EF000265
[1025] Shearer, C., Bistline, J., Inman, M., & Davis, S. J. (2014). The effect of natural gas supply on US renewable energy and CO2 emissions. *Environmental Research Letters, 9.* doi: 10.1088/1748-9326/9/9/094008

reductions are not large enough for natural gas to play an expanded role in efforts to manage emissions. They conclude that under the best of circumstances, natural gas-fired electric power offers a modest benefit toward abating climate change, while if poorly developed (i.e., with extensive methane leaks, estimated by these authors to be on the order of 4 percent or higher), or if used to displace energy efficiency or renewable energy, natural gas could seriously contribute to increased greenhouse gas emissions.[1026]

- August 5, 2014 – Reporting in *Scientific American,* the science news organization Climate Central outlined the natural gas-related factors that threaten any ability to achieve climate goals through the proposed Clean Power Plan. "No one has any idea how much methane is leaking from our sprawling and growing natural gas system. This is a major problem, because without a precise understanding of the leak rate natural gas could actually make climate change worse." Referring to an interactive Climate Central tool that runs various methane leakage scenarios, the article notes that, even given modest leak rates and an aggressive transition, "we could still end up with little or no climate benefits by 2030 after an enormous financial and political investment in natural gas."[1027]

- July 25, 2014 –EPA's Office of Inspector General reports that the agency "has placed little focus and attention on reducing methane emissions from pipelines in the natural gas distribution sector." According to this report, the EPA acknowledged in 2012 that leaks from natural gas pipelines "accounted for more than 13 million metric tons of carbon dioxide equivalent emissions," are almost 100 percent methane, and represent more than 10 percent of total methane emissions from natural gas systems in the United States. Nevertheless, as report went on to note, the EPA does not have the partnerships in place to begin controlling methane leaks, such as with the Pipeline and Hazardous Materials Safety Administration, nor has it conducted a comprehensive analysis of emissions factors, relying instead on a 1996 study with a "high level of uncertainty."[1028]

- May 15, 2014 – A recent review of existing data on life cycle emissions of methane from natural gas systems concluded that, as a strategy for addressing climate change, natural gas is a "bridge to nowhere." The review found that, over a 20-year time frame, natural gas is as bad as or worse than coal and oil as a driver of climate change.[1029] Referencing this review and other recent studies, *Bloomberg Business News* reported that the EPA has underestimated the impact of methane leakage resulting from the production, transmission, and distribution of natural gas and is using outdated estimates of methane's

[1026] Busch, C. & Gimon, E. (2014). Natural gas versus coal: Is natural gas better for the climate. *The Electricity Journal, 27*(7), 97-111.
[1027] Climate Central. (2014, August 5). Methane leak rate proves key to climate change goals. *Scientific American.* Retrieved from http://www.scientificamerican.com/article/methane-leak-rate-proves-key-to-climate-change-goals/
[1028] U.S. Environmental Protection Agency Office of Inspector General. (2014, July 25). *Improvements needed in EPA efforts to address methane emissions from natural gas distribution pipelines*. Report No. 14-P-0324. Retrieved from http://www.epa.gov/oig/reports/2014/20140725-14-P-0324.pdf
[1029] Howarth, R. W. (2014). A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas [Abstract]. *Energy Science & Engineering*. doi: 10.1002/ese3.35

potency compared to more recent estimates from the Intergovernmental Panel on Climate Change (IPCC).[1030]

- April 25, 2014 – A reassessment of the heat-trapping potential of greenhouse gases revealed that current methods of accounting underestimate the climate-damaging impact of methane pollution from all sources, including drilling and fracking operations.[1031]

- April 14, 2014 – A study from researchers at Purdue University, NOAA, Cornell University, University of Colorado at Boulder, and Pennsylvania State University, published in *Proceedings of the National Academy of Sciences* found very high levels of methane emissions above many wells being drilled at fracking sites in Pennsylvania. Levels were 100-1,000 times above the estimates of federal regulators, who have always assumed very low methane emissions as wells are drilled.[1032, 1033]

- February 26, 2014 – The United Nations' top environmental official, Achim Steiner, argued that the shale gas rush is "a liability" in efforts to slow climate change and that a switch from coal to natural gas is delaying critical energy transition to renewables.[1034]

- February 13, 2014 – A major study in *Science* by Stanford University, Massachusetts Institute of Technology, and the U.S. Department of Energy found that methane leaks negate any climate benefits of natural gas as a fuel for vehicles, and that the EPA is significantly underestimating methane in the atmosphere.[1035] Lead author Adam R. Brandt told the *New York Times*, "Switching from diesel to natural gas, that's not a good policy from a climate perspective."[1036] This study also concluded that the national methane leakage rate is likely between 3.6 and 7.2 percent of production.

[1030] Childers, A. (2014, May 9). EPA underestimates fracking's impact on climate change. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2014-05-09/epa-underestimates-fracking-s-impact-on-climate-change.html
[1031] Edwards, M. R., & Trancik, J. E. (2014). Climate impacts of energy technologies depend on emissions timing. *Nature Climate Change, 4*, 348-352. doi: 10.1038/NCLIMATE2204
[1032] Caulton, D. R., Shepson, P. B., Santoro, R. L., Sparks, J. P., Howarth, R. W., Ingraffea, A. R., . . . Miller, B. R. (2014). Toward a better understanding and quantification of methane emissions from shale gas development. *Proceedings of the National Academy of Sciences of the United States of America*. doi: 10.1073/pnas.1316546111
[1033] Banjeree, N. (2014, April 14). EPA drastically underestimates methane released at drilling sites. *Los Angeles Times*. Retrieved from http://www.latimes.com/science/sciencenow/la-sci-sn-methane-emissions-natural-gas-fracking-20140414,0,2417418.story
[1034] Goldenberg, S. (2014, February 26). Achim Steiner: Shale gas rush "a liability" in efforts slow climate change. *Guardian*. Retrieved from http://www.theguardian.com/environment/2014/feb/26/achim-steiner-shale-gas-rush-climate-change-energy
[1035] Brandt, A. R., Heath, G. A., Kort, E. A., O'Sullivan, F., Petron, G., Jordaan, S. M., . . . Harriss, R. (2014). Methane leaks from North American natural gas systems. *Energy and Environment, 343*(6172), 733-735. doi: 10.1126/science.1247045
[1036] Davenport, C. (2014, February 13). Study finds methane leaks negate benefits of natural gas as a fuel for vehicles. *The New York Times*. Retrieved from http://www.nytimes.com/2014/02/14/us/study-finds-methane-leaks-negate-climate-benefits-of-natural-gas.html?smid=tw-share

- January 15, 2014 – As reported by the *Guardian*, a new study by BP concluded that shale gas "…will not cause a decline in greenhouse gases" and will do little to cut carbon emissions.[1037]

- December 30, 2013 – An analysis of fracking-related truck transportation in the Susquehanna River Basin in Pennsylvania found that greenhouse gas emissions from frack water and waste hauling operations were 70-157 metric tons of CO_2 equivalent per gas well.[1038]

- November 11, 2013 – In a letter to California Governor Jerry Brown, twenty of the nation's top climate scientists warned that pro-fracking policies will worsen climate disruption and harm California's efforts to be a leader in reducing greenhouse gas emissions. The letter called on Governor Brown to place a moratorium on fracking.[1039] On November 21, 2013, a group of Governor Brown's former policy and campaign advisors made a similar request in light of concerns about the effects of fracking on climate change and water pollution. [1040]

- October 18, 2013 – A team of researchers from multiple institutions including Harvard, the University of Michigan, and NOAA reported that methane emissions due to drilling activities in the south-central U.S. may be almost five times greater than reported by the world's most comprehensive methane inventory. "These results cast doubt on the US EPA's recent decision to downscale its estimate of national natural gas emissions by 25-30 percent," the authors wrote.[1041] As the *New York Times* reported, "The analysis also said that methane discharges in Texas and Oklahoma, where oil and gas production was concentrated at the time, were 2.7 times greater than conventional estimates. Emissions from oil and gas activity alone could be five times greater than the prevailing estimate."[1042]

- October 18, 2013 – A major study spearheaded by Stanford University's Energy Modeling Forum concluded that fracking and the shale gas revolution will have no long-

[1037] Harvey, F., & Macalister, T. (2014, January 16). BP study predicts greenhouse emissions will rise by almost a third in 20 years. *The Guardian*. Retrieved from http://www.theguardian.com/business/2014/jan/15/bp-predicts-greenhouse-emissions-rise-third?CMP=twt_gu

[1038] Gilmore, K. R., Hupp, R. L., & Glathar, J. (2014). Transport of Hydraulic Fracturing Water and Wastes in the Susquehanna River Basin, Pennsylvania. *Journal of Environmental Engineering, 140*. doi: 10.1061/(ASCE)EE.1943-7870.0000810

[1039] Rogers, P. (2013, November 12). Top climate scientists call for fracking ban in letter to Gov. Jerry Brown. *San Jose Mercury News*. Retrieved from http://www.mercurynews.com/ci_24509392/top-climate-scientists-call-fracking-ban-letter-gov

[1040] McNary, S. (2013, November 21). Former advisors to Gov. Brown request fracking ban. *Southern California Public Radio*. Retrieved from http://www.scpr.org/blogs/politics/2013/11/21/15248/former-advisors-to-gov-brown-request-fracking-ban/

[1041] Miller, S. M., Wofsy, S. C., Michalak, A. M., Kort, E. A., Andrews, A. E., Biraud, S. C., . . . Sweeney, C. (2013). Anthropogenic emissions of methane in the United States. *Proceedings of the National Academy of Sciences, 110*(50), 20018-20022. doi: 10.1073/pnas.1314392110

[1042] Wines, M. (2013, November 25). Emissions of methane in U.S. exceed estimates, study finds. *The New York Times*. Retrieved from http://www.nytimes.com/2013/11/26/us/emissions-of-methane-in-us-exceed-estimates-study-finds.html?_r=0 term climate benefit. The study brought together a working group of about 50 experts and advisors from companies, government agencies, and universities, and modeling teams from 14 organizations. The study also found that build-out of infrastructure for fracking and natural gas will discourage efforts to conserve energy and boost efficiency. The study did not examine methane leaks in order to weigh in on the short-term climate impacts of natural gas.[1043]

- October 11, 2013 – As reported in the *Guardian*, key climate scientists argued that the growth in fracking across the United States is hurting the United States' credibility on climate change.[1044]

- October 2, 2013 – Updated measurements from the IPCC determined that methane is even worse for the climate than previously thought. The IPCC determined that methane is 34 times more potent as a greenhouse gas in the atmosphere than CO2 over a 100-year timeframe, and 86 times more potent over a 20-year timeframe.[1045]

- September 27, 2013 – The IPCC formally embraced an upper limit on greenhouse gases for the first time, warning that the world will exceed those levels and face irreversible climatic changes in a matter of decades unless steps are taken soon to reduce emissions. The IPCC reported that humanity faces a "carbon budget"—a limit on the amount of greenhouse gases that can be produced by industrial activity before irreversible, damaging consequences—of burning about a trillion metric tons of carbon. The world is on track to hit that by around 2040 at the current rate of energy consumption.[1046]

- August 12, 2013 – A *New Scientist* review of the science on fracking and global warming concluded that fracking could accelerate climate change rather than slow it.[1047]

- May 28, 2013 – A research team led by Jeff Peischl, an associate scientist at NOAA and the Cooperative Institute for Research in Environmental Sciences, estimated that methane leakage from Los Angeles-area oil and gas operations was about 17 percent.[1048, 1049]

[1043] Huntington, H. (2013). Changing the game? Emissions and market implications of new natural gas supplies. *Energy Modeling Forum, 1*. Retrieved from https://emf.stanford.edu/publications/emf-26-changing-game-emissions-and-market-implications-new-natural-gas-supplies
[1044] Magill, B. (2013, October 11). Fracking hurts US climate change credibility, say scientists. *Guardian*. Retrieved from http://www.theguardian.com/environment/2013/oct/11/fracking-us-climate-credibility-shale-gas
[1045] IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P. M. Midgley (eds.)]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. doi: 10.1017/CBO9781107415324.
[1046] Gillis, J. (2013, September 27). U.N. climate panel endorses ceiling on global emissions. *The New York Times*. Retrieved from http://www.nytimes.com/2013/09/28/science/global-climate-change-report.html?pagewanted=all
[1047] Pearce, F. (2013, August 12). Fracking could accelerate global warming. *New Scientist*. Retrieved from http://www.newscientist.com/article/dn24029-fracking-could-accelerate-global-warming.html#.UpEWqsQ3uSo
[1048] Peischl, J., Ryerson, T. B., Brioude, J., Aikin, K. C., Andrews, A. E., Atlas, E., . . . Parrish, D. D. (2013). Quantifying sources of methane using light alkanes in the Los Angeles basin, California. *Journal of Geophysical Research: Atmospheres, 118*(10), 4974-4990. doi: 10.1002/jgrd.50413
[1049] Ogburn, S. (2014, May 15). Solving the Case of California's Extra Methane. *Scientific American Global RSS*. Retrieved from http://www.scientificamerican.com/article/solving-the-case-of-californias-extra-machine/

- May 2013 – A group of scientists and journalists studying climate change, led by energy systems analyst Eric Larson of Princeton University and the news organization Climate Central, reported that the often-purported 50 percent climate advantage of natural gas over coal is unlikely to be achieved over the next three to four decades given methane leaks and other factors.[1050] The 50 percent claim is based on the fact that natural gas produces half as much carbon dioxide when burned than coal, but it ignores the significant greenhouse gas impacts of methane leakage that occurs throughout the life cycle of natural gas production, transmission, and distribution.

- January 2, 2013 – A NOAA study found methane emissions from oil and gas fields in Utah to be as high as nine percent of production. These levels are considered extremely damaging to the climate.[1051]

- November 2012 – A review by the United Nations Environment Programme found that emissions from fracking, as well as other unconventional natural gas extraction methods, could increase global warming in the short-term and be comparable to coal over a 100-year timeframe.[1052]

- November 2012 – The International Energy Agency (IEA) found that a large natural gas boom—even with improvements in place to reduce leakage—would eventually lead to greenhouse gas concentrations of 650 parts per million and a global temperature rise of 3.5 degrees Celsius, far exceeding the 2 degree Celsius limit which is critical to avoid the most severe effects of climate change.[1053]

- May 29, 2012 – The *Guardian* summarized a special report on natural gas by the IEA: "A 'golden age of gas' spurred by a tripling of shale gas from fracking and other sources of unconventional gas by 2035 will stop renewable energy in its tracks if governments do not take action."[1054]

- February 2012 – A study published in *Environmental Research Letters* found that the carbon dioxide emitted from the burning of natural gas —even neglecting the impacts of methane leakage—contributes significantly to greenhouse gas emissions that are driving climate change.[1055]

[1050] Larson, E. D. (2013). Natural gas & climate change. *Climate Central*. Retrieved from http://assets.climatecentral.org/pdfs/NaturalGas-and-ClimateChange.pdf
[1051] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. *Nature, 493*(7430), 12. doi: 10.1038/493012a
[1052] Global Environmental Alert Service. (2012). Gas fracking: Can we safely squeeze the rocks? United Nations Environmental Programme. Retrieved from http://www.unep.org/pdf/UNEP-GEAS_NOV_2012.pdf
[1053] World Energy Outlook 2012, (November 2012). *Golden Rules for a Golden Age of Natural Gas—World Energy Outlook Special Report on Unconventional Gas*, International Energy Agency. Retrieved from http://www.iea.org/publications/freepublications/publication/name,27408,en.html
[1054] Harvey, F. (2012, May 29). 'Golden age of gas' threatens renewable energy, IEA warns. *Guardian*. Retrieved from http://www.theguardian.com/environment/2012/may/29/gas-boom-renewables-agency-warns
[1055] Myhrvold, N. P., & Caldeira, K. (2012). Greenhouse gases, climate change and the transition from coal to low-carbon electricity. *Environmental Research Letters, 7*(1). doi: 10.1088/1748-9326/7/1/014019

- February 7, 2012 – A NOAA study of Colorado gas fields measured methane emissions of about four percent, a significant percentage that could be very damaging to the climate.[1056]

- December 29, 2011 – As reported by the *New York Times,* levels of methane in the atmosphere have been steadily rising since 2007—coinciding with the onset of the fracking boom and posing a serious threat to the Earth's climate.[1057]

- October 2011 – A study from the National Center for Atmospheric Research concluded that substituting the use of natural gas for coal will increase, rather than decrease, the rate of global warming for many decades.[1058]

- July 6, 2011 – According to the U.S. Energy Information Administration and other research, significant amounts of methane are leaking from aging gas pipelines and infrastructure.[1059]

- April 2011 – A comprehensive analysis of the greenhouse gas footprint of natural gas from shale formations found that between 3.6 percent to 7.9 percent of the methane from natural gas production wells escapes into the atmosphere, rather than being combusted, thereby undermining any climate benefits of gas over coal as a source of energy.[1060, 1061]

[1056] Tollefson, J. (2012, February 7). Air sampling reveals high emissions from gas field. *Nature*. Retrieved from http://www.nature.com/news/air-sampling-reveals-high-emissions-from-gas-field-1.9982
[1057] Gillis, J. (2011, December 29). The puzzle of rising methane. *The New York Times*. Retrieved from http://green.blogs.nytimes.com/2011/12/29/the-puzzle-of-rising-methane/
[1058] Wigley, T. M. (2011). Coal to gas: The influence of methane leakage. *Climatic Change, 108*(3), 601-608. doi: 10.1007/s10584-011-0217-3
[1059] McKenna, P. (2011, July 6). Thousands of gas leaks under Boston and San Francisco. *New Scientist*. Retrieved from http://www.newscientist.com/article/mg21128203.800-thousands-of-gas-leaks-under-boston-and-san-francisco.html#.UpEbbMQ3uSp
[1060] Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change, 106*(4), 679-690. doi: 10.1007/s10584-011-0061-5
[1061] Howarth, R. W., Santoro, R., & Ingraffea, A. (2012). Venting and leaking of methane from shale gas development: Response to Cathles et al. *Climatic Change, 113*(2), 537-549. doi: 10.1007/s10584-012-0401-0

Threats from fracking infrastructure

The infrastructure for drilling and fracking operations is complex, widespread, and poses its own risks to public health and the climate. Beginning where silica sand is mined and processed and ending where gas is burned or liquefied for export, infrastructure includes pipelines, compressor stations, dehydrators, processing plants, flare stacks, gas-fired power plants, and storage depots through which oil or gas is moved, filtered, pressurized, warehoused, refined, and vented. It also includes injection wells and recycling facilities that dispose and treat the prodigious amounts of liquid waste that fracking generates. Air pollution is produced at every stage of the process. [Note: harm from flare stacks is included in Air Pollution and is not taken up in the sub-sections that follow.]

Sand mining and processing

In the Upper Midwest, the boom in silica sand mining threatens both air and water quality. It has transformed rural areas into industrialized zones and introduced complex public health risks that are not well understood. Silica dust is a well-known cause of both lung cancer and silicosis. Precise exposures to downwind communities remain uncertain. Until recently, the center of frack sand mining was western Wisconsin. However, sand mines in the Permian Basin of west Texas now provide one quarter of the total U.S. supply of frack sand. Texas sand is considered inferior to Wisconsin sand, which is crush-resistant and ideally shaped to prop open fractures to allow oil and gas to flow up the borehole. However, Texas sand is up to 50 percent cheaper as it does not incur the cost of rail transport to reach the booming Permian Basin oil wells.

- March 7, 2019 – The Minnesota Supreme Court announced that it would hear oral arguments on the legality of Winona County's ban on the mining of silica sand for use in fracking operations. A Winona County judge, as well as a Minnesota Court of Appeals, sided against Minnesota Sands, LLC and ruled in favor of the county legislature.[1062] The ban prohibits mining sand for industrial purposes but allows mining for construction purposes. The county has argued that it is within its rights to protect the health of its citizens. Its original ordinance, passed on November 22, 2016, was the first countywide ban in the nation on the extraction of silica sand for use in drilling and fracking operations. It became the subject of a lawsuit by Minnesota Sands on the grounds that the ordinance violates the federal Commerce Clause of the U.S. Constitution.[1063, 1064]

[1062] Winona Daily News Staff, & Associated Press. (2019, March 7). Challenge to Winona County's frac sand ban to be heard by state Supreme Court next month. *Winona Daily News.* Retrieved from https://www.winonadailynews.com/news/local/challenge-to-winona-county-s-frac-sand-ban-to-be/article_bd2474ea-e6a7-5f9f-8108-c957de307aad.html

[1063] Rogers, C. (2018, October 31). Supreme Court takes frac sand case. *Winona Post.* Retrieved from http://www.winonapost.com/Article/ArticleID/61409/Supreme-Court-takes-frac-sand-case

[1064] Browning, D. (2018, July 30). Appeals court upholds Winona County ban on frac sand mining. *Star-Tribune.* Retrieved from http://www.startribune.com/minnesota-appeals-court-upholds-winona-county-ban-on-frac-sand-mining/489529801/

- December 27, 2018 – Wisconsin's frack sand mining industry had a volatile year in 2018. Mines that had closed in 2016 due to market downturns reopened on news of increased drilling activity. However, later in the year, the price for sand dropped dramatically as sand mines opened in Texas to serve fracking operations in the nearby Permian Basin. Wisconsin sand companies then closed mines again, with one company laying off 37 employees.[1065]

- July 17, 2018 – As part of an industry-funded study, a research team retrospectively assessed the silica dust exposure among workers in the industrial sand industry, which includes sand used for fracking. Workers who went on to develop silicosis had significantly more exposure to silica dust than those who did not. Results showed decreases in exposure throughout the industry over time, driven in part by the establishment of workplace regulations in the 1970s that helped accelerate silica dust control programs. Adjustment for use of respiratory protection showed only modest reductions in estimated exposures.[1066]

- May 11, 2018 – The dunes sagebrush lizard in western Texas is imperiled because of booming demand for frack sand. "It's really a new threat and it just sort of came in all at once and really has the potential to wipe out a lot of lizard habitat, if not controlled," said a petition to the U.S. Fish and Wildlife Service that urged the agency to add the dunes sagebrush lizard to the endangered species list.[1067] Sand mines in the Permian Basin of west Texas now provide one quarter of the total U.S. supply of frack sand. Texas sand is up to 50 percent cheaper than Wisconsin sand as it does not incur the cost of rail transport to reach the booming Permian Basin oil wells, although it is considered inferior to Wisconsin sand, which is crush-resistant and ideally shaped to prop open fractures to allow oil and gas to flow up the borehole.[1068]

- August 7, 2017 – A University of Iowa team evaluated the impact of frack sand mining and processing on the concentration of particulate matter in the air of surrounding communities. Sampling in 17 homes located within 800 meters from sand mining activities, the team found that, overall, particulate matter and silica concentrations were lower than regulations and guidelines established to prevent silicosis but spiked when winds blew over the facility. They concluded that particulate matter levels from fracking sand mining and processing were "unlikely to cause chronic adverse health conditions." Sampling for this study, which took place in 2014, did not consider the impact of living

[1065] Kremer, R. (2018, December 27). 2018 was a roller-coaster year for Wisconsin's frac sand industry. *Wisconsin Public Radio*. Retrieved from https://www.wpr.org/2018-was-roller-coaster-year-wisconsins-frac-sand-industry
[1066] Rando, R. J., Vacek, P. M., Glenn R. E., Kwon, C. W., & Parker, J. E. (2018). Retrospective assessment of respirable quartz exposure for a silicosis study of the industrial sand industry. *Annals of Work Exposures and Health, 62*(8), 1021-1032. doi: 10.1093/annweh/wxy064
[1067] Krebs, N. (2018, May 11). In west Texas, fracking companies face a tough challenger—the dunes sagebrush lizard. *Texas Standard.* Retrieved from https://www.texasstandard.org/stories/in-west-texas-fracking-companies-face-a-tough-challenger-the-dunes-sagebrush-lizard/
[1068] Wethe, D. (2018, July 10). Why this sand from Texas is suddenly worth $80 a ton. *Bloomberg*. Retrieved from https://www.yahoo.com/news/why-sand-texas-suddenly-worth-134140942.html

near multiple adjacent frack sand operations. The industry in western Wisconsin has expanded considerably since that time.[1069]

- November 25, 2017 – In Minnesota, a district judge upheld Winona County's ban on the mining, processing, and loading of frack sand. In her decision, the judge referenced public health and safety threats, fragility of the water quality in the area, and evidence for harm from sand mines in other areas. Winona is the first county in the United States to pass a countywide ban on frack sand extraction. Efforts to replicate the ban are now ongoing in neighboring counties.[1070, 1071]

- July 5, 2016 – The Wisconsin Department of Natural Resources (DNR) released a *Strategic Analysis for Public Review* of the state's industrial sand mining industry that downplayed environmental health effects from air pollution. There are 128 industrial sand mine facilities in Wisconsin, including the mines themselves and processing and rail loading facilities. The DNR identified airborne particulate matter as a primary concern for industrial sand mining facilities and said that air quality monitors in western Wisconsin have not detected a problem.[1072] Researchers, organizations, and the native community involved in monitoring impacts of the frack sand industry challenged these findings, pointing to lack of data collection on the most dangerous kind of particulate matter called PM2.5, which represents fine particles that are less than 2.5 microns in width. These critics noted that the U.S. Environmental Protection Agency (EPA) had previously expressed concerns about the DNR's approach to regulating PM2.5.[1073] Regarding groundwater, the report described elevated levels of several metals in wastewater holding ponds at the sand mines, presenting a risk to groundwater quality.

- March 25, 2016 – The Occupational Safety and Health Administration (OSHA) amended its existing standards for occupational exposure to respirable crystalline silica, "having determined that employees exposed to respirable crystalline silica at the previous permissible exposure limits face a significant risk of material impairment to their health."[1074] Key provisions include the reduction of the permissible exposure limit to 50 micrograms per cubic meter of air, averaged over an 8-hour shift. The standards cover many industries with some having two years to comply; the hydraulic fracturing industry

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[1069] Peters, T. M., O'Shaughnessy, P. T., Grant, R., Altmaier, R., Swanton, E., Falk, J., . . . Thorne, P. S. (2017). Community airborne particulate matter from mining for sand used as hydraulic fracturing proppant. *Science of the Total Environment, 609*, 1475-1482. doi: 10.1016/j.scitotenv.2017.08.006

[1070] McKinney, M. (2017, November 25). Judge's ruling on Winona County ban of frac sand mining stirs interest. *Minneapolis Star-Tribune.* Retrieved from http://www.startribune.com/judge-s-ruling-on-winona-county-frac-sand-ban-stirs-interest/459974433/

[1071] Rogers, C. (2017, November 22). District court upholds county frac sand ban. Winona Post. Retrieved from http://www.winonapost.com/Article/ArticleID/57056/District-court-upholds-county-frac-sand-ban

[1072] Wisconsin Department of Natural Resources. (2016). *Industrial sand mining in Wisconsin: Strategic analysis for public review.* Retrieved from http://dnr.wi.gov/topic/EIA/documents/ISMSA/ISMSA.pdf

[1073] Hubbuch, C. (2016, July 6). DNR releases frac sand analysis to immediate criticism from environmental group. *LaCrosse Tribune.* Retrieved from http://lacrossetribune.com/news/local/dnr-releases-frac-sand-analysis-to-immediate-criticism-from-environmental/article_bce8ea56-fff1-52ae-97cb-c67cfb120a1f.html

[1074] Occupational Safety and Health Administration. (2016, March 25). Occupational exposure to respirable crystalline silica. *Federal Register.* Retrieved from https://www.federalregister.gov/articles/2016/03/25/2016-04800/occupational-exposure-to-respirable-crystalline-silica is allowed an additional five-year extension for engineering controls, until June 23, 2021.[1075] The *New York Times* reported that safety experts have advocated for a tightening of silica exposure standards for the past forty years but that "progress was stymied for decades by resistance from affected companies and regulatory inaction." The article reported that many oil and gas companies in particular were not meeting the current silica exposure standard. The new rules, when fully in effect, are estimated to save 600 lives and prevent 900 new cases of silicosis per year.[1076]

- March 1, 2016 – University of Wisconsin anthropologist Thomas Pearson conducted in-depth interviews examining the impact of frack sand mining on sense of community, quality of life, and place in nearby residents. His findings indicated that the sudden influx of this heavy extractive industry has eroded residents' sense of place and belonging and that these experiences are rarely taken into account by policymakers. Residents report "significant anxiety and stress from truck traffic, noise, light pollution, and uncertainty about environmental health impacts," and distress caused by drastic changes to long-familiar landscapes over which they have no control. Pearson concluded that policymakers should pay closer attention to the uneven distribution of benefits and costs and "recognize that the costs go beyond quantifiable economic or environmental impacts."[1077]

- January 29, 2016 – The Institute for Wisconsin's Health, Inc. released its Health Impact Assessment (HIA) on frack sand mining operations in western Wisconsin, prepared with the participation of 15 local and tribal health departments. According to the report, the HIA was a collaborative effort. The scope of the report was limited to the potential for community-level health effects of industrial sand mining in western Wisconsin. Regarding air quality, the report concluded that health effects from the impact of industrial sand mining on community-level air quality related to particulate matter are unlikely, and that it was also unlikely that community members would be exposed to respirable crystalline silica from industrial sand mining as currently regulated. Regarding water quality, the report concluded that contamination is possible; however, health effects were unlikely. Quality of life effects were likely, but variable.[1078] Though it was a "Level 1 Partner" for the report, the Ho-Chunk Nation responded to the HIA with criticism, writing, "we are disappointed with the conclusions drawn in the report, particularly in the section on air quality impacts, and we believe a more robust assessment of the air quality impacts is required before such conclusions can be drawn." They wrote that the HIA failed to provide an accurate and complete analysis of the health threats posed by this

[1075] Occupational Safety and Health Administration. (2016, March 25). OSHA's Final Rule to protect workers from exposure to respirable crystalline silica. United States Department of Labor, Washington, DC. Retrieved from https://www.osha.gov/silica/

[1076] Meier, B. (2016, March 24). New rules aim to reduce silica exposure at work sites. *The New York Times.* Retrieved from http://www.nytimes.com/2016/03/24/business/new-rules-aim-to-reduce-silica-exposure-at-work-sites.html?_r=1

[1077] Pearson, T. (2016). Frac sand mining and the disruption of place, landscape, and community in Wisconsin. *Human Organization, 75*(1), 47-58. doi: http://dx.doi.org/10.17730/0018-7259-75.1.47

[1078] Boerner, A., Young, N., & Young, D. (2016). *Health impact assessment of industrial sand mining in western Wisconsin.* Institute for Wisconsin's Health, Inc., Madison, WI. Retrieved from http://www.instituteforwihealth.org/uploads/1/2/7/8/12783470/iwhi_industrial_sand_w_covers.pdf industry because of the limited scope, and "minimal discussion about fine particulate matter (or PM2.5), which likely presents the biggest threat from industrial sand mining operations.[1079] As reported by Rochester, Minnesota's *Post-Bulletin*, Crispin Pierce, director of University of Wisconsin-Eau Claire's environmental public health program, "believes the study ignored important air quality data collected by university students at sand mining sites at Bloomer, New Auburn and Augusta during the past 18 months," which he described as "the only work that looked at these fine particles."[1080]

- November 6, 2015 – According to findings from a pilot study led by Crispin Pierce (see entry above), levels of fine particulate matter (PM2.5) are not being adequately measured near frack sand operations. Air monitors set up by Pierce and his team consistently showed higher readings than detections measured by Wisconsin's DNR.[1081] In some instances, PM2.5 levels exceeded the EPA guideline of 12 micrograms per cubic meter of air. In an accompanying news story, Pierce noted that the state's air quality data largely comes from industry itself. "'The DNR so far has continued to shy away from doing their own monitoring,' he said. 'The monitoring I've seen so far is inadequate. People aren't looking at PM2.5, and they really should be—from unbiased sources.'"[1082]

- October 15, 2015 – *InsideClimate News* reported on the response of nearby communities to the "bust" cycle of the frack sand industry in Wisconsin and Minnesota. Reactions reported included ongoing concerns that the industry does not provide permanent economic prosperity. Municipalities and community organizations are using the lull to advance protections in advance of a possible upturn: "Towns in the region are also trying to strengthening their local zoning ordinances, such as adding rules to limit industrial noise and light pollution. In other cases, communities are trying to oust pro-sand advocates from office."[1083]

- June 30, 2015 – Because the amount of sand used per fracking well has increased, demand for silica sand by the oil and gas industry is still growing even though new drilling activity has taken a downturn. A global investment bank reported that fracking operations now require an average of 4.2 million pounds of sand per well. A few years

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[1079] Ho-Chunk Nation. (2016, March 9). *Concerns about air quality impacts and human health remain after release of industrial sand mining Health Impact Assessment* [Press release]. Retrieved from http://midwestadvocates.org/assets/resources/Frac%20Sand%20Mining/20160309HoChunkHIARelease.pdf
[1080] Lindquist, E. (2016, February 4). Report downplays frac sand link to health troubles. *Post-Bulletin*. Retrieved from http://www.postbulletin.com/news/local/report-downplays-frac-sand-link-to-health-troubles/article_b3023c6c-fe74-5028-a7a4-6238fa035eaa.html
[1081] Walters, K., Jacobson, J., Kroening, Z., & Pierce, C. (2015). PM2.5 Airborne particulates near frac sand operations. *Journal of Environmental Health 78,* 8-12.
[1082] Schuessler, R. (2015, November 6). Wisconsin locals fear dust from mines for fracking sand even as boom wanes. *Aljazeera America.* Retrieved from http://america.aljazeera.com/articles/2015/11/6/wisconsin-locals-fear-frac-sand-mining.html
[1083] Hirji, Z. (2015, October 15). In fracking downturn, sand mining opponents not slowing down. *InsideClimate News*. Retrieved from http://insideclimatenews.org/news/14102015/fracking-struggles-sand-mining-opponents-momentum-Minnesota-Wisconsin

ago, silica sand comprised 9.5 percent of fracking fluid but now is closer to 20 percent. Further "rising intensity" of sand use is expected.[1084]

- June 15, 2015 – An investigative report by *EnergyWire* documented self-reported health impacts among residents of southwestern Wisconsin who live near silica sand mining operations that service the fracking industry. Exposure to silica dust is a proven cause of silicosis and lung cancer. (See further entries on silica sand exposure among workers in the section, "Occupational Health and Safety Hazards.") Residents near frack sand mine operations reported exposure to dust pollution and respiratory problems. Air monitoring data from the Wisconsin DNR showed that none of the state's 63 active sand mines were in violation for particulate matter, but, as the author noted, the state measured particles only 10 micrometers in diameter or larger.[1085] Below this diameter, crystalline silica particles are small enough to bypass the body's natural clearance mechanisms and are likely to lodge deep in the lungs where they can initiate scarring, autoimmune reactions, and tumor formation.[1086]

Pipelines and compressor stations

There are more than 300,000 miles of natural gas transmission pipelines in the United States. They are serviced, every 40 to 100 miles, by compressor stations that maintain the pressure of the gas flowing through them. (Pump stations do the same for oil pipelines.) Compressor stations and pipelines are significant sources of air pollutants, including benzene and formaldehyde, constituting potential health risks to those living nearby while offering no economic benefits. Instead, they are associated with loss of tax revenue and economic development for the communities where they are sited and which they traverse. Pipelines and compressor stations vent methane into the atmosphere as part of routine maintenance operations and represent a climate risk. They are also accident prone. The Medical Society of the State of New York, the Massachusetts Medical Society, and the American Medical Association have each called for comprehensive health impact assessments regarding the health and safety risks associated with natural gas pipelines, which include fires, explosions, and leaks.

- March 4, 2019 – *E&E News* investigated accidents involving "gathering lines," which are small diameter pipelines that carry oil or gas from wellheads to processing facilities. Nationally, there are 450,000 miles of gathering lines. However, only high-pressure gathering lines in urban areas are regulated, and these represent only 18,000 miles of

[1084] Chapa, S. (2015, June 30). Demand for sand: frac sand use per well goes up amid low oil prices. *San Antonio Business Journal*. Retrieved from http://www.bizjournals.com/sanantonio/blog/eagle-ford-shale-insight/2015/06/demand-for-sand-frac-sand-use-per-well-goes-up.html
[1085] King, P. (2015, June 15). Frac sand towns question whether rules protect them against silica pollution. *EnergyWire*. Retrieved from http://www.eenews.net/stories/1060020192
[1086] U.S. Department of Labor, Occupational Safety and Health Administration. (n.d.) Dust and its control. Retrieved from https://www.osha.gov/dsg/topics/silicacrystalline/dust/chapter_1.html

pipeline. The Pipeline and Hazardous Materials Safety Administration (PHMSA) has no rules for the rest. Nor do most states. Hence, it is not known how many fatalities have occurred due to explosions of gathering lines because no records are kept in rural areas. Rural gathering lines "don't have to be marked, built to standards or regularly inspected. Unlike for transmission lines, operators don't have to have emergency response plans for when they leak or explode."[1087]

- February 20, 2019 – During a polar vortex on January 30, 2019, a compressor station at an underground gas storage depot in Macomb County, Michigan was destroyed by an explosion after an equipment malfunction triggered emergency venting of gas. The extremely low temperatures prevented the methane plume from dispersing, and high winds pushed it along the ground until the gas encountered heat from another compressor station and exploded. The resulting gas shortage necessitated a statewide emergency call to residents and businesses to voluntarily turn down thermostats and reduce natural gas use. General Motors in Flint suspended operations for three days.[1088]

- January 1, 2019 – As part of the planned Atlantic Bridge pipeline project, which will ferry fracked natural gas from New Jersey through New England and into Canada, Calgary-based Enbridge Inc. (formerly Spectra Energy) applied to site a 7,700-horsepower compressor station in Weymouth, Massachusetts, south of Boston. The Enbridge compressor station in Weymouth would maintain pipeline pressure needed to push the gas north to Maine and Canada. In 2016, the company offered the town $47 million to drop its opposition to the plan, which would place the compressor station in a port area immediately adjacent to densely populated neighborhood, the highly utilized Fore River lift bridge, a power plant, a sewage pumping station, and a gas metering station. Instead, residents and local political leaders rejected this offer and demanded a Health Impact Assessment (HIA). Ordered by Governor Charlie Baker in July 2017 and released in January 2019, this study received considerable criticism from the public health community due to its deviation from standard HIA methodologies. The HIA showed that the Fore River Basin already suffered from levels of benzene, formaldehyde, and other air toxics that exceeded state guidelines for these carcinogens while concluding that adding another source of these same pollutants would have negligible impact on residents' health.[1089, 1090] Shortly thereafter, the Massachusetts Department of Environmental Protection issued an air quality permit for the compressor station. This decision—and the HIA's conclusion on which it was based—was immediately contested

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[1087] Lee, M., & Soraghan, M. (2019, March 4). Deadly pipelines, no rules. *E&E News.* Retrieved from https://www.eenews.net/stories/1060123021

[1088] LeBlanc, B. (2019, February 20). Consumers CEO: Two natural gas plants still down after Jan. 30 fire. *Detroit News.* Retrieved from https://www.detroitnews.com/story/news/local/michigan/2019/02/20/consumers-energy-two-plants-still-down-after-fire-emergency-appeal/2928041002/

[1089] The Massachusetts Department of Environmental Protection, the Massachusetts Department of Public Health, & the Metropolitan Area Planning Council. (2019, January 1). Health Impact Assessment of a proposed natural gas compressor station in Weymouth, MA. Retrieved from https://www.mass.gov/files/documents/2019/02/14/Health-Impact-Assessment-Weymouth-Final-Report.pdf

[1090] Trufant, Jessica. (2019, January 11). Regulators issue air permit for Weymouth compressor station. *The Patriot Ledger.* Retrieved from https://www.patriotledger.com/news/20190111/regulators-issue-air-permit-for-weymouth-compressor-station by independent public health researchers. In February 2019, Greater Boston Physicians for Social Responsibility (GBPSR) issued their own report on the health risks of the Weymouth compressor that outlined their concerns about the safety and emergency response hazards associated with the proposed compressor and rejected the "no health impact" conclusion of the HIA. While the HIA acknowledged that the residents of the Fore River Basin already experienced excess rates of lung disease, heart disease, and cancer, the GBPSR report argued that disproportionately health-burdened people "require greater, not lesser, environmental safeguards." [1091, 1092] At this writing, the air quality permit, which was greenlighted by the HIA's findings, is under appeal before the Massachusetts Department of Environmental Protection.

- December 18, 2018 – "Given that many pipelines transport volatile, flammable, or toxic oil and liquids, and given the potential consequences of a successful physical or cyber-attack, pipeline systems are attractive targets for terrorists, hackers, foreign nations, criminal groups, and others with malicious intent," according to a report from the U.S. Government Accountability Office that urged the U.S. Department of Homeland Security's Transportation Security Administration (TSA) to address weaknesses in its management of pipeline security. TSA oversees the physical security and cybersecurity of the more than 2.7 million miles of gas, oil, and hazardous liquid pipelines in the United States.[1093]

- December 14, 2018 – The California Public Utilities Commission (CPUC) took action against Pacific Gas and Electric Company (PG&E) for what CPUC said are systemic violations of rules to prevent damage to natural gas pipelines during excavation activities. PG&E had been noncompliant with the law pertaining to the locating and marking of natural gas distribution pipelines, as well as related requirements to inform construction personnel and private persons on the location of PG&E's underground pipes and other natural gas infrastructure in a timely and accurate manner.[1094, 1095, 1096]

- December 10, 2018 – The Atlantic Coast Pipeline is a 600-mile project led by Dominion Energy that would extend from West Virginia to eastern North Carolina. Construction was halted when the U.S. Court of Appeals stayed a permit from the U.S. Fish and

[1091] Greater Boston Physicians for Social Responsibility. (2019, February 7). Health risks of a proposed compressor station in Weymouth, Massachusetts. Retrieved from https://d279m997dpfwgl.cloudfront.net/wp/2019/02/GB-PSR-Report-on-Health-Risks-of-Proposed-Weymouth-Compressor-Station_Feb-7-2019.pdf

[1092] Trufant, Jessica. (2019, February 7). Doctors' group challenges report on Weymouth compressor station. Retrieved from https://www.patriotledger.com/news/20190207/doctors-group-challenges-report-on-weymouth-compressor-station

[1093] U.S. Government Accountability Office (GAO). (2018, December 18). *Critical infrastructure protection: Actions needed to address significant weaknesses in TSA's Pipeline Security Program management.* GAO-19-48. Retrieved from https://www.gao.gov/products/GAO-19-48

[1094] California Public Utilities Commission (CPUC). (2018, December 14). Order instituting investigation and order to show cause. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M246/K120/246120841.PDF

[1095] California Public Utilities Commission (CPUC). (2018, December 14). CPUC opens case against PG&E for potential natural gas safety violations. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M250/K897/250897740.PDF

[1096] Gonzales, R. (2018, December 14). PG&E falsified gas pipeline safety records, regulators say. *NPR.* Retrieved from https://www.npr.org/2018/12/14/677003961/pg-e-falsified-gas-pipeline-safety-records-regulators-say

Wildlife Service that had authorized building the pipeline in critical habitat for four endangered species: the Indiana bat, the rusty-patched bumblebee, the clubshell mussel, and a shrimp-like crustacean called the Madison Cave isopod.[1097]

- November 15, 2018 – An *E&E News* analysis of interstate pipeline enforcement found that interstate pipelines have caught fire or exploded 137 times since 2010. In 90 percent of those disasters, no fines were levied by PHMSA (the federal agency that directly regulates 350,000 miles of pipelines, more than 400 natural gas storage facilities, and 26 liquefied natural gas facilities). PHMSA's reluctance to levy fines is a direct result of federal pipeline laws, which were largely drafted after 1994 when deregulation was a federal priority.[1098]

- November 1, 2018 – A Russian team used a cartographic model to assess the potential impact on health and environment of compressor station emissions during scheduled outages and repairs. They described a method of gas flow redistribution that would obviate the need for large-scale venting of methane into the atmosphere.[1099]

- October 11, 2018 – Overpressurizing a natural gas distribution system while replacing aging pipelines triggered 80 simultaneous natural gas explosions in Massachusetts' Merrimack Valley on September 13, 2018. One teenager was killed, 23 were injured, 130 buildings were destroyed or damaged, and thousands evacuated from communities in Lawrence, Andover, and North Andover. The explosions cost Columbia Gas more than $1 billion.[1100]

- September 10, 2018 – A landslide triggered by four days of intense rain caused a pipeline explosion that burned down a house in Beaver County, Pennsylvania and prompted evacuations. This pipeline, built by Energy Transfer Partners (which merged with Sunoco in 2017), was part of the Mariner 2 East Pipeline that is intended to carry the liquid hydrocarbon, ethane, to coastal ports where it will be exported for plastics manufacturing abroad. In western Pennsylvania, ethane co-occurs with methane in the shale bedrock and is released during fracking operations.[1101, 1102, 1103]

[1097] Murawski, J. (2018, December 10). Atlantic Coast Pipeline construction halts as court reviews 4 endangered species. *Raleigh News and Observer.* Retrieved from https://www.newsobserver.com/news/business/article222856155.html

[1098] Soraghan, M. (2018, November 15). No penalties for 90% of pipeline blasts. *E&E News.* Retrieved from https://www.eenews.net/stories/1060106253

[1099] Strizhenok, A. V., & Korelskiy, D. S. (2019). Estimation and reduction of methane emissions at the scheduled and repair outages of gas-compressor units. *Journal of Ecological Engineering, 20*(1), 46-51. Advance online publication. Retrieved from https://doi.org/10.12911/22998993/93943

[1100] National Transportation Safety Board. (2018, October 11). Preliminary report pipeline: Over-pressure of a Columbia Gas of Massachusetts low-pressure natural gas distribution system. Retrieved from https://www.ntsb.gov/investigations/AccidentReports/Pages/PLD18MR003-preliminary-report.aspx

[1101] Mamula, K., & Litvak, A. (2018, September 10). Officials believe landslide may have triggered massive gas pipeline explosion in Beaver County. *Pittsburgh Post-Gazette.* Retrieved from http://www.post-gazette.com/local/west/2018/09/10/gas-explosion-in-center-township-Beaver-County/stories/201809100067

[1102] Litvak, A. (2018, October 27). Pipeline ruptures bring new scrutiny to Pennsylvania geology. *Pittsburgh Post-Gazette.* Retrieved from

- August 10, 2018 – A joint investigation by the *Charleston Gazette-Mail* and *ProPublica* found that pipeline operators continue to break environmental rules, and state and federal agencies continue to clear roadblocks to allow these projects to move forward despite serious unanswered questions.[1104]

- July 25, 2018 – The Attorneys General of six states (Massachusetts, Rhode Island, New Jersey, Maryland, Illinois, Washington) and the District of Columbia submitted comments to the Federal Energy Regulatory Commission (FERC) on how the Commission should revise its approach to certifying new natural gas transportation facilities. They recommended that the Commission assess need on a comprehensive, regional basis; consider environmental harm, including climate impacts that consider the social costs of carbon; and more heavily weigh the harm of eminent domain. They urged better incorporation of state and local land use policies. And they recommended that the Commission no longer issue partial notices to proceed with construction when rehearing requests are pending.[1105]

- May 24, 2018 – The Office of the Inspector General at the Department of Energy audited FERC's Natural Gas Certification Process. It found that FERC lacked a consistent process for tracking public comments on proposed pipeline projects, suggesting that all comments might not be reviewed. "In the absence of a consistent methodology, we did not verify to what degree comments received by FERC were considered, aggregated, and reflected in the environmental documents or final orders for the certificate applications during our review," the report concluded. "The lack of a consistent methodology could increase the risk that FERC may not address significant and impactful public comments in the environmental document or final order."[1106, 1107]

- May 16, 2018 – A team of researchers in Alberta, Canada investigated how noise from natural gas compressor stations and oil wells affected the behavior and communication of

https://apnews.com/2e0005ec7db342a290199a4d8464b5a0?fbclid=IwAR0URr9dtHnpoe7YkokfOOVDUcyVdmeXejjUgVSIAeoY5gZH6Olm394NMkU

[1103] Litvak, A. (2018, September 14). Who gets to say where it's safe to build a pipeline? *Pittsburgh Post-Gazette.* Retrieved from https://www.post-gazette.com/business/powersource/2018/09/14/Who-gets-to-say-where-it-s-safe-to-build-a-pipeline-natural-gas-beaver-county-explosion-DEP-Pennsylvania/stories/201809140058

[1104] Mishkin, K., & Ward Jr., K. (2018, August 10). What happens when a pipeline runs afoul of government rules? Authorities change the rules. *ProPublica*. Retrieved from https://www.propublica.org/article/west-virginia-halted-mountain-valley-pipeline

[1105] Comments of the Attorneys General of Massachusetts, Illinois, Maryland, New Jersey, Rhode Island, Washington, and the District of Columbia. FERC Docket PL18-1-000. (2018, July 25). Certification of New Interstate Natural Gas Facilities. Retrieved from https://www.mass.gov/files/documents/2018/07/26/Multistate%20Comments-FERC%201999%20PL%20Policy%20Review.pdf

[1106] McKenna, P. (2018, May 31). Public comments on pipeline plans may be slipping through cracks at FERC, audit says. *Inside Climate News.* Retrieved from https://insideclimatenews.org/news/31052018/public-comments-oil-gas-pipelines-ferc-review-energy-department-inspector-general-audit

[1107] The Office of the Inspector General at the Department of Energy. (2018, May 24). *The Federal Energy Regulatory Commission's Natural Gas Certification Process.* Audit Report: DOE-OIG-18-33. Retrieved from https://www.energy.gov/ig/downloads/audit-report-doe-oig-18-33

Savannah sparrows (*Passerculus sandwichensis*). The results showed that alarm responses and feeding visits were impaired by noise-producing infrastructure. Savannah sparrows were less vigilant when provisioning nestlings and distracted from their reproductive tasks when in the vicinity of compressor stations. "Our observation that Savannah sparrows are less responsive to anti-predator signals in the vicinity of natural gas compressor stations is of conservation concern and adds to a growing body of evidence that noisy anthropogenic structures have the potential to negatively affect birds by interfering with acoustic communication."[1108] Previous research in the same region found that the Savannah sparrow altered its song structure and song features when exposed to noise from oil and gas infrastructure, including compressor stations, and that these noise-altered songs were less effective at provoking responses from other birds.[1109, 1110] Similarly, researcher working in the San Juan Basin of New Mexico found that chronic noise from drilling and fracking operations, including compressor stations, affected levels of stress hormones in songbirds and masked critical acoustic cues in ways that decreased the birds' ability to survive and reproduce.[1111, 1112]

- April 26, 2018 – Studies that investigate the health impacts of drilling and fracking activities typically incorporate the distance between participants' home addresses and well pads and do not consider potential exposures to emissions from other ancillary pieces of infrastructure. A study led by Johns Hopkins University researchers working in Pennsylvania attempted to develop exposure metrics for air emissions from compressor stations, flare stacks, and impoundments. The research team identified 457 compressor stations in Pennsylvania and 1419 compressor station engines. Data on compressor stations engines were not available electronically, and only 361 stations could be confirmed as operational. The team found that compressor engines, impoundments, and flaring events are all potential sources of emissions related to drilling and fracking that have not previously been accounted for in epidemiological studies "in part because data are not readily available. The value of including these additional sources of information on [fracking], particularly in health studies, remains unknown."[1113]

1108 Antze, B., & Koper, N. (2018). Noisy anthropogenic infrastructure interferes with alarm responses in Savannah sparrows (*Passerculus sandwichensis*). *Royal Society Open Science, 5,* 172168. doi: 10.1098/rsos.172168

1109 Warrington, M. H., Curry, C. M., Antze, B., & Koper, N. (2018). Noise from four types of extractive energy infrastructure affects song features of Savannah Sparrows. *The Condor: Ornithological Applications, 120*(1), 1-15. Advance online publication. Retrieved from https://bioone.org/journals/the-condor/volume-120/issue-1/CONDOR-17-69.1/Noise-from-four-types-of-extractive-energy-infrastructure-affects-song/10.1650/CONDOR-17-69.1.short

1110 Curry, C. M., Des Brisay, P. G., Rosa, P., & Koper, N. (2018). Noise source and individual physiology mediate effectiveness of bird songs adjusted to anthropogenic noise. *Scientific Reports*, *8*(1), 3942. doi: 10.1038/s41598-018-22253-5

1111 Kleist, N. J., Guralnick, R. P., Cruz, A., Lowry, C. A., & Francis, C. D. (2018). Chronic anthropogenic noise disrupts glucocorticoid signaling and has multiple effects on fitness in an avian community. *PNAS, 115*(4), E648-E657. doi: 10.1073/pnas.1709200115

1112 University of Colorado at Boulder. (2018, January 8). Noise from oil and gas operations stresses birds, hinders reproduction. *AAAS EurekAlert.* Retrieved from https://www.eurekalert.org/pub_releases/2018-01/uoca-nfo010318.php

1113 Koehler, K., Ellis, J. H., Casey, J. A., Manthos, D., Bandeen-Roche, K., Platt, R., & Schwartz, B. S. (2018). Exposure assessment using secondary data sources in unconventional natural gas development and health studies. *Environmental Science & Technology, 52*, 6061-6069. doi: 10.1021/acs.est.8b00507

- April 26, 2018 – Pipelines are inspected and cleaned through a process called pigging, in which devices are placed inside, and travel through, the pipe. Pigs can be used to force water or air through a pipeline, check for obstructions, detect leaks, scrape debris from the pipe wall, prevent corrosion, or apply coatings. Pigging is necessarily accompanied by venting of hydrocarbon gases into the air, including methane. A federal settlement acknowledged that the use of the maintenance pigging technique is a major source of harmful emissions in pipeline systems carrying fracked gas extracted from shale that also contains other hydrocarbons, such as natural gas liquids. "The settlement between the U.S. Department of Justice, Environmental Protection Agency and Pennsylvania Department of Environmental Protection and two MarkWest subsidiaries … alleges the company failed to apply for or comply with air pollution permits. As a result, the company unlawfully vented hundreds of tons of natural gas and volatile organic compounds."[1114]

- October 12, 2017 – Researchers at University of Albany's Institute for Health and the Environment prepared a 300-page technical report on the health effects of the emissions from 18 natural gas compressor stations in New York State. The team found that, collectively, these sites released 40 million pounds of 70 different contaminants over a seven-year period, making natural gas compressor stations the seventh largest point source of air pollution in the state. By volume, the largest emissions were nitrogen oxides, carbon monoxide, volatile organic compounds (VOCs), formaldehyde, and particulate matter. Exposure to these chemicals is linked to cancer, as well as cardiovascular, neurological, and developmental disorders. The authors noted, "The potential health impacts of the large volumes of pollutants generated by natural gas compressor stations have not been addressed, let alone answered, by those arguing for their construction and expansion."[1115]

- October 11, 2017 – A study of airborne methane emissions from assorted components of natural gas infrastructure in California, including compressor stations and storage facilities, confirmed earlier studies in finding widely variable leakages. The results suggested that a significant fraction of the methane emitted from storage facilities may, in fact, be escaping from their associated compressor stations.[1116]

- July 17, 2017 – A comprehensive investigation of the pipeline approval process by the Center for Public Integrity, *StateImpact Pennsylvania,* and National Public Radio found that FERC, which is charged with ensuring the public's interest, routinely assesses need based on company filings and functions as an agency captured by industry interests, concluding, "at every turn, the agency's process favors the pipeline companies." The

[1114] Patterson, B. (2018, April 26). MarkWest agrees to pay millions in federal settlement over 'pig' emissions. *West Virginia Public Broadcasting.* Retrieved from https://www.wvpublic.org/post/markwest-agrees-pay-millions-federal-settlement-over-pig-emissions#stream/0

[1115] Russo, P. N., & Carpenter, D. O. (2017, October 12). *Health effects associated with stack chemical emissions from NYS natural gas compressor stations, 2008-2014.* Retrieved from https://www.albany.edu/about/assets/Complete_report.pdf

[1116] Mehrotra, S., Faloona, I., Suard, M., Conley, S., & Fischer, M. L. (2017). Airborne methane emission measurements for selected oil and gas facilities across California. *Environmental Science & Technology 51*(21), 12981–12987. doi: 10.1021/acs.est.7b03254 result, according to this analysis of more than 500 pipeline cases, is that the financial interests of the gas industry, and not market demand or public necessity, is driving the ongoing pipeline build-out. In some cases, utility companies have complex financial ties to the pipeline companies that service them.[1117] Continuing this investigation, *InsideClimate News* then reviewed several large, new pipeline proposals in the Marcellus and Utica Shale regions, focusing on joint ventures and interlocking financial relationships between customers (state-regulated utilities) and suppliers (pipeline companies). Affiliate agreements that allow parent companies of utilities to seek federal certificates for interstate pipelines—which typically allow a 14 percent return on equity—contribute to the ongoing frenzy of pipeline construction even when natural gas demand is flat. Existing pipelines, the investigation noted, run at only slightly more than half capacity.[1118]

- July 12, 2017 – A Canadian study found that oil and gas infrastructure, including compressor stations, contributes to habit fragmentation and increases parasitism by cowbirds on Savannah sparrow nests in the Northern Great Plains. Populations of North American grassland songbirds, including the Savannah sparrow, are declining precipitously, mostly due to habitat loss and degradation. These results suggest that "brood parasitism associated with oil and natural gas infrastructure may result in additional pressures that reduce the productivity of this declining grassland songbird."[1119]

- May 16, 2017 – An analysis of records from state agencies revealed that low-pressure flow lines at oil and gas well sites are responsible for more than 7,000 spills, leaks, and accidents since 2009. Flow lines carry oil, gas, or wastewater from scattered pieces of equipment within a production site. Other than in New Mexico, operators are not required to report gas leaks from flow lines. A fatal explosion in April 2017 in a Firestone, Colorado home built on top of an oil field was triggered when an abandoned flow line seeped gas into a basement where it ignited. Two people were killed and one person was badly injured. Soon after, Colorado Governor John Hickenlooper ordered a statewide review of all oil and gas lines located near occupied buildings. Preliminary data showed that 16,000 wells across Colorado have flow lines that lie within 1,000 feet of homes. Corrosion is a leading cause of flow line failures.[1120, 1121]

[1117] Lombardi, K., & Hopkins, J. S. (2017, July 17). Natural gas building boom fuels climate worries, enrages landowners. *NPR.org.* Retrieved from http://www.npr.org/2017/07/17/536708576/natural-gas-building-boom-fuels-climate-worries-enrages-landowners

[1118] McKenna, P. (2007, August 3). Pipeline payday: How builders win big, whether more gas is needed or not. *InsideClimate News.* Retrieved fromhttps://insideclimatenews.org/news/02082017/natural-gas-pipeline-boom-corporate-profit-bubble-limited-demand-climate-emissions

[1119] Bernath-Plaisted, J., Nenninger, H., & Koper, N. (2017). Conventional oil and natural gas infrastructure increases brown-headed cowbird (*Molothrus ater*) relative abundance and parasitism in mixed-grass prairie. *Royal Society Open Science, 4*(7), 170036. doi: 10.1098/rsos.170036

[1120] Soraghan, M. (2017, May 16). Flow lines cited in more than 7K spills. *E&E News.* Retrieved from https://www.eenews.net/stories/1060054568

[1121] Lee, M. (2017, June 12). Fatal explosion threatens more upheaval over drilling in Colo. *E&E News.* Retrieved from https://www.eenews.net/stories/1060055846

- February 15, 2017 – A team of researchers from University of Texas investigated emissions from natural gas compressor stations throughout Pennsylvania and New York. They found that compressors emitted highly variable plumes of methane that spread downwind and were measurable a full mile away at levels that could expose nearby residents, especially during temperature inversions. The researchers concluded, "Our data indicate that compressor stations are likely sources of methane emissions and presumably co-emitted air contaminants, and can sporadically/episodically emit methane at relatively high levels…if such facilities are to be permitted to release specified amounts of contaminants, those amounts should be actively measured and verified. Without measurement there can be no assurance that permit conditions are being met."[1122]

- November 30, 2016 – A CityLab investigation used data from the Pipeline and Hazardous Materials Safety Administration to map all significant U.S. pipeline accidents between 1986 and 2016 and concluded, "wherever pipelines are extended, deadly accidents will follow." Pipeline accidents over the past 30 years have resulted in 548 deaths, more than 2,500 injuries, and over $8.5 billion in damages. Accidents are particularly common in Texas and Louisiana.[1123]

- July 5, 2016 – The National Energy Board, Canada's pipeline watchdog, gave two of Canada's largest pipeline companies six months to fix severe deficiencies in pipelines, ultimately issuing an emergency safety order in February 2016. Newly released federal documents showed that Texas-based Kinder Morgan and Alberta-based Enbridge were both looking into the use of defective parts purchased from Thailand-based Canadoil Asia that recently went bankrupt. U.S. regulators warned of these deficiencies eight years prior. At least one Canadian pipeline with defective materials exploded during that period.[1124]

- June 10, 2016 – EPA Region 2 submitted comments to FERC on Docket Nos. PFI6-3, Eastern System Upgrade Project, which includes new natural gas compressor stations in Hancock and Highland, New York. The EPA submission suggested an analysis of whether this project was needed; clarification of what is meant by a loop system; evaluation of alternatives; a comprehensive analysis of cumulative, indirect, and secondary impacts; information on greenhouse gas emissions and climate change impacts; a Health Impact Assessment; the inclusion of all pollution prevention practices; and a consideration of environmental justice concerns.[1125] The company agreed to provide funding toward a health study but wished to retain the ability to determine the

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[1122] Payne, B. F., Ackley, R., Wickler, A. P., Hildenbrand, Z., Carlton, Jr., D. D., & Schug, K. A. (2017). Characterization of methane plumes downwind of natural gas compressor stations in Pennsylvania and New York. *Science of the Total Environment, 580*, 1214-21. doi: 10.1016/j.scitotenv.2016.12.082

[1123] Joseph, G. (2016, November 30). 30 years of oil and gas pipeline accidents, mapped. *CityLab.* Retrieved from https://www.citylab.com/environment/2016/11/30-years-of-pipeline-accidents-mapped/509066/

[1124] De Souza, M. (2016, July 5). How Canada's pipeline watchdog secretly discusses 'ticking time bombs' with industry. *National Observer.* Retrieved from http://www.nationalobserver.com/2016/07/05/news/how-canada%E2%80%99s-pipeline-watchdog-secretly-discusses-ticking-time-bombs-industry

[1125] EPA Region 2. (2016, June 10). Docket Nos. PFI6-3, Eastern System Upgrade Project (comments). Retrieved from https://elibrary.ferc.gov/idmws/file_list.asp?document_id=14468753 study parameters.[1126] Skeptical of the health study's funding and parameters, residents and potentially impacted towns objected to the company's dismissal of the towns' laws prohibiting the construction and operation of heavy industrial use facilities. The Deputy Supervisor of one of the affected towns "said he was encouraged by the federal Environmental Protection Agency's comments on the project's preliminary federal application. He said the EPA concerns were 'the same as ours.'"[1127]

- April 27, 2016 – In its report on two natural gas pipeline expansion projects in Appalachia, the Institute for Energy Economics and Financial Analysis demonstrated that the Atlantic Coast and Mountain Valley pipelines are "emblematic of the risks that such expansion creates for ratepayers, investors and landowners." The report concluded that pipelines out of the Marcellus and Utica region are being overbuilt, putting ratepayers at risk of paying for excess capacity, landowners at risk of losing their property to unnecessary projects, and investors at risk of loss. The report stated that FERC facilitates this building of excess pipeline capacity and its approach for assessing need is insufficient.[1128]

- April 22, 2016 – The federal Agency for Toxic Substances and Disease Registry (ATSDR) released a report on air quality near a natural gas compressor station in Brooklyn Township, Susquehanna County, Pennsylvania, finding levels of fine particulate matter (PM2.5) at levels that can damage human health in those with long-term exposure. Evaluating data from an 18-day EPA field air monitoring event, the report found that the average ambient 24-hour PM2.5 concentration observed at one residence (19 µg/m3) was higher than the nearest regional National Ambient Air Quality Standards (NAAQS) monitoring station (12.3 µg/m3) in Scranton, PA, over the same period. ATSDR concluded that there was evidence that long-term exposure to PM2.5 at the levels found can cause an increase in mortality, respiratory problems, hospitalizations, preterm births, and low birth weight. The agency said that in the short term, exposure could be harmful to sensitive populations, such as those with respiratory problems or heart disease. The agency recommended that sensitive individuals monitor air quality and limit activity accordingly, and that the PA DEP work to reduce other sources of PM and its precursors.[1129]

- April 3, 2016 – The Southwest Pennsylvania Environmental Health Project issued a *Technical Report* in response to the January 29, 2016 federal ATSDR report on the Brigich compressor station in Chartiers Township, Washington County, Pennsylvania.

[1126] Mayer, F. (2016, April 27). Millennium to pay for health study. *River Reporter.* Retrieved from http://www.riverreporter.com/news/4302/2016/04/27/millennium-pay-health-study

[1127] Julse, D. (2016, June 22). Highland concerned about study underfunding. *River Reporter.* Retrieved from http://www.riverreporter.com/news/4302/2016/06/22/highland-concerned-about-study-underfunding

[1128] Kunkel, C., & Sanzillo, T. (2016). *Risks associated with natural gas pipeline expansion in Appalachia.* The Institute for Energy Economics and Financial Analysis. Retrieved from http://ieefa.org/wp-content/uploads/2016/04/Risks-Associated-With-Natural-Gas-Pipeline-Expansion-in-Appalachia-_April-2016.pdf

[1129] Agency for Toxic Substances and Disease Registry. (2016, April 22). *Health Consultation: Brooklyn Township PM2.5, Brooklyn Township, Susquehanna County, Pennsylvania.* U.S. Department of Health and Human Services, Atlanta, GA. Retrieved from http://www.atsdr.cdc.gov/HAC/pha/BrooklynTownship/BrooklynTwnsp_pm2-5_HC_Final_04-22-2016_508.pdf

ATSDR detected chemicals that had been reported at gas sites previously, and this confirmation of their presence provided "an important acknowledgement that neighbors of such facilities are being exposed (often at very close range) to chemicals that bring with them the possibility of short- and long-term health effects." The report stated that, in conjunction with the monitoring work of the EPA, ATSDR "provided a solid set of data." However, due to the limitations of the methodologies available to them, the authors were "concerned that there was, in the end, an underestimate of risk to community members."[1130]

- April 1, 2016 – Kinder Morgan, the largest energy infrastructure company in North America, suspended construction of a $1 billion pipeline project that would have carried gasoline and diesel fuel across the southeastern United States. Construction was suspended after landowners protested the seizure of their property, a Georgia Superior Court judge upheld a decision denying a certificate that would have allowed the company to use eminent domain, and the state legislature passed legislation to block the property seizure.[1131]

- March 26, 2016 – According to a Boston University-led study, fugitive emissions from urban natural gas pipeline systems were the largest anthropogenic source of the greenhouse gas methane in the United States and contribute to the risk of explosions in urban environments, with 15 percent of leaks qualifying as potentially explosive.[1132] "All leaks must be addressed, as even small leaks cannot be disregarded as 'safely leaking,'" concluded the report authors. In an interview with *InsideClimate News*, the lead author said that in addition to weighing the safety risks from gas leaks, regulators and utility companies must also consider the climate impact of leaks when determining priorities for repairing and replacing pipes.[1133]

- March 7, 2016 – A lawsuit filed against FERC in U.S. District Court in Washington, D.C challenged the agency's relationship with industry, reported *Penn Live*: "The suit accuses the commission of regulatory capture, a situation in which corporations control regulators." FERC receives all of its funding from the energy companies that it regulates and had never rejected a pipeline plan, which, according to the complainant, demonstrates "clear bias and corruption."[1134]

[1130] Southwest Pennsylvania Environmental Health Project. (2016, April 3). ATSDR releases investigation of Pennsylvania compressor station. *Response to Governmental Action and Publication*, *1*. Retrieved from http://www.environmentalhealthproject.org/resources/research-factsheets

[1131] McKenna, P. (2016, April 1). Property rights outcry stops billion-dollar pipeline project in Georgia. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/01042016/palmetto-pipeline-kinder-morgan-georgia-eminent-domain-oil-gas-republicans

[1132] Hendrick, M. F., Ackley, R., Sanaie-Movahed, B., Tang, X., & Phillips, N.G. (2016). Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments. *Environmental Pollution, 213,* 710–716. doi:10.1016/j.envpol.2016.01.094

[1133] McKenna, P. (2016, March 31). Methane hazard lurks in Boston's aging, leaking gas pipes, study says. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/30032016/boston-natural-gas-pipelines-leaking-methane-climate-change-explosion

[1134] Pynes, M. (2016, March 7). Federal agency funded by energy industry has never rejected a pipeline plan. *PennLive.com.* Retrieved from http://www.pennlive.com/news/2016/03/pipeline_fights_raise_big_ques.html#incart_article_small

- February 26, 2016 – Congressman Chris Gibson (NY-19), in response to citizen concerns, sent a letter to FERC regarding the proposed 41,000-horsepower compressor station in southern Rensselaer County, New York, part of the Northeast Energy Direct (NED) pipeline project. He discussed the inadequacy of federal exposure standards with regard to exposures at compressor sites and lack of medical expertise in these decisions. He requested public health expertise on all Environmental Assessment and Environmental Impact Statement teams, an independent panel to review the federal exposure standards around compressor stations, and "a transparent and effective review process."[1135] His call was supported by other elected officials, as well as public health researcher David O. Carpenter, MD, who has studied compressor station pollutants.[1136]

- January 29, 2016 – ATSDR, in collaboration with the EPA Region 3 Air Protection Division, conducted an exposure investigation to evaluate exposures of residents living near the Brigich natural gas compressor station in Chartiers Township, Washington County, Pennsylvania. ATSDR concluded that, although exposure to the levels of chemicals detected in the ambient air was not expected to harm the health of the general population, "some sensitive subpopulations (e.g., asthmatics, elderly) may experience harmful effects from exposures to hydrogen sulfide and PM 2.5 [and] [s]ome individuals may also be sensitive to aldehyde exposures, including glutaraldehyde." According to ATSDR, one of the study's limitations was that the sampling "may not have adequately captured uncommon but significant incidents when peak emissions (e.g. unscheduled facility incidents, blowdowns or flaring events) coincide with unfavorable meteorological conditions (e.g. air inversion)." ATSDR recommendations included reducing exposures to the chemicals of concern to protect sensitive populations, continued collection of emissions data for long-term and peak exposures, and air modeling to better understand ambient air quality.[1137]

- December 8, 2015 – The Niagara County Legislature, following the recommendations of the Medical Society of the State of New York, called for a Health Impact Assessment (HIA) on natural gas infrastructure, including compressor stations, and co-hosted a conference in Albany on the Medical Society's health findings. A compressor station with twin compressors, part of the "2016 Northern Access Plan" to transfer gas from Pennsylvania to Canada, is proposed for the county.[1138]

[1135] Gibson, C. (2016, February 26). Compressor station needs review. *Sullivan County Democrat.* Retrieved from http://scdemocratonline.com/webpages/letterdetail.aspx?id=9f047d33-ba32-4027-883b-ff2e457ebb7a

[1136] Nearing, B. (2016, March 31). Gibson: Federal natural gas air pollution safety standards may be obsolete. *Albany Times Union*. Retrieved from http://www.timesunion.com/business/article/Gibson-Federal-natural-gas-air-pollution-safety-7221271.php

[1137] Agency for Toxic Substances and Disease Registry. (2016, January 29). *Health Consultation: Exposure Investigation, Natural Gas Ambient Air Quality Monitoring Initiative Brigich Compressor Station, Chartiers Township, Washington County, Pennsylvania.* Retrieved from http://www.atsdr.cdc.gov/HAC/pha/Brigich_Compressor_Station/Brigich_Compressor_Station_EI_HC_01-29-2016_508.pdf

[1138] Staff. (2015, December 8). County lawmakers call for study on compressor health risks. *Lockport Union-Sun & Journal.* Retrieved from http://www.lockportjournal.com/news/local_news/county-lawmakers-call-for-study-on-compressor-health-risks/article_932989cd-058a-594f-9ef2-e52827db85a6.html

- November 9, 2015 – Following the 2010 heavy oil spill in Michigan's Kalamazoo River, Congress ordered an audit that spotlighted the industry's poor record of spotting leaks. *Politico* reported on the 2015 regulatory structure ultimately unveiled in response, determining the proposal "fails to patch that hole in the nation's pipeline safety net." "While the agency's proposed rule expands the number of pipelines that must have a leak-detection system in place, it sets no basic standards for how well that technology should work. Instead, safety advocates say, it lets pipeline operators decide for themselves whether they are adequately prepared."[1139]

- October 16, 2015 – The EPA urged FERC to consider "whether the Northeast Energy Direct pipeline could be combined with other projects, rather than constructing a new system that would have a host of environmental impacts," reported Oneonta, New York's *Daily Star*. The EPA also advised "that the gas demand addressed by NED's application could be met by renewable forms of energy such as solar and wind power…"[1140] (Note: Kinder Morgan withdrew its NED pipeline application in April 2016.)

- September 17, 2015 – At a shale gas conference, industry representatives espoused the construction of new pipelines as necessary to re-invigorate the gas industry in the Marcellus. Speakers noted that FERC approval can be expected to now take longer, by about six months, blaming environmental groups for the delays.[1141]

- September 9, 2015 – New pipelines are failing at a rate on par with gas transmission lines installed before the 1940s, according to an analysis of federal data by the Pipeline Safety Trust, reported by *S&P Global Market Intelligence*. "The gas transmission lines installed in the 2010s had an annual average incident rate of 6.64 per 10,000 miles over the time frame considered, even exceeding that of the pre-1940s pipes. Those installed prior to 1940 or at unknown dates had an incident rate of 6.08 per 10,000 miles." The director of the National Transportation Safety Board's Office of Railroad, Pipeline and Hazardous Materials Investigations "agreed that the rapid construction of pipelines in the U.S. is likely a contributing factor."[1142]

- August 18, 2015 – Houston Advanced Research Center (HARC) scientists addressed "the commonly acknowledged sources of uncertainty which are the lack of sustained monitoring of ambient concentrations of pollutants associated with gas mining, poor quantification of their emissions, and inability to correlate health symptoms with specific emission events." They concluded that "more contemporary monitoring and data analysis techniques should take the place of older methods to better protect the health of nearby

[1139] Schor, E. (2015, November 9). The hole in Obama's pipeline safety plan. *Politico.* Retrieved from http://www.politico.com/story/2015/11/obama-pipeline-safety-plan-oil-215617

[1140] Mahoney, J. (2015, October 16). EPA: Can local pipeline plans merge? *Daily Star.* Retrieved from http://www.thedailystar.com/news/local_news/epa-can-local-pipeline-plans-merge/article_f2836510-a96b-5c2d-9892-755b94b1f640.html?mode=jqm

[1141] Packel, D. (2015, September 17). Energy honchos lament FERC pipeline approval delays. *Law 360.* Retrieved from http://www.law360.com/publicpolicy/articles/697120/energy-honchos-lament-ferc-pipeline-approval-delays

[1142] Smith, S. (2015, September 9). As US rushes to build gas lines, failure rate of new pipes has spiked. *SNL Financial.* Retrieved from https://www.snl.com/InteractiveX/Article.aspx?cdid=A-33791090-11060 residents and maintain the integrity of the surrounding environment." "Real-time mobile monitoring, microscale modeling and source attribution, and real-time broadcasting of air quality and human health data over the World Wide Web" have been demonstrated, they wrote, by past, current, and planned future monitoring studies in the Barnett and Eagle Ford shale regions.[1143] Founded as a technology incubator in 1982 by Houston oilman George P. Mitchell, HARC later re-aligned to focus on sustainable development.

- August 14, 2015 – HARC scientists found that port operations involving petrochemicals may significantly increase emissions of air toxics, including peaks of carcinogenic benzene of up to 37 ppb. The scientists matched the benzene spikes with pipeline systems. The spikes were at levels much higher than those reported in the EPA's 2011 National Emissions Inventory. The authors recommended the use of updated methods for ambient monitoring.[1144] Lead scientist Jay Olaguer said in a related interview that "government regulators should wake up to the reality of the situation, that their methods of tracking air pollution need to be updated so that the samples are taken in real time and can catch it when toxic vapors of this magnitude are released."[1145]

- July 15, 2015 – Rensselaer County lawmakers passed a resolution asking the state of New York to freeze the approval process for the Northeast Energy Direct pipeline—which would carry fracked gas from Pennsylvania to Boston—until it conducts a comprehensive health impact assessment for natural gas pipelines.[1146]

- July 8, 2015 – Researchers from West Virginia University completed leak and loss audits for methane emissions at three natural gas compressor stations and two natural gas storage facilities, with a "leak" defined as an unintended release of natural gas due to malfunction of a component, and a "loss" defined as an intended release of natural gas. In terms of frequency, most emissions were leaks, but on a mass basis, losses were the dominant source of methane emissions (88 percent). The top loss emitters were engine exhausts (accounting for nearly half), packing vents, and slop tanks. Emissions from compressor blowdowns were not included.[1147] A related study by a University of Houston

[1143] Olaguer, E. P., Erickson, M., Wijesinghe, A., Neish, B., Williams, J., & Colvin, J. (2015). Updated methods for assessing the impacts of nearby gas drilling and production on neighborhood air quality and human health. *Journal of the Air & Waste Management Association, 66*, (2), 173-183. doi: 10.1080/10962247.2015.1083914
[1144] Olaguer, E. P., Erickson, M. H., Wijesinghe, A., & Neish, B. S. (2015). Source attribution and quantification of benzene event emissions in a Houston ship channel community based on real-time mobile monitoring of ambient air. *Journal of the Air & Waste Management Association, 66*, (2), 164-172. doi: 10.1080/10962247.2015.1081652
[1145] Wray, D. (2016, February 23). Scientists discover pipelines belching benzene in East Houston. *Houston Press.* Retrieved from http://www.houstonpress.com/news/scientists-discover-pipelines-belching-benzene-in-east-houston-8181569
[1146] Nearing, B. (2015, July 15). County: Put study before any permit. *Albany Times-Union.* Retrieved from http://www.timesunion.com/news/article/County-Put-study-before-any-permit-6387404.php
[1147] Johnson, D. R., Covington, A. N., & Clark, N. N. (2015). Methane emissions from leak and loss audits of natural gas compressor stations and storage facilities. *Environmental Science & Technology, 49,* 8132-8138. doi: 10.1021/es506163m

team found that emission rates from compressor stations in Texas' Barnett Shale were far higher than from well pads.[1148, 1149]

- July 7, 2015 – Seeking a method to bridge the gap between bottom-up and top-down methods of measuring methane emissions, Purdue University, University of Houston, the National Oceanic and Atmospheric Administration (NOAA), Environmental Defense Fund, and independent researchers surveyed eight high-emitting point sources in the Barnett Shale using an aircraft-based "mass balance" approach. Results from four gas processing plants and one compressor station highlighted the importance of addressing methane "super-emitters" and confirmed that self-reports from the Greenhouse Gas Reporting Program underestimated actual emission rates by a factor of 3.8 or higher, due to "underestimated facility emissions, temporal variability of emissions, and the exclusion of nonreporting facility emissions."[1150]

- July 7, 2015 – Using relatively easy-to-acquire and inexpensive stable isotopic and alkane ratio tracers, researchers are now able to distinguish methane arising from natural gas production and transport from agricultural and urban methane sources, and, in addition, to distinguish between methane released from shale gas as opposed to conventional wells. Initial research from the University of Cincinnati, University of California at Irvine, and the Environmental Defense Fund found that methane in the Barnett Shale hydraulic fracturing region near Fort Worth, Texas, represents a complex mixture of these sources. This new approach, used for ground-level measurements, can complement and extend top-down approaches, allowing for more accurate inventories of thermogenic and biogenic sources of methane emissions.[1151]

- July 1, 2015 – In New York State, Schoharie County supervisors and medical professionals demanded comprehensive health impact assessments as a precondition for permitting natural gas pipelines and compressor stations.[1152]

- June 12, 2015 – The Agency for Toxic Substances and Disease Registry investigated the health effects of ruptured gas pipelines in an analysis of data in a database on acute petroleum-related releases to which seven states contribute (Louisiana, New York, North Carolina, Oregon, Tennessee, Utah, and Wisconsin). From 2010 to 2012, there were

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[1148] Lan, X., Talbot, R., Laine, P., & Torres, A. (2015). Characterizing fugitive methane emissions in the Barnett Shale area using a mobile laboratory. *Environmental Science & Technology, 49*, 8139-8146. doi: 10.1021/es5063055

[1149] Song, L., & Hirji, Z. (2015, July 8). Methane emissions in Texas fracking region 50 percent higher than EPA estimates. *InsideClimate News.* Retrieved from http://insideclimatenews.org/news/08072015/methane-emissions-texas-fracking-region-50-higher-epa-estimates-oil-gas-drilling-barnett-shale-environmental-defense-fund

[1150] Lavoie, T. N., Shepson, P. B., Cambaliza, M. O. L., Stirm, B. H., Karion, A., Sweeney, C., . . . Lyon, D. (2015). Aircraft-based measurements of point source methane emissions in the Barnett Shale Basin. *Environmental Science & Technology, 49,* 7904−7913. doi: 10.1021/acs.est.5b00410

[1151] Townsend-Small, A., Marrero, J. E., Lyon, D. R., Simpson, I. J., Meinardi, S., & Blake, D.R. (2015). Integrating source apportionment tracers into a bottom-up inventory of methane emissions in the Barnett Shale hydraulic fracturing region. *Environmental Science & Technology, 49,* 8175−8182. doi: 10.1021/acs.est.5b00057

[1152] Adams, K. (2015, July 1). Schoharie County officials ask new studies on gas lines: Report say dangers are equivalent to fracking. *Daily Gazette*, Retrieved from http://www.dailygazette.com/news/2015/jul/01/0701_gasline/?print

1,369 such incidents, which resulted in 259 injuries. More than three-quarters of these incidents were related to natural gas distribution. Equipment failure accounted for half of all incidents; human error accounted for 40 percent. The report noted the "continuing occurrence" of petroleum release incidents—including from natural gas pipeline ruptures—which have "the potential to cause mass casualties and environmental contamination."[1153]

- June 9, 2015 – The American Medical Association (AMA) adopted a resolution, "Protecting Public Health from Natural Gas Infrastructure," that was based on a resolution adopted by the Medical Society of the State of New York. (See below.) The resolution states, "Our AMA recognizes the potential impact on human health associated with natural gas infrastructure and supports legislation that would require a comprehensive Health Impact Assessment regarding the health risks that may be associated with natural gas pipelines."[1154]

- May 2, 2015 – The Medical Society of the State of New York adopted a resolution, "Protecting Public Health from Natural Gas Infrastructure," that recognizes the potential impact to human health and the environment of natural gas pipelines and calls for a governmental assessment of these risks.[1155]

- March 3, 2015 – Researchers with the Southwest Pennsylvania Environmental Health Project measured ambient levels of particulate and volatile air pollutants from fracking-related operations and calculated expected human exposures in Washington County, Pennsylvania. Extremely high exposures peaked at night when air was still. These fluctuating exposure events mimic, in frequency and intensity, the episodic nature of health complaints among residents. Over a one-year period, compressor stations were responsible for more extreme exposure events (118) than well pads or gas processing plants.[1156]

- February 24, 2015 – As part of a literature review on the health impacts of compressor stations, the Southwest Pennsylvania Environmental Health Project reported that peak emissions of fine particles tended to occur during construction time, that day-to-day emissions during operational time can fluctuate greatly, and that a compressor blowdown typically represented the single largest emission event during operations. Hence, documentation of these fluctuations cannot be captured by calculating yearly averages. A blowdown is an intentional or accidental release of gas through the blowdown valve that

[1153] Anderson, A. R. (2015, June 12). Health effects of cut gas lines and other petroleum product release incidents—seven states. *Morbidity and Mortality Weekly Report*, *64,* 601-605.
[1154] American Medical Association. (2015). H-135.930 Protecting public health from natural gas infrastructure, Resolution 519, A-15. Retrieved from https://www.ama-assn.org/sites/default/files/media-browser/public/hod/a15-hod-resolutions.pdf
[1155] Medical Society of the State of New York. (2015). 2015 House of Delegates Actions: Public Health and Education. Retrieved from http://www.mssny.org/Documents/HOD/Actions/ActionPHE.pdf
[1156] Brown, D. R., Lewis, C., & Weinberger, B. I. (2015). Human exposure to unconventional natural gas development: a public health demonstration of periodic high exposure to chemical mixtures in ambient air. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering, 50,* 460-72. doi: 10.1080/10934529.2015.992663

creates a 30- to 60-meter-high gas plume. Blowdowns, which are used to release pressure, can last as long as three hours. The authors noted that blowdowns result in periods of high levels of volatile organic compound releases and that anecdotal accounts associate blowdowns with burning eyes and throat, skin irritation, and headache.[1157] There is neither a national or state inventory of compressor station accidents nor a body of peer-reviewed research on the public health impacts of compressor stations.

- February 17, 2015 – A Boston study found that emissions from residential, end-use natural gas infrastructure was a significant source of atmospheric methane—two to three times larger than previously presumed—and accounted for 60 to 100 percent of methane, depending on the season. Of all the natural gas in the downstream component of the natural gas system, 2.7 percent was lost to the atmosphere.[1158]

- February 10, 2015 – A team of engineers from Pennsylvania and Colorado examined methane emissions from natural gas compressor stations and found that vents, valves, engine exhaust, and equipment leaks were also major emissions sources. There was considerable variation in emissions among the 45 compressor stations measured. Surprisingly, substantial emissions were found even when compressors were not operating.[1159]

- December 27, 2014 – A *Pittsburgh Tribune-Review* investigation found that the vast majority of natural gas "gathering lines"—pipelines that take natural gas from rural well pads to processing plants—were regulated by neither federal nor state pipeline safety laws. The United States has nearly 230,000 miles of natural gas gathering lines that are unregulated, operating without safety standards or inspection. These pipelines are among the largest and highest-pressure pipes in use and carry gas at nearly three times the pressure of transmission lines, which transport the gas from the processing plants to urban distribution networks.[1160]

- November 11, 2014 – An analysis by a Carnegie Mellon University research team of 40,000 pipeline accidents from 1968 to 2009 found that comparatively few accidents accounted for a large share of total property damage, whereas a large share of fatalities and injuries were caused by numerous, small-scale accidents. There are 2.4 million miles

[1157] Southwest Pennsylvania Environmental Health Project (2015, February 24). Summary on compressor stations and health impacts. Retrieved from http://www.environmentalhealthproject.org/wp-content/uploads/2012/03/Compressor-station-emissions-and-health-impacts-02.24.2015.pdf

[1158] McKain, K., Down, A., Raciti, S. M., Budney, J., Hutyra, L. R., Floerchinger, C., . . . Wofsy, S.C. (2015). Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts. *Proceedings of the National Academy of Sciences, 112,* 1941-46. doi: 10.1073/pnas.1416261112

[1159] Subramanian, R., Williams, L. L., Vaughn, T. L., Zimmerle, D., Roscioli, J. R., Herndon, S. C., . . . Robinson, A.L. (2015). Methane emissions from natural gas compressor stations in the transmission and storage sector: measurements and comparisons with the EPA Greenhouse Gas Reporting Program protocol. *Environmental Science & Technology, 49,* 3252-61. doi: 10.1021/es5060258

[1160] Wereschlagin, M. (2015, December 27). Rural gas gathering pipelines kindle concerns about safety laws. *Pittsburgh Review-Tribune*. Retrieved from http://triblive.com/news/editorspicks/7362085-74/lines-gas-safety#axzz3NAHfzYF8 of natural gas pipeline in the United States and 175,000 miles of hazardous liquid pipeline (which includes crude oil).[1161]

- October 30, 2014 – A research team led by David O. Carpenter at University at Albany found high levels of formaldehyde near 14 compressor stations in three states. In Arkansas, Pennsylvania, and Wyoming, formaldehyde levels near compressor stations exceeded health-based risk levels. The authors noted that compressor stations can produce formaldehyde through at least two routes: it is created as an incomplete combustion byproduct from the gas-fired engines used in compressor stations. It is also created when fugitive methane, which escapes from compressor stations, is chemically converted in the presence of sunlight. Formaldehyde is a known human carcinogen. Other hazardous air pollutants detected near compressor stations in this study were benzene and hexane. One air sample collected near a compressor station in Arkansas contained 17 different volatile compounds. (See entry for October 30, 2014 in Air Pollution.)

- October 15, 2014 – In comments to FERC, New York's Madison County Health Department reviewed the literature on compressor station emissions and expressed concerns about associated health impacts, including documented correlations between health problems and residential proximity to compressor stations. It also reviewed health outcomes associated with exposures to chemicals known to be released from compressor stations, including VOCs, carbonyls and aldehydes, aromatics, and particulate matter. In addition, gas from fracking operations transiting through compressor stations may carry gaseous radon. The Health Department noted a troubling lack of information on the intensity, frequency, and duration of emission peaks that occur during the blowdowns and large venting episodes that are a normal part of compressor operations.[1162]

- September 16, 2014 – Noting the proximity of a proposed high-pressure pipeline to Indian Point Nuclear Facility, as well as the evidence linking compressor station emissions to negative health impacts, New York's Rockland County legislature adopted a resolution calling for a comprehensive Health Impact Assessment in regards to Spectra Energy's planned Algonquin Incremental Market (AIM) natural gas pipeline, compressor, and metering stations expansion project.[1163] This resolution follows on the heels of similar resolutions expressing health concerns about the AIM project from both Westchester and Putnam County legislatures.[1164, 1165]

[1161] Siler-Evans, K., Hanson, A., Sunday, C., Leonard, N., & Tumminello, M. (2014). Analysis of pipeline accidents in the United States from 1968 to 2009. *International Journal of Critical Infrastructure Protection, 7,* 257-69. doi: 10.1016/j.ijcip.2014.09.002

[1162] New York State Madison County Health Department (2014, October 15). Comments to the Federal Energy Regulatory Committee concerning docket no. CP14-497-000, Dominion Transmission, Inc. Retrieved from https://www.madisoncounty.ny.gov/sites/default/files/publicinformation/madison_county_doh_comments_-_docket_no._cp14-497-000.pdf

[1163] Rockland County Legislature. (2014, September 16). *Resolution No. 404 of 2014 urging that health, safety and planning concerns be addressed and mitigated in the Environmental Review and all other review processes before project permissions be granted for Spectra Energy's Algonquin Incremental Market (AIM) Natural Gas Pipeline, Compressor and Metering Stations Expansion Project.* Retrieved from https://sape2016.files.wordpress.com/2014/05/rockland-aim-resolution.pdf

[1164] Board of Legislators County of Westchester, State of New York. (2014, July 21). *Resolution RES-2014-80*

- January 24, 2013 – A report prepared for the Clean Air Council by an independent consulting firm to evaluate air quality impacts from the Barto Compressor Station in Penn Township, Lycoming County, Pennsylvania predicted "large exceedances" of the nitrogen dioxide (NO_2) 1-hour NAAQS. Researchers used allowable emissions in the PA DEP permit, the 2006-2010 meteorological data and the latest EPA modeling guidance for the model's prediction. Three techniques were used, and for two of the techniques, NAAQS exceedances occurred within a mile of the plant. The report concluded, "NO_2 impacts from the Barto plant alone are very significant since its emissions cause large exceedances of the 1-hour NAAQS."[1166]

- July 13, 2011 – A Fort Worth air quality study assessed the impact of drilling and fracking operations, and ancillary infrastructure, on concentrations of toxic air pollutants in the city of Fort Worth, Texas. The study found that compressor stations were a significant source of fracking-related air pollution. The compressor engines were responsible for over 99 percent of the hazardous air pollutants emitted from compressor stations, of which 67 percent was formaldehyde.[1167]

Gas storage

Gas storage facilities include not only manmade holding tanks but also geological formations, most notably, aquifers, abandoned salt caverns, and depleted oil fields left over from mining and drilling operations. These unlined cavities were not created with the intent to store pressurized hydrocarbon gases, nor are they engineered for this purpose. The 3,600-acre Aliso Canyon gas storage facility, located in a depleted oil field in southern California, released more than 100,000 metric tons of methane into the air of the San Fernando Valley over a four-month period beginning in October 2015 before it was finally contained in February 2016. This massive methane leak—the largest in U.S. history—is the greenhouse gas equivalent of a half million cars driving for a year. The plume itself was visible from space. More than 8,000 families in the nearby community of Porter Ranch were evacuated and

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Algonquin Incremental Marketing Project resolution. Retrieved from https://sape2016.files.wordpress.com/2014/05/080414-wcbol-resolution-no-80-2014-requesting-due-diligence-on-environment-p.pdf

[1165] Putnam County Legislature. (2014, May 9). *Resolution #104, Resolution regarding the Algonquin Incremental Market (AIM) Project.* Retrieved from https://sape2016.files.wordpress.com/2014/05/putnam-county-resolutions-104-163-and-182-1.pdf

[1166] Tran, K. T. (2013, January 24). *AERMOD modeling of NO2 impacts of the Barto Compressor Station: Final report.* Prepared for the Clean Air Council, Philadelphia, PA. Retrieved from http://www.pennfuture.org/UserFiles/File/MineDrill/Marcellus/CAC_EmissionsNO2_CompressorBarto_20130124.pdf

[1167] Eastern Research Group. (2011, July 13). City of Forth Worth natural gas air quality study, final report. Retrieved from http://www.shaledigest.com/documents/2011/Air%20Quality%20Studies/Ft%20Worth%20Natural%20Gas%20Air%20Quality%20Study%20Final%20Report%20ERG%20Research%207-13-2011r.pdf. See also Energy Research Group. (2011, July 19). Forth Worth natural gas air quality study final report, pubic meeting presentation. Retrieved from http://fortworthtexas.gov/uploadedFiles/Gas_Wells/110719_ERG.pdf?v=110725

relocated, thousands were sickened, and two public schools closed. The immediate cause of the Aliso Canyon blowout was a cracked well casing and lack of a shut-off valve. Data released in 2018 as part of a new U.S. Department of Transportation rule reveal that there are more than 10,000 Aliso-style storage wells with gas flowing through only a single unprotected pipe—that is, with a single point of failure. Of the nearly 400 natural underground storage facilities in the United States, 296 of them have one or more of these wells, and they are located in 32 states.

- February 1, 2019 – An assessment of gas leakage from different types of natural gas storage facilities that established a mathematical model to predict leakage points showed that long-term periodic injection of gas and improper construction will lead to some degree of gas leakage risks, no matter what kind of construction process is used to create the gas storage reservoir.[1168]

- January 2, 2019 – Plans by Alton Natural Gas to create a massive gas storage hub in salt caverns north of Halifax, Nova Scotia were delayed due to "project and regulatory planning," and the company has asked the Nova Scotia Utility and Review Board to extend its cavern construction permit. The plan involves hollowing out underground salt deposits using water from the tidal Shubenacadie River. The brine waste would then be dumped into the river, twice a day at high tide, over a two- to three-year period. Members of the Sipekne'katik First Nation argue that the project will harm the ecology of the tidal river, which runs through the middle of Nova Scotia. They have continuously occupied and protested at the site since 2014.[1169]

- August 20, 2018 – A research team investigated the geomechanics of an underground natural gas storage facility in China. They noted that geological factors and engineering factors can both contribute to leaks. Engineering factors include problems with casing integrity, cementing quality, and salt cavern operating pressure. Geological factors include challenges posed by the complexity of geological formations, imperfect sealing by the caprock, and the presence of faults. Using geological analysis, permeability tests, and CT scans, the authors determined that the risk of leakage in this salt cavern underground gas storage arises mainly from a failure of wellbore tightness within a mudstone interlayer.[1170]

- July 12, 2018 – The New York State Department of Environmental Conservation denied a permit for liquified petroleum gas storage (propane) in abandoned salt caverns on the shoreline of Seneca Lake. "The record demonstrates that the impacts of this project on

[1168] Wei, X., & Zhichao, Z. (2019). Study on the production mode and leakage risk of gas storage well completion. *IOP Conference Series: Earth and Environmental Science, 233*(4), 042007. doi: 10.1088/1755-1315/233/4/042007
[1169] The Canadian Press. (2019, January 2). More delays for underground cavern gas storage plan north of Halifax. *ConstructConnect.* Retrieved from https://canada.constructconnect.com/dcn/news/resource/2019/01/delays-underground-cavern-gas-storage-plan-north-halifax
[1170] Chen, X., Li, Y., Liu, W., Ma, H., Ma, J., Shi, X., & Yang, C. (2019). Study on sealing failure of wellbore in bedded salt cavern gas storage. *Rock Mechanics and Rock Engineering, 52*(1), 215–228. Advance online publication. doi: 10.1007/s00603-018-1571-5

the character of the local and regional community, including but not limited to the environmental setting and sensitivity of the Finger Lakes area and the local and regional economic engines (e.g., wine, agricultural and tourism industries), are significant and adverse and the project does not avoid or minimize those impacts to the maximum extent practicable. Furthermore, the significant adverse impacts on community character are not outweighed or balanced by social, economic or other considerations, and cannot be avoided or minimized to the maximum extent practicable by the proposed mitigation measures." Concerns were also raised about the structural integrity of the caverns following disclosure by the gas storage company that additional pressure testing in the caverns would be required to assess possible leaks.[1171, 1172] The previous year, a subsidiary of the same company scrapped a parallel plan to expand the storage of natural gas in adjacent salt caverns along the lake shore.[1173]

- June 22, 2018 – A research team undertook an analysis to determine why the roof of China's first salt cavern underground gas storage facility collapsed, as determined by a sonar test after just 1.3 years of use. They concluded that the main reasons for the collapse were the large-span flat roof, a too-rapid decrease in internal gas pressure, and localized damage that led to massive collapse. They also concluded that this cavern has a high risk of roof collapse taking place again. The study includes evaluations of other similar incidents worldwide. Using geomechanical modeling, the authors developed a "new failure prediction index, consisting of volume shrinkage, dilatancy safety factors, displacement, vertical stress, and equivalent strain."[1174]

- May 4, 2018 – A new Department of Transportation rule requires gas companies that operate storage facilities to disclose information about design, leaks, and repairs of their wells. According to data released on April 4, 2018 as part of this rule, more than 10,000 wells have gas flowing through only a single unprotected pipe—that is, with a single point of failure. Of the nearly 400 natural underground storage facilities in the United States, 296 of them have one or more of these wells, and they are in 32 states.[1175] These statistics update an earlier estimate by Harvard University researcher Drew Michanowicz,

[1171] State of New York Department of Environmental Conservation. (2018, July 12). Decision of the Commissioner, final supplemental environmental impact statement and SEQRA findings statement. Retrieved from https://www.dec.ny.gov/hearings/114139.html

[1172] Platsky, J. (2018, May 23). Crestwood acknowledges possible leaks in proposed LPG storage in Seneca Lake mines. *Ithaca Journal.* Retrieved from https://eu.pressconnects.com/story/news/local/2018/05/21/crestwood-seneca-lake-gas-storage/629768002/

[1173] Campbell, J. (2018, July 12). Crestwood's Seneca Lake propane storage facility rejected by DEC. *Ithaca Journal.* Retrieved from https://www.pressconnects.com/story/news/2018/07/12/dec-rejects-plan-crestwood-propane-storage-facility-seneca-lake/779605002/

[1174] Wang, T., Yang, C., Chen, J., & Daemen, J. J. K. (2018). Geomechanical investigation of roof failure of China's first gas storage salt cavern. *Engineering Geology, 243*, 59-69. doi: 10.1016/j.enggeo.2018.06.013

[1175] U.S. Department of Transportation, Pipelines and Hazardous Materials Safety Administration. (2018). Gas distribution, gas gathering, gas transmission, hazardous liquids, liquefied natural gas (LNG), and underground natural gas storage (UNGS) annual report data. Retrieved from https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids who, consulting earlier databases, had pegged the number of Aliso-type wells at about 2,700.[1176] (See also entry for May 24, 2017.)

- March 6, 2018 – Illinois has the largest amount of natural gas storage in salt formations in the nation. Some of these storage sites underlie the Mahomet Aquifer, which provides drinking water for 14 counties in east-central Illinois. Prompted by an October 2016 report by a federal task force in the aftermath of California's Aliso Canyon natural gas leak, a team from the University of Illinois' Prairie Research Institute created an introductory guide to provide basic information about the Mahomet Aquifer and natural gas storage in east-central Illinois.[1177] (See also entry for October 18, 2016.)

- January 18, 2018 – The California Council of Science and Technology released a 910-page report analyzing the safety risks of all 14 facilities in the state that store gas in depleted oil fields. Among its findings: gas companies do not disclose the chemicals that are pumping underground; state regulators lack necessary information to assess risks; and many wells servicing the storage fields are 60 to 90 years old with no regulatory limit to the age of the well.[1178]

- December 1, 2017 – A University of Southern California-led team investigated the roots causes of the catastrophic Aliso Canyon gas storage blow-out, which began October 23, 2015 and continued for four months before being contained. Using methodology designed to capture both social and technological factors, the team concluded that corporate dysfunction and lack of government oversight were the driving forces responsible for the accident. "Risk analysis is vital for safe well operations and relies on analyzing prior data records, yet no national standards for well records were in place prior to the accident. There was no clear overarching agency that was in control of the accident's intervention and aftermath."[1179] In a subsequent news piece from the university, Najmedin Meshkati, senior author of the study, said, "SoCal Gas had lenient requirements for infrastructure record keeping, no comprehensive risk management plan, and no testing programs or plans in place to remediate substandard wells. The company needs to improve its safety culture."[1180]

[1176] Michanowicz, D. (2018, May 14). The Aliso Canyon gas leak was a disaster. There are 10,000 more storage wells out there just like it. *Los Angeles Times*. Retrieved from http://www.latimes.com/opinion/op-ed/la-oe-michanowicz-aliso-canyon-gas-leak-20180514-story.html

[1177] Locke, R., Roadcap, G., Stumpf, A., Leetaru, H., Kelly, W., & Winkel, R. (2018). *An introductory guide to the Mahomet Aquifer and natural gas storage in East-Central Illinois.* Prairie Research Institute. Retrieved from https://www.ideals.illinois.edu/bitstream/handle/2142/99145/PRI%20Intro%20Guide%20to%20the%20Mahomet%20Aquifer%20and%20Natural%20Gas%20Storage_02.22.2018_printed.pdf?sequence=2&isAllowed=y

[1178] Birkholzer, J., & Long, J. C. S. (2018, January 18). *Long-term viability of underground natural gas storage in California: an independent review of scientific and technical information.* California Council of Science and Technology. Retrieved from https://ccst.us/reports/natural-gas-storage/

[1179] Tabibzadeh, M., Stavros, S., Ashtekar, M. S., & Meshkati, N. (2017). A systematic framework for root-cause analysis of the Aliso Canyon Gas Leak using the AcciMap methodology: Implication for underground gas storage facilities. *Journal of Sustainable Energy Engineering, 5*(3). doi: 10.7569/JSEE.2017.629515

[1180] Vuong, Z. (2018, February 15). Who should be held responsible for the Aliso Canyon gas leak? *USC News.* Retrieved from http://news.usc.edu/136300/who-should-be-held-responsible-for-the-aliso-canyon-gas-leak/

- November 22, 2017 – The U.S. Government Accountability Office (GAO) reported that, two years after the Aliso Canyon blow-out, the Pipeline and Hazardous Materials Safety Administration (PHMSA) is failing to inspect natural gas storage sites in a timely manner, as called for by the Department of Transportation's interim standards. Until 2016, states set the standards for 211 of the nation's 415 gas storage sites, while the 204 sites that were connected to interstate pipelines had no standards at all. Collectively, these 415 natural gas storage sites contain about 17,000 wells that inject or withdraw natural gas from the underground formations below, which include depleted oil and gas reservoirs, abandoned mines, depleted aquifers, and hard rock caverns. The GAO noted that more than 300 cities and towns are located near natural gas storage sites.[1181]

- June 21, 2017 – In response to requests from the oil and natural gas industry, the White House announced that it will delay implementation of a rule that would have set national standards for underground natural gas storage. Prompted by the 2015 disaster at Aliso Canyon and developed under the previous administration, this federal interim rule had called for phasing out single-point-of-failure, single-containment designs of the type that made impossible the task of swiftly shutting off the impaired Aliso Canyon well once it began leaking.[1182]

- May 24, 2017 – A national assessment of thousands of underground gas storage wells by a Harvard School of Public Health team found that more than 20 percent are similar in design to the well that failed at Aliso Canyon. These obsolete wells, with single failure points and a median age of 74 years, operate in 19 states and represent more than half of the working capacity for U.S. natural gas. More than 2,700 of these wells were not originally designed to hold gas and, as at Aliso Canyon, have been repurposed to do so. An estimated 210 of these repurposed wells (located in Pennsylvania, Ohio, New York, and West Virginia) are more than 100 years old and entirely lack cement zonal isolation methods. Study author Jonathan Buonocore said, "Partly because no federal safety regulations apply to natural gas storage wells or their operations (now pending), very little aggregate information was available. . . . After we identified this data gap, we realized we needed to build our own database to begin to assess this previously inapparent hazard." With the 50 percent increase in domestic natural gas production over the last ten years, natural gas storage is at an all time high and in demand.[1183, 1184]

[1181] U.S. Government Accountability Office. (2017, November 22). *Natural gas storage: Department of Transportation could take additional steps to improve safety enforcement planning*. GAO-18-89. Retrieved from https://www.gao.gov/assets/690/688553.pdf.

[1182] Nemec, R. (2017, June 21). PHMSA pauses stricter natural gas storage rules for clarification. *Natural Gas Intel*. Retrieved from http://www.naturalgasintel.com/articles/110856-phmsa-pauses-stricter-natural-gas-storage-rules-for-clarification

[1183] Michanowicz, D. R., Buonocore, J. J., Rowland, S. T., Konschnik, K. E., Goho, S. A., & Bernstein, A.S. (2017). A national assessment of underground gas storage identifying wells with designs likely vulnerable to a single-point-of-failure. *Environmental Research Letters, 12*(6). doi: 10.1088/1748-9326/aa7030

[1184] Institute of Physics. (2017, May 24). Study uncovers widespread leak risk for US underground natural gas storage wells. *Phys.Org.* Retrieved from https://phys.org/news/2017-05-uncovers-widespread-leak-underground-natural.html

- October 21, 2016 – The California Air Resources Board determined that the Aliso Canyon gas storage facility released 100,000 tons of methane, becoming the largest ever natural gas leak in U.S. history.[1185]

- October 18, 2016 – A federal task force issued a report with 44 recommendations intended to prevent another Aliso Canyon-style disaster. Chief among them is a phase-out of "single-point of failure" designs.[1186]

- July 13, 2016 – As reported by the *Los Angeles Daily News,* Los Angeles County health officials were prepared to go to court to ensure that the Southern California Gas Company complies with an order to pay for professional comprehensive cleaning in the homes of residents who were relocated due to the Aliso Canyon gas leak. The company had filed legal papers asking that the order "to remove dust and oily mist from up to 35,000 homes be nullified," after their report of having cleaned 1,700 homes to date. The Los Angeles County Health Department said the company had done a poor job on these and did not follow protocol to remove the metal particles, including barium, manganese, vanadium, aluminum, and iron previously identified in household surface dust.[1187]

- July 9, 2016 – California's South Coast Air Quality Management District and Southern California Gas Company were still at an impasse seven months after the company was given an abatement order that included a community health study on the potential impacts of exposures from the massive Aliso Canyon leak. The company was ordered to commit to paying "reasonable costs" for the study.[1188]

- June 22, 2016 – The first federal legislation of gas storage facilities was signed into law. The Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2016 includes a provision in response to the Aliso Canyon gas leak requiring PHMSA to develop regulations for the construction and operation of underground natural gas storage facilities.[1189] (See entry below, of February 8, 2016, for analysis of the likely shortcomings of these first federal regulations and their inability to prevent a leak such as that at Aliso Canyon.)

[1185] California Air Resources Board. (2016, October 21). Determination of total methane emissions from Aliso Canyon natural gas leak incident. Retrieved from https://www.arb.ca.gov/research/aliso_canyon/aliso_canyon_methane_emissions-arb_final.pdf

[1186] U.S. Department of Energy and U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration. (2016, October 18). Ensuring safe and reliable underground natural gas storage: Final report of the interagency task force on natural gas storage safety. Retrieved from https://energy.gov/sites/prod/files/2016/10/f33/Ensuring%20Safe%20and%20Reliable%20Underground%20Natural%20Gas%20Storage%20-%20Final%20Report.pdf

[1187] Abram, S. (2016, July 13). SoCalGas slammed for poor cleanup of Porter Ranch homes. *Los Angeles Daily News.* Retrieved from http://www.dailynews.com/health/20160713/socalgas-slammed-for-poor-cleanup-of-porter-ranch-homes

[1188] Bartholomew, D. (2016, July 9). Gas Company, pollution agency at odds over cost of Porter Ranch health study. *Los Angeles Daily News.* Retrieved from http://www.dailynews.com/government-and-politics/20160709/gas-company-pollution-agency-at-odds-over-cost-of-porter-ranch-health-study

[1189] Cama, T. (2016, June 22). Obama signs pipeline safety bill. *The Hill.* Retrieved from http://thehill.com/policy/energy-environment/284479-obama-signs-pipeline-safety-bill

- June 20, 2016 – As reported in *Geophysical Research Letters*, an airborne instrument onboard a NASA satellite was able to detect and quantify the size and shape of the methane plume from the Aliso Canyon gas leak as the event occurred.[1190] This is the first time a natural gas leak has been visible from space, according to the authors of the study.[1191]

- May 4, 2016 – Southern California Gas Company said that costs related to the Aliso Canyon natural gas storage facility leak reached an estimated $665 million. The utility company let the Securities and Exchange Commission know they carry policies with a combined limit available "in excess of $1 billion," but according to the *Los Angeles Times,* legal experts and lawyers said that $1 billion in insurance might not be enough for what they ultimately need.[1192]

- April 12, 2016 – California energy agencies issued a report indicating the threat of widespread summer power outages if no gas can be withdrawn from Aliso Canyon. The report was met with criticism. "Consumer groups and utility critics contend that the blackout warnings are an irresponsible scare tactic to ensure that Southern California Gas Company is allowed to keep storing gas at the facility and that ratepayers will pay for upgrades to store even more fuel there."[1193]

- April 6, 2016 – The *Los Angeles Times* reported that, though prices for homes in Porter Ranch adjacent to the Aliso Canyon gas storage leak held up, sales declined. After the leak that began October 23, 2015, sales from December 2015 to February 2016 declined 20 percent from the year before. Disclosures for homes in the area "now include a mention of the community's proximity to the gas field and the recent problems."[1194]

- March 18, 2016 – The California State Oil and Gas Division of the Department of Conservation issued penalties totaling $75,000 for three separate violations after finding incidents of intentional venting of gas at the Aliso Canyon gas field and malicious concealment of those acts. Both are violations of the state gas regulations.[1195] Following the Aliso Canyon gas storage leak, the California State Public Utilities Commission ordered a statewide survey of California's 12 natural gas storage fields and found 229

[1190] Thompson, D. R., Thorpe, A. K., Frankenberg, C., Green, R. O., Duren, R., Guanter, L., …Ungar, S. (2016). Space-based remote imaging spectroscopy of the Aliso Canyon CH_4 superemitter. *Geophysical Research Letters* 43(12). doi: 10.1002/2016GL069079

[1191] Mooney, C. (2016 June 15). This gas leak was so massive that NASA saw it from space. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2016/06/15/this-gas-leak-was-so-massive-that-nasa-saw-it-from-space/?utm_term=.1e66d8da1423

[1192] Penn, I. (2016, May 4). Costs related to Aliso Canyon leak reach an estimated $665 million. *Los Angeles Times.* Retrieved from http://www.latimes.com/business/la-fi-aliso-canyon-costs-20160504-snap-story.html

[1193] Penn, I. (2016, April 12). 'This is a threat. This is not a report.' Critics call blackout warnings a scare tactic to keep Aliso Canyon open. *Los Angeles Times.* Retrieved from http://www.latimes.com/business/la-fi-gas-field-20160412-story.html

[1194] Khouri, A. (2016, April 6). Gas leak disrupts Porter Ranch housing market. *Los Angeles Times.* Retrieved from http://www.latimes.com/business/realestate/la-fi-porter-ranch-sales-20160406-story.html

[1195] California Department of Conservation. (2016, March 18). State oil & gas division issues $75,000 fine to operator for illegally venting natural gas. NR#2016-06. Retrieved from http://www.conservation.ca.gov/index/Documents/2016-06%20DOC%20fines%20oil%20operator%20$75,000.pdf faulty valves, flanges and leaky wellheads and a 230th leak at an abandoned well; eight were deemed hazardous.[1196]

- March 14, 2016 – Methane and ethane emissions were measured to determine spatial patterns and source attribution of urban methane in the Los Angeles Basin. The surveys demonstrated the prevalence of fugitive methane emissions across the Los Angeles urban landscape and that fossil fuel sources accounted for 58–65 percent of methane emissions.[1197]

- February 25, 2016 – Measurements of methane and other chemicals were taken by aerial equipment following the October gas release from a faulty well in the Aliso Canyon storage field. The data demonstrated that the blowout of this single well created the largest known anthropogenic point source of methane in the United States. The leak lasted 112 days and released a total of 97,100 tons of methane and 7,300 tons of ethane into the atmosphere. This was equal to 24 percent of the methane and 56 percent of the ethane emitted each year from all other sources in the Los Angeles Basin combined.[1198] Aliso Canyon was already a major pollution source before the massive leak.[1199] As determined by the study and reported by major news outlets, the recent methane link is officially the worst in U.S. history.[1200, 1201]

- February 18, 2016 – Stanford and UCLA scientists reported to *InsideClimate News* that the lack of measurement data for the entire 100+ days of community exposures to the Aliso Canyon methane leak, combined with gaps in the science about many of the chemicals, hinders the ability to understand the health impacts of the leak. "'The first week is when we would expect the highest gas concentrations to reach the neighborhood because the pressures in the storage field were the highest,' said Robert Jackson, an earth system science professor at Stanford University who measured methane concentrations in nearby communities during the leak. 'And yet we don't have any information or data for

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[1196] St. John, P. (2016, March 23). 229 leaks found in state's underground gas storage facilities, most considered minor. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/lanow/la-me-ln-gas-leaks-storage-wells-20160322-story.html

[1197] Hopkins, F. M., Kort, E. A., Bush, S. E., Ehleringer, J. R., Lai, C.-T., Blake, D. R., & Randerson, J. T. (2016). Spatial patterns and source attribution of urban methane in the Los Angeles Basin. *Journal of Geophysical Research: Atmospheres, 121*(5), 2490–2507. doi: 10.1002/2015JD024429

[1198] Conley, S., Franco, G., Faloona, I., Blake, D. R., Peischl, J. & Ryerson, T. B. (2016). Methane emissions from the 2015 Aliso Canyon blowout in Los Angeles, CA. *Science.* Advance online publication. doi: 10.1126/science.aaf2348

[1199] Lobet, I. & Reicher, M. (2016, February 14). *inewsource.org.* Retrieved from http://inewsource.org/2016/02/14/aliso-canyon-major-pollution/

[1200] Akpan, N. (2016, February 25). Los Angeles methane leak was officially the worst in U.S. history, study says. *PBS Newshour.* Retrieved from http://www.pbs.org/newshour/rundown/los-angeles-methane-leak-is-officially-the-worst-in-u-s-history/

[1201] Khan, A. (2016, February 25). Porter Ranch leak declared largest methane leak in U.S. history. *Los Angeles Times.* Retrieved from http://www.latimes.com/science/sciencenow/la-sci-sn-porter-ranch-methane-20160225-story.html that first week at least.'" Jackson noted that even after monitoring was initiated, it was intermittent rather than continuous.[1202]

- February 18, 2016 – Independent regional experts from USC and UCLA interviewed by Southern California Public Radio expressed skepticism that an industry-funded study ordered by the South Coast Air Quality Management District following the Aliso Canyon methane leak would be rigorously designed to answer specific questions about sub-chronic, cumulative exposures, including hydrogen sulfide, which was measured in the nearby Porter Ranch community at levels far greater than the average across American cities.[1203]

- February 13, 2016 – The Los Angeles County Department of Health prepared a *Supplemental Report* for its Expanded Air Monitoring Plan concerning the Southern California Gas Company's Aliso Canyon storage facility long-term gas leak. The report addressed "chemicals of health concern" including toluene, ethylbenzene, xylene, hydrocarbons, VOCs, metals, and radon and concluded, "all results suggest that chemical exposures experienced by residents as a result of the gas leak are below the levels of concern that have been established by various regulatory agencies."[1204] Remaining challenges named by the report itself included possible gaps in data collection, other chemicals present for which no sampling occurred, and further study of the symptoms reported by the public. Many independent scientists did not concur with the Department of Health's ongoing statements that chemical exposures were below levels of concern. Issues raised included monitoring not initiated until a week after the leak began, lack of continuous monitoring, and reliance on "grab samples." Speaking to *InsideClimate News,* John Bosch, a retired air-monitoring expert with more than 30 years' experience at the EPA said, "Grab samples may be OK as a first-tier guestimate of what the problem is, but you really have to have continuous monitoring."[1205]

- February 8, 2016 – PHMSA announced that it might issue its first federal safety regulations for gas storage sites such as Aliso Canyon, while also suggesting site operators voluntarily follow guidelines that the proposed rules (which would likely take years to issue) will likely mirror. According to a report in *InsideClimate News*, these guidelines would not require systems to stop the flow of gas in an emergency or mandate redundancies to prevent methane from leaking into the environment." If PHMSA

[1202] McKenna, P. (2016, February 18). What will be the health impact of 100+ days of exposure to California's methane leak? *InsideClimate News*. Retrieved from http://insideclimatenews.org/news/17022016/health-impacts-aliso-canyon-porter-ranch-methane-leak-california-socal-gas

[1203] O'Neill, S. (2016, February 18). Did the Porter Ranch gas leak cause long-term health damage? *89.33 KPCC*. Retrieved from http://www.scpr.org/news/2016/02/18/57666/did-the-porter-ranch-gas-leak-cause-long-term-heal/

[1204] Los Angeles County Department of Health. (2016, February 13). *Aliso Canyon gas leak, Results of air monitoring and assessments of health, Supplemental report: Updated results and expanded chemical testing.* Retrieved from http://www.publichealth.lacounty.gov/media/docs/SUPPLEMENTAL%20-Aliso%20Canyon%20Gas%20Leak-%20Results%20of%20Air%20Monitoring%20and%20Assessments%20of%20Health%20-%202-13-16.pdf

[1205] McKenna, P. (2016, February 18). What will be the health impact of 100+ days of exposure to California's methane leak? *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/17022016/health-impacts-aliso-canyon-porter-ranch-methane-leak-california-socal-gas proceeds to adopt industry guidelines, the resulting rules “may not address two key issues that turned Aliso Canyon into a disaster: emergency shutoff valves and a safer configuration of pipes.” Further, even with new regulations, storage units would most likely remain under state jurisdiction, “though state authorities may adopt any new federal rules.”[1206] A subsequent story reported on members of Congress pressing PHMSA to create the first federal standards for the 418 underground gas storage facilities for which it has authority to set regulations. In the hearing before a subcommittee of the House Committee on Transportation and Infrastructure, California representatives “spoke about their efforts to speed up PHMSA’s rulemaking for underground gas storage.”[1207]

- February 5, 2016 – As part of the Expanded Air Monitoring Plan, Los Angeles County Department of Health provided results for the primary chemicals of concern to assess health effects in residents, pets, and other animals in the community during the Southern California Gas Aliso Canyon storage facility leak. Those chemicals included methane, odorants, and benzene. The maximum level of methane detected was 4,340 ppm and the maximum level of benzene was 30.6 ppb. Early on, average weekly benzene levels that were close to the 1 ppb chronic exposure limit/ health protective level. “Methane levels have remained above normal, but have decreased substantially over time,” the report summarized. It also stated that odorants “… remained below instrument detection limits throughout the entire period, including immediately after the leak, even at locations near the leaking well,” and that “[b]enzene and other chemicals were originally detectable at levels above normal from within community sampling sites, but peak levels remained below acute exposure thresholds.”[1208] While the Los Angeles County Department of Health concluded that “health effects resulting from the on-going leak should be limited to short-term effects resulting from exposure to the odorants,” independent scientists, noting data gaps, have challenged these conclusions.

- January 25, 2016 – Some health experts and residents of Porter Ranch, California, adjacent to the Aliso Canyon gas field leak, expressed concern about long-term exposure to the odorous component of the gas, mercaptans, to which regulators attributed several symptoms of residents. Mercaptans are sulfurous chemicals that are added to natural gas to aid in the detection of leaks. Though California regulators have said the health problems, such as headaches, vomiting, and nosebleeds are temporary and will not lead to long-term damage, medical researchers described data gaps to *InsideClimate News.* There is “virtually no research on prolonged exposure to mercaptans.” Further, some researchers suggest the health problems may have been caused by different chemicals in

[1206] McKenna, P. (2016, February 8). New federal gas storage regulations likely to mimic industry's guidelines. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/08022016/federal-gas-storage-regulations-likely-mimic-industry-guidelines-aliso-canyon-phmsa-api

[1207] Song, L. (2016, February 26). *InsideClimate News*. U.S. pipeline agency pressed to regulate underground gas storage. Retrieved from https://insideclimatenews.org/news/26022016/phmsa-pipeline-regulator-pressed-regulate-underground-natural-gas-storage-aliso-canyon-methane

[1208] Los Angeles County Department of Health. (2016, February 5). Aliso Canyon gas leak: Results of air monitoring and assessments of health. Retrieved from http://www.publichealth.lacounty.gov/media/docs/AlisoAir.pdf the gas, and that "regulators have downplayed the significance of other contaminants that are also present in the leak."[1209]

- January 19, 2016 – Peter Richman, MD, president of the Los Angeles County Medical Association told the *Los Angeles Daily News* that, at nearly three months after the Aliso Canyon methane leak began, physicians had yet to receive a formal statement from the Los Angeles County Department of Public Health about airborne chemical pollutants related to the gas leak or guidelines on how to answer questions from patients about long-term health effects. Richman expressed special concern about prolonged exposure to methane and trace chemicals known to be carcinogenic. Another area physician reported that, as of the interview date, his urgent care practice had seen a hundred patients whose symptoms were consistent with exposure to leak-related pollutants.[1210]

- January 14, 2016 – Boston University researcher Nathan Phillips and Bob Ackley of Gas Safety USA drove a high precision GIS-enabled gas analyzer through roads throughout California's San Fernando Valley adjacent to the Aliso Canyon gas leak in early January 2016. Early results showed methane levels elevated 2-67 times the background level.[1211]

- January 13, 2016 – Investigations into the possible cause of the gas leak in Aliso Canyon included the consideration that nearby fracking may have contributed to casing failure. In an email to the *Los Angeles Daily News*, California Department of Conservation Chief Deputy Jason Marshall said that their investigation will examine well records, including those pertaining to "well stimulation operations."[1212] According to a 2015 report prepared for the California Council on Science and Technology, hydraulic fracturing is used about twice yearly to enhance storage "mostly in one facility serving southern California (Aliso Canyon)."[1213]

- January 13, 2016 – "Aliso Canyon is a wake-up call," according to a *Rocky Mountain PBS News* investigative report on the state of U.S. natural gas infrastructure. Natural gas is no longer a cleaner fuel than coal when methane leakage rates exceeds 2-4 percent, but the vast size of the nation's interconnected natural gas storage and pipeline systems

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[1209] Song. L. (2016, January 25). Mercaptans in methane leak make Porter Ranch residents sick, and fearful. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/22012016/porter-ranch-residents-health-effects-methane-leak-aliso-canyon-california

[1210] Abram, S. (2016, January 19,). Doctors treating Porter Ranch residents want more gas-leak guidance. *Los Angeles Daily News*. Retrieved from http://www.dailynews.com/health/20160119/doctors-treating-porter-ranch-residents-want-more-gas-leak-guidance

[1211] Bartholomew, D. (2016, January 14). 'Plume chaser' researchers fan out across San Fernando Valley to map reach of Porter Ranch gas leak. *Los Angeles Daily News.* Retrieved from http://www.dailynews.com/environment-and-nature/20160114/plume-chaser-researchers-fan-out-across-san-fernando-valley-to-map-reach-of-porter-ranch-gas-leak

[1212] Wilcox, G. J. (2016, January 13). Regulators probing whether fracking was connected to Aliso Canyon gas well leak. *Los Angeles Daily News.* Retrieved from http://www.dailynews.com/environment-and-nature/20160113/regulators-probing-whether-fracking-was-connected-to-aliso-canyon-gas-well-leak

[1213] Long, J. C. S., Feinstein, L. C., Birkholzer, J., Jordan, P., Houseworth, J., Dobson, P. F., . . . Gautier, D. L. (2015). *An independent scientific assessment of well stimulation in California, Volume I: Well stimulation technologies and their past, present, and potential future use in California.* California Council on Science and Technology, Sacramento, CA. Retrieved from https://ccst.us/publications/2015/2015SB4-v1.pdf makes difficult the task of tallying all the micro-leaks spread across the entire network and answering fundamental questions about exactly how much methane is being lost. The PBS report also expressed concern about the age of many of the system's component parts. According to the piece, nearly half (46 percent) of the nation's transmission pipelines, designed to carry high-pressure gas over long distances, were built in the 50s and 60s and are now more than a half century old.[1214]

- December 30, 2015 – According to the *Los Angeles Daily News,* which unearthed November 2014 state regulatory filing documents, the Southern California Gas Company knew about the corrosion and potential for leakage at Aliso Canyon prior to the massive blow-out. "In written testimony to the California Public Utilities Commission, [SoCalGas Director of Storage Operations Phillip] Baker described a reactive maintenance process that hinted at major leakage problems underground."[1215]

- November 20, 2015 – California state agencies collaborated with Aviation Scientific to measure methane emission rates at two early November dates, finding rates of 44,000±5,000 kilograms of methane per hour and 50,000±16,000 kilograms of methane per hour. The results indicated that the Aliso Canyon gas leak would have contributed about a quarter of California's methane emissions for the time period studied.[1216]

- November 20, 2015 – According to the *Los Angeles Times*, one month into the Aliso Canyon ongoing gas leak, Southern California Gas warned that it "might need several months" to plug the leak. An order from California's Division of Oil, Gas and Geothermal Resources, "stated that an 'uncontrolled flow of fluids' and gas was escaping and the operator had failed to fully inform state officials about the well's status. Steve Bohlen, the state oil and gas supervisor, also directed the company to submit a schedule for remediation work or for drilling a relief well."[1217]

- October 19, 2015 – *Houston Public Media* reported on the 125 caverns carved out of salt storing natural gas liquids (NGLs), thousands of feet under the city of Mont Belvieu, Texas, east of Houston. "There have been fiery accidents here. But nothing like what happened 23 years ago at a different [NGL] storage site 100 miles to the west. 'A bomb-like blast literally blew residents in this small community out of their beds this morning, said a reporter for Dallas's Channel 8 as he did a live report just outside the city of Brenham." That blast, which killed three and injured 21, was reportedly caused by the

[1214] Wirfs-Brock, J. (2016, January 13). Vast California methane leak is dire but not unique in aging infrastructure. *Rocky Mountain PBS News.* Retrieved from http://inewsnetwork.org/2016/01/13/vast-california-methane-leak-is-dire-but-not-unique-in-aging-infrastructure/
[1215] Reicher, M. (2015, December 30). SoCalGas knew of corrosion at Porter Ranch gas facility, doc shows. *Los Angeles Daily News*. Retrieved from http://www.dailynews.com/general-news/20151230/socalgas-knew-of-corrosion-at-porter-ranch-gas-facility-doc-shows
[1216] California Air Resources Board. (2015, November 20). Report on greenhouse gas emissions from Aliso Canyon leak. *Los Angeles Times.* Retrieved from http://documents.latimes.com/report-greenhouse-gas-emissions-aliso-canyon-leak/
[1217] Barboza, T. (2015, November 20). Natural gas leak that's sickening Valley residents could take months to fix. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-1121-gas-leak-20151121-story.html

lack of an emergency shut-off valve. There are no federal standards in place for such requirements. Twenty-three years later, a month prior to the *Houston Public Media* report, “at a hearing held by the U.S. Senate Committee on Commerce, Science, & Transportation, Donald Santa, head of the Interstate Natural Gas Association of America, told the senators that it was only in recent weeks that the industry approved standards for storing natural gas.” Texas did enact legislation a year after the deadly blast “and now requires emergency shutoff valves and inspections for leaks every five years.”[1218]

- October 5, 2011 – The federal district court in Topeka struck down Kansas gas-safety laws in 2010, and 11 underground storage sites with a capacity of more than 270 billion cubic feet of gas have gone uninspected, leaving thousands of Kansans to live on and around uninspected gas-storage fields.[1219]

- 2008 – When considering the possibility of storing natural gas in a variety of underground gas storage facilities, the UK government commissioned the British Geological Survey to identify the main types of facilities currently in operation worldwide along with any documented or reported failures and incidents which have led to release of stored product. The researchers found that California had the most incidents, but concluded that many of these problems and geological factors would not necessarily be applicable to the UK. The incidents most relevant to gas storage in the UK resulted from a failure of either the man-made infrastructure (well casings, cement, pipes, valves, flanges, compressors etc.), or human error, which has included overfilling of caverns and inadvertent intrusion. Extreme natural events, including earthquakes, also played a role. The researchers looked closely at incidents in salt caverns that had been repurposed to store gas. They reported that “early salt cavern storage in the US was done in brine wells that had been solution mined [in which salt deposits are melted away with hot water or steam] without consideration for subsequent storage in the depleted caverns. This practice sometimes resulted in later problems for storage operations in retrofitted brine caverns.” The authors conclude that the rate for a geological failure of the storage cavity in an underground gas storage facility is of the order of 10^{-5} failures per well year.[1220]

Liquefied natural gas (LNG) facilities

LNG is methane vapor that has been turned into liquid through a cryogenic process that lowers the temperature of the gas to its condensation point (– 259^{o} F). Chilling natural gas to its liquid state shrinks its volume by a factor of 600, allowing LNG to be transported to places

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[1218] Fehling, D. (2015, October 19). On edge of Houston, underground caverns store huge quantities of natural gas liquids. *Houston Public Media*. Retrieved from http://www.houstonpublicmedia.org/articles/news/2015/10/19/124674/on-edge-of-houston-underground-caverns-store-huge-quantities-of-natural-gas-liquids/

[1219] Lefler, D. (2011, October 5). Lawsuit leaves large gas storage fields in Kansas unregulated. *Wichita Eagle.* Retrieved from http://www.kansas.com/news/article1071558.html

[1220] Keeley, D. (Health and Safety Laboratory). (2008). *Failure rates for underground gas storage: Significance for land use planning assessments.* Health and Safety Laboratory for the Health and Safety Executive, Derbyshire, UK. Retrieved from http://www.hse.gov.uk/research/rrpdf/rr671.pdf

where pipelines don't reach, as when it is exported overseas on massive tanker ships. LNG is also sometimes used as vehicle fuel in, for example, long-haul trucks. LNG facilities encourage fracking by creating storage for the glut of gas that fracking has created, by enabling its export, and by driving up prices and profit margins. LNG facilities are capital-intensive and consist of liquefaction plants, import/export terminals, tanker ships, regasification terminals, and inland storage equipment.

LNG liquefaction requires immense energy in order to achieve the ultra-low temperatures required for condensation. An LNG facility typically requires its own power plant. Because they rely on evaporative cooling, LNG tanks are leaky by design: to maintain the liquid at super-chilled temperatures and prevent explosions, vaporized gas is vented from storage tanks directly into the atmosphere. Larger tanks are engineered to capture boiled-off gas, but this process is not leak-proof. Before it is combusted or sent down a pipeline, LNG must be regasified via an energy-intensive process that requires massive infrastructure of its own, including periodic flaring to control pressure. Refrigeration, venting, leaks, flaring, and shipping make LNG more energy intensive than conventional natural gas. A recent analysis shows that exporting large quantities of LNG from the United States will likely cause global greenhouse gas emissions to rise not only because of its energy penalty but also because LNG exports add more fossil fuels to the global market and extend the lifespan of U.S. coal-fired plants.

LNG creates acute public safety risks. LNG explodes when spilled into water and, if spilled on the ground, can turn into rapidly expanding, odorless clouds that can flash-freeze human flesh and asphyxiate by displacing oxygen. If ignited at the source, LNG vapors can become flaming "pool fires" that burn hotter than other fuels and cannot be extinguished. LNG fires burn hot enough to cause second-degree burns on exposed skin up to a mile away. LNG facilities pose significant risks to nearby population centers and have been identified as potential terrorist targets.

- July 13, 2018 – A retrospective look at the risk management and risk governance used to develop and construct three LNG facilities in Gladstone, Australia evaluated the process by which multiple stakeholders—including government, business, community, and environmental groups—contributed to decision-making and management. The framework developed by the International Risk Governance Council was used for comparison. Environmental, social, and economic impacts occurred during construction, including death of harbor marine life, increased housing prices, and increased cost of living. Several problems in risk assessment and management were identified, including lack of cooperation between organizations at the onset of construction; disagreement as to whether monitoring and compliance mechanisms were adequate; and concern that the government was reactive to problems, rather than attempting to prevent or mitigate risks. Several recommendations were made to improve the risk management process of future projects.[1221]

[1221] van der Vegt, R. G. (2018). Risk assessment and risk governance of liquefied natural gas development in Gladstone, Australia. *The Extractive Industries and Society, 6*(1), 58-66. doi: 10.1111/risa.12977

- February 12, 2018 – Two LNG storage tanks were shut down at Cheniere Energy's Sabine Pass export facility after leaking LNG was found in a containment ditch around one of the tanks and 14 separate natural gas leaks were discovered around the base of a second tank. The Sabine Pass facility is located on the U.S. Gulf Coast on the border between Texas and Louisiana. Emergency procedures were put into place to assure the safety of the 107 on-site workers, but the public was not notified about this incident until more than two weeks later. Inspection revealed four cracks up to six feet long in the outer shell of the tank that had leaked LNG. These tanks are double walled, but only the inner tank is designed to tolerate the super-chilled temperature of LNG. The outer tank, rated to only -25^{o} F, became brittle upon contact with -260^{o} F LNG. The resulting investigation uncovered a long history of safety issues at this plant, including 11 other incidents involving these tanks that had occurred as far back as 2008 (when Sabine Pass was operating as an LNG import facility) after the federal Pipeline and Hazardous Materials Safety Administration (PHMSA) ordered Cheniere to conduct a root cause analysis and turn over records of any prior leaks.[1222] The agency also issued an order stating, "continued operation of the affected tanks without corrective measures is or would be hazardous to life, property, and the environment." Sabine Pass facility was required to receive written authorization from the Federal Energy Regulatory Commission (FERC) before the tanks could be put back in service.[1223] As part of a later hearing, parts of which were closed to the press and to the public, an accident investigator with PHMSA said that she had struggled with the company to get information "timely and in enough detail."[1224] In April 2018, the parties agreed to resolve the issue without administrative proceedings or litigation.[1225]

- November 20, 2017 – Using a hybrid lifecycle and energy strategy analysis, a team of energy researchers investigated the potential climate impacts of U.S. LNG exports to Asia. They found that gas emissions were widely variable, dependent on the specific destination and the ultimate purpose for which the gas is used. Despite this range, under a scenario in which U.S. LNG exports continue to rise, "emissions are not likely to decrease and may increase significantly" because of additional energy demand, higher U.S. emissions, and increased methane leakage. The study also predicted that increased LNG exports could actually prolong the lifespans of coal-fired plants within the United States. All together, these factors, "have the very real potential to undermine any prospective climate benefit in the long run." Going forward, policymakers must consider "the complete climate ramifications of LNG exports."[1226] *E&E News*, reporting on the study, quoted one of the authors as saying, "The implications of our paper are that the

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[1222] Mandel, J., & Soraghan, M. (2018, February 12). Feds order partial shutdown at Cheniere LNG export site. *E&E News.* Retrieved from https://www.eenews.net/stories/1060073537

[1223] Schleifstein, M. (2018, February 10). Sabine Pass LNG ordered to shut down leaking gas storage tanks. *Nola.com.* Retrieved from http://www.nola.com/environment/index.ssf/2018/02/sabine_pass_lng_ordered_to_shu.html

[1224] Klump, E., & Soraghan M. (2018, March 22). Cheniere says no public danger from Sabine Pass leaks. *E&E News.* Retrieved from https://www.eenews.net/stories/1060077135

[1225] Cheniere settles Sabine Pass LNG tanks issue with PHMSA. *LNG World News.* Retrieved from https://www.lngworldnews.com/cheniere-settles-sabine-pass-lng-tanks-issue-with-phmsa/

[1226] Gilbert, A. Q., & Sovacool, B. K. (2017). US liquefied natural gas (LNG) exports: Boom or bust for the global climate? *Energy, 141*, 1671-1680. doi: 0.1016/j.energy.2017.11.098

greenhouse gas impacts from exporting U.S. natural gas…here at home and abroad, can be very, very bad."[1227]

- November 16, 2017 – A legal analysis in the *Energy Law Journal* examined the contested decision by the Federal Energy Regulatory Commission to authorize the expansion of the Dominion Cove Point LNG facility to allow for export as well as import activity, by examining the multiple direct and indirect effects of the expansion. Direct effects included impacts on water quality, the North Atlantic right whale, and the public safety of local residents. Indirect effects included an increase in domestic fracking, increase in tanker traffic, and exacerbation of climate change as export markets increase demand for natural gas. Because this latter set of problems is not directly related to facility expansion but rather to increased LNG exports, two different federal agencies have jurisdiction. The responsibilities of FERC and the Department of Energy (DOE) were clarified regarding this distinction. FERC handles the environmental review, while the DOE regulates export of LNG. In the case of Cove Point, FERC had issued a finding of no significant impact and was therefore not legally required to investigate indirect effects such as climate change. The analysis therefore concluded that FERC followed proper procedures and that the DOE would be a more appropriate target of legal action because of its control over LNG exports. This analysis reveals the diffusion of responsibility among federal agencies regulating LNG facilities and the legal difficulties of addressing far-removed, indirect harms.[1228]

- July 25, 2017 – Citing volatile market conditions, Malaysia's energy giant Petronas cancelled plans for a massive LNG export terminal at the mouth of the Skeena River on British Columbia's remote northwest coast in Canada. As reported extensively by *The Tyee,* the project was the target of intense protest by First Nations people and the subject of many lawsuits, as it threatened public health and would industrialize pristine salmon habitat. "At one time as many as twenty LNG projects were proposed for coastal communities, but not one has been built. The majority of largely Asian-backed proponents have now cancelled or deferred their projects. A 50 percent drop in global oil prices combined with a 70 percent drop in global LNG prices forced Petronas to…scuttle a number of projects over the last two years."[1229]

- July 10, 2017 – Using a lifecycle assessment and optimization analysis to forecast the environmental impacts of LNG, researchers modeled three usage scenarios: hydrogen production; electricity generation; and vehicle fuel. The model assumed LNG transport by pipeline only, and not by tanker. The highest environmental impact in each case was

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[1227] Gilmer, E. M., & Mandel, J. (2017, December 15). Increased LNG exports would spell trouble for climate – study. *E&E News.* Retrieved from https://www.eenews.net/stories/1060069129
[1228] Rhodes, K. (2017). The weakest link: The consistent refusal to consider far-removed indirect effects of the expansion of LNG terminals. *Energy Law Journal, 38* (2), 431-453.
[1229] Nikiforuk, A. (2017, July 25). 'Basic economics' kill $11-billion LNG project on BC's coast. *The Tyee.* Retrieved from https://thetyee.ca/News/2017/07/25/LNG-Project-BC-Coast-Killed/?utm_source=facebook&utm_medium=social&utm_content=072517-4&utm_campaign=editorial-0717

global warming potential (GWP), and the highest GWP occurred when LNG was used as vehicle fuel.[1230]

- April 11, 2017 – The World Bank Group, which makes loans to developing nations for capital projects like infrastructure, released environmental, health, and safety guidelines for LNG facilities. These guidelines address the risks of spills, fire, explosions, air quality impacts, venting, flaring, and fugitive emissions. Also addressed was the danger of "roll-over," a phenomenon that occurs when layers of LNG of different density in a storage tank mix inappropriately. The result can be a rapid release of vapors and rise in pressure, potentially leading to catastrophic structural damage of the tank.[1231]

- March 30, 2017 – Transportation researchers identified and assessed potential risks to public safety from LNG transport on inland waterways and as a fuel for vessels and ferries. The hazards included the possibility of collision with other ships or with stationary objects such as bridges, as well as the threats of vapor release, flash and jet fires, boiling liquid expanding vapor explosion, and rapid phase transition. Firefighting strategies for different scenarios were proposed.[1232]

- March 9, 2017 – Liquefaction, LNG transport, and LNG evaporation determined more than 50 percent of LNG's global warming potential (GWP) in a "cradle to gate" life cycle analysis of LNG imported to the UK from Qatar. The analysis confirmed the dangerous effect of fugitive methane emissions on the total GWP of the supply chain. Other important parameters affecting GWP included the shipping distance and the tank volume.[1233]

- December 22, 2016 – Methane emissions from the heavy-duty transportation sector have climate change implications, according to a "pump-to-wheels" evaluation of natural gas powered vehicles and the compressed natural gas and LNG stations that fuel them. While fueling stations themselves leak methane, tailpipe and crankcase emissions were the highest sources.[1234]

- May 2, 2016 –The potential economic and greenhouse gas (GHG) impacts of importing LNG to Hawaii for electricity generation was modeled. Methane is a potent GHG, and although the use of LNG would decrease the local GHG output of Hawaii's electrical

[1230] Zhang, Y., Jiang, H., Li, J., Shao, S., Hou, H., Qi, Y., & Zhang, S. (2017). Life cycle assessment and optimization analysis of different LNG usage scenarios. *International Journal of Life Cycle Assessment.* Advance online publication. doi: 10.1007/s11367-017-1347-2

[1231] World Bank Group. (2017). Environmental, health, and safety guidelines for liquefied natural gas facilities. Retrieved from https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_policy_ehs-lng

[1232] Galieriková, A., Kalina, T., & Sosedová, J. (2017). Threats and risks during transportation of LNG on European inland waterways. *Transport Problems,12*(1), 73-81. doi: 10.20858/tp.2017.12.1.7

[1233] Tagliaferri, C., Clift, R., Lettieri, P., & Chapman, C. (2017). Liquefied natural gas for the UK: A life cycle assessment. *International Journal of Life Cycle Assessment, 22*, 1944–1956. doi: 10.1007/s11367-017-1285-z

[1234] Clark, N. N., McKain, D. L., Johnson, D. R., Wayne, W. S., Li, H., Akkerman, V., … Ugarte, O. J. (2017). Pump-to-wheels methane emissions from the heavy-duty transportation sector. *Environmental Science & Technology, 51*(2), 968-976. doi: 10.1021/acs.est.5b06059 sector, lifecycle (global) GHG emissions would likely increase. This study did not examine other potential environmental impacts of LNG. Currently, the majority of Hawaii's electricity is provided by oil-fired generation.[1235]

- November 12, 2015 – New York Governor Andrew Cuomo rejected a heavily contested proposal to construct an LNG terminal 19 miles off the coast of Long Island. From his letter to the Maritime Administration: "The security and economic risks far outweigh any potential benefits….The potential for disaster with this project during extreme weather or amid other security risks is simply unacceptable." The governor also noted the risks posed to scallop and squid fisheries as well as the project's conflict with a proposed large-scale, offshore wind farm.[1236]

- September 30, 2015 – Measurements of the gaseous and particulate emissions of a cruise ferry on the Baltic Sea using a dual-fuel engine showed that LNG is not a clean fuel for ships. Methane made up about 85 percent of the vessel's hydrocarbon emissions. Particulate emissions showed a huge amount of volatile and nonvolatile particles, both of which are hazardous to human health.[1237]

- September 26, 2014 – The U.S. Government Accountability Office (GAO) issued a report of the federal process for reviewing applications to export LNG. As part of the process, the DOE and FERC consider public comment. Numerous environmental concerns include the risk that exports will increase hydro-fracking for natural gas, along with its associated environmental effects and greenhouse gas emissions. Under the National Environmental Policy Act, the DOE must consider the environmental effects of its decisions.[1238]

- April 23, 2014 –The dynamics and hazards from a LNG spill are not well understood and require further research, according to a comprehensive review of research into the LNG production chain from Australia that examined vapor production, vapor dispersion, and mechanisms of combustion. Noting the "intrinsic process safety issues" of LNG as well as potential attraction as a terrorist target, authors described various threats to human safety, including pool fires, jet fires, and vapor cloud explosions.[1239]

- December 14, 2009 – Certain LNG hazards are not "understood well enough to support a terminal siting approval," according to a Congressional Research Service (CRS) report that summarizes LNG hazards in the context of federal rules related to where LNG

[1235] Coffman, M., Bernstein, P., Wee, S., & Schafer, C. (2017). Economic and GHG impacts of natural gas for Hawaii. *Environmental Economics and Policy Studies, 19*, 519–536. doi: 10.1007/s10018-016-0157-2
[1236] Santora, M. (2015, November 12). Cuomo rejects natural gas port proposed off Long Island. *The New York Times.* Retrieved from https://www.nytimes.com/2015/11/13/nyregion/cuomo-rejects-natural-gas-port-proposed-off-long-island.html?_r=0
[1237] Anderson, M., Salo, K., & Fridell, E. (2015). Particle- and gaseous emissions from an LNG powered ship. *Environmental Science & Technology, 49,* 12568−12575. doi: 10.1021/acs.est.5b02678
[1238] U.S. Government Accountability Office. (2014, September). *Federal approval process for liquefied natural gas exports.* GAO-14-762. Retrieved from https://www.gao.gov/assets/670/666177.pdf
[1239] Ikealumba, W. C., & Wu, H. Some recent advances in liquefied natural gas (LNG) production, spill, dispersion, and safety. *Energy & Fuels, 28(6),* 3556–3586. doi: 10.1021/ef500626u

terminals are located. Potential risks include pool fires and flammable vapor clouds, as well as the possibility of terrorist attacks. The analysis points out the need for additional LNG safety research.[1240]

- July 7, 2009 – Because LNG projects are among the most expensive energy projects, the reserves of gas to justify the investment need to be large enough to guarantee about 30 years of production, according to a report by the Joint Research Centre of the European Union.[1241]

- May 13, 2008 – LNG infrastructure is "inherently hazardous and it is potentially attractive to terrorists," according to a CRS study that was prepared at a time when the United States was a net importer of LNG. Security of tankers, import terminals, and inland storage plants were identified as issues of concern. Serious risks include pool fires with intense heat, which can occur when LNG spills near an ignition source; flammable vapor clouds that can drift until reaching an ignition source; and a rapid phase transition that can generate a flameless explosion. As per this report, there have been 13 serious accidents at onshore LNG terminals since 1944.[1242]

- February 22, 2007 – The GAO examined the results of studies on the consequences of an LNG spill and discussed expert opinion about the consequences of a terrorist attack on an LNG tanker. The studies indicate that 30 seconds of exposure to the heat of an LNG fire could cause burns up to a distance of about one mile. The experts concluded that this would be the most likely public safety hazard, with the risk of explosion less likely. Recommendations were made for further studies, including evaluating the possibility of "cascading failure," where multiple LNG tanks on a ship might fail in sequence.[1243]

- September 9, 2003 – As part of a larger investigation of potential terrorist targets in wake of the 9/11 attacks, the CRS provided a background report to the U.S. Congress on the security of LNG terminals in the United States. At the time, the United States was a net importer of natural gas, and LNG was shipped from overseas to U.S. ports. CRS identified LNG tanker ships and storage infrastructure as "vulnerable to terrorism," noting that tankers could be turned as weapons against coastal cities and that inland LNG facilities are typically located near large population centers. The CRS further noted that

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[1240] [Name redacted]. (2009, December). *Liquefied natural gas (LNG) import terminals: Siting, safety, and regulation.* Congressional Research Service. RL32205. Retrieved from https://www.everycrsreport.com/files/20091214_RL32205_e95cb50c88dbd56a2c8f706b2d521ef7ae81ee00.pdf

[1241] Kavalov, B., Petric, H., & Georgakaki, A. (2009). *Liquefied natural gas for Europe—some important issues for consideration.* European Commission Joint Research Centre, Reference Report. doi: 10.2790/1045.

[1242] Parfomak, P. W. (2008, May). *Liquefied natural gas (LNG) infrastructure security: Issues for Congress.* Congressional Research Service. RL32073. Retrieved from https://www.hsdl.org/?view&did=486464

[1243] U.S. Government Accountability Office. (2007, February). *Public safety consequences of a terrorist attack on a tanker carrying liquefied natural gas need clarification.* GAO-07-316. Retrieved from https://www.gao.gov/new.items/d07316.pdf the public cost of security for LNG shipments, via Coast Guard escorts of tankers through coastal shipping channels, was considerable ($40,000-$80,000 per tanker).[1244]

- August 1, 1995 – The U.S. Department of Transportation identified three important hazardous properties of LNG: flammability hazards (fire or explosion from ignition of leaks); toxicity hazards (asphyxiation from exposure to non-odorized fuel gas); cryogenic hazards (personal injury plus structural failure of equipment from prolonged exposure to extremely cold temperatures.)[1245]

Gas-fired power plants

Found in every state except Vermont, natural gas-fired power plants surpassed coal-burning plants as the leading source of electrical generation in the United States in 2016. There are two types of gas-fueled power plants: combined cycle plants and simple cycle plants. Both types are major emitters of carbon dioxide, uncombusted methane, and nitrogen oxides, which contribute to the formation of ground-level ozone (smog). Combined cycle gas plants reuse waste heat to generate additional electricity and are roughly equivalent in efficiency to an older coal plant. Simple cycle gas plants—also called peaker plants—can be turned on and off faster to meet fluctuating energy demands when electricity needs peak, but they are much less efficient and more polluting than combined cycle plants. Simple cycle peaker plants can often generate more nitrogen oxides and more carbon monoxide than coal plants.

Gas-fired combined cycle plants were formerly promoted as a bridge to reduce emissions while renewables ramp up. However, within the last four years, renewable prices have fallen low enough to allow a transition directly from coal to solar and wind power, revealing that gas plants, with long returns on investment, are more barrier than bridge to renewable energy. At the same time, the lifecycle emissions of both types of gas-fired power plants have been shown to be far higher than previously estimated. New natural gas plants lock in demand for gas for longer than current climate scenarios dictate, which call for net-zero carbon emissions by mid-century. Gas plants thus risk becoming stranded assets, meaning that they would need to be decommissioned well before the end of their lifespan.

Gas-fired simple cycle plants used on demand as peakers are becoming obsolete as battery technology now allows for the storage of renewable energy, decreasing the need for gas plants to provide power in times of peak demand.

Emerging evidence shows a variety of health impacts to people living near gas-fired power plants.

[1244] Congressional Research Service. (2003, September 9). *Liquefied natural gas (LNG) infrastructure security: Background and issues for Congress*. Retrieved from http://www.energy.ca.gov/lng/documents/CRS_RPT_LNG_INFRA_SECURITY.PDF

[1245] U.S. Dept. of Transportation, Federal Transit Administration. (1995, August 1). *Summary of assessment of the safety, health, environmental and system risks of alternative fuel*. Retrieved from https://rosap.ntl.bts.gov/view/dot/8403

- February 11, 2019 – The mayor of Los Angeles announced that the city will close rather than modernize three gas-fired power plants after the California legislature passed a bill requiring the state to get 100 percent of its electrical power from climate-friendly sources by 2045. Instead, the city will pursue clean energy technologies with battery storage. The Scattergood, Haynes, and Harbor natural gas plants will be phased out by 2029.[1246] In a press statement, Los Angeles mayor Eric Garcetti said, "This is the beginning of the end of natural gas in Los Angeles. The climate crisis demands that we move more quickly to end dependence on fossil fuel, and that's what today is all about."[1247]

- February 8, 2019 – The Arizona Corporation Commission voted to extend the state moratorium on buying or building new gas-fired power plants and called for energy storage to provide peak power rather than additional natural gas plants.[1248]

- April 1, 2018 – Integrating environmental, economic, and social factors to evaluate overall sustainability, a British team compared shale gas with other electricity options in the United Kingdom. Fracking emerged as one of the least sustainable ways to produce electricity. Specifically, shale gas ranked seventh out of nine options for electrical generation, with wind and solar energy scoring the best and coal the worst. These results suggest that "a future electricity mix … would be more sustainable with a lower rather than a higher share of shale gas."[1249, 1250]

- July 14, 2017 – A European team evaluated the performance of coal- and gas-fired power plants that are used to back up renewable energy as the European Union transitions to greater reliance renewable sources for electrical generation. As renewables increasingly dominate, traditional fossil fuel plants will be required to ramp up and down and cycle on and off more frequently, However, these ramping and cycling events will negatively impact the operation of the fossil fuel power plants, as they will become fatigued, resulting in higher operational and maintenance costs, reduced lifetime, degraded performance, and higher emissions of air pollution over time. Gas plants are generally more efficient, faster, and less polluting than coal, but under certain conditions will

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[1246] Associated Press. (2019, February 11). Mayor: LA will ditch plan to rebuild natural gas plants. *U.S. News & World Report.* Retrieved from https://www.usnews.com/news/best-states/california/articles/2019-02-11/mayor-la-will-ditch-plan-to-invest-billions-in-fossil-fuels

[1247] Groom, N. (2019, February 12). Los Angeles abandons new natural gas plants in favor of renewables. *Reuters*. Retrieved from https://www.reuters.com/article/us-usa-california-natgas/los-angeles-abandons-new-natural-gas-plants-in-favor-of-renewables-idUSKCN1Q12C9

[1248] Wichner, D. (2019, February 8). Regulators extend ban on new gas power plants in Arizona. *Arizona Daily Star.* Retrieved from https://tucson.com/business/regulators-extend-ban-on-new-gas-power-plants-in-arizona/article_5d492ca0-5763-5fe5-8eac-29f63cbe2b72.html

[1249] Cooper, J., Stamford, L., & Azapagic, A. (2018). Sustainability of UK shale gas in comparison with other electricity options: Current situation and future scenarios. *Science of The Total Environment, 619-620*, 804-814. doi: 10.1016/j.scitotenv.2017.11.140

[1250] Gabatiss, Josh. (2018, January 16). Fracking is one of the least sustainable ways to produce electricity. *The Independent.* Retrieved from https://www.independent.co.uk/environment/fracking-electricity-production-energy-shale-gas-extraction-sustainable-a8160661.html produce more nitrogen oxides (a component of smog) and more carbon monoxide than coal-fired plants. Current fossil fuel technology will need significant and costly improvements in order to handle the increased gradients, number of starts, lower minimum load and emissions.[1251]

- February 1, 2017 – There is a high degree of uncertainty about the methane emissions from natural gas-fired power plants. As part of a study that also included oil refineries, a Purdue University team evaluated methane emissions from three gas-fired power plants in Utah, Indiana, and Illinois during hours of peak operation. Both fugitive methane leaks from the facility at large as well as uncombusted methane from the stacks were measured using aircraft. Results showed that average methane emission rates were larger than facility-reported estimates by factors of 21-120. The authors concluded that gas-fired power plants "may be significant contributors to annual methane emissions in the U.S. despite lack of facility emission reporting in U.S. inventories. Futhermore, results suggest that the primary source of methane emissions at these facilities may be from noncombustion sources."[1252]

- June 28, 2015 – Pregnant women living near gas-fired power plants were more likely to give birth prematurely, according to a study of more than 400,000 infants born in Florida between 2004 and 2005. This study investigated associations between adverse birth outcomes and residential proximity to several types of power plants, including those burning oil, gas, and solid waste.[1253]

- September 22, 2012 – An investigation of methane and nitrous oxide emissions at eight different gas-fired power plants in Korea found that emissions can vary depending on combustion technologies. Results from this study differed both from those used as default emission rates by the Intergovernmental Panel on Climate Change and from those measured in Japan. The authors concluded that technology-specific and country-specific emission factors for gas-fired power plants need to be established.[1254]

- February 27, 2012 – Using hospitalization data, a research team working in New York State examined whether living near a fuel-fired power plant increased the rate of hospitalization for asthma, acute respiratory infections, and chronic obstructive pulmonary disease, all of which have known links to air pollution exposure. Preliminary analyses of hospitalization rates associated with a residence in a zip code with a power plant stratified by type of fuel used (coal, gas, oil, or solid waste) did not show clear or

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[1251] Gonzalez-Salazar, M. A., Kirsten, T., & Prchlik, L. (2018). Review of the operational flexibility and emissions of gas- and coal-fired power plants in a future with growing renewables. *Renewable and Sustainable Energy Reviews, 82*, Part 1, 1497-1513. Advance online publication. doi: 10.1016/j.rser.2017.05.278

[1252] Lavoie, T. N., Shepson, P. B., Gore, C. A., Stirm, B. H., Kaeser, R., Wulle, B., . . . Rudek, J. (2017). Assessing the methane emissions from natural gas-fired power plants and oil refineries. *Environmental Science & Technology, 51*(6), 3373-3381. doi 10.1021/acs.est.6b05531

[1253] Ha, S., Hu, H., Roth, J., Kan, H., & Xu, X. (2015). Associations between residential proximity to power plants and adverse birth outcomes. *American Journal of Epidemiology, 182*(3), 215-224. doi: 10.1093/aje/kwv042

[1254] Lee, S., Kim, J., Lee, J., Lee, S., & Jeon, E.-C.. (2012). A study on the evaluations of emission factors and uncertainty ranges for methane and nitrous oxide from combined-cycle power plant in Korea. *Environmental Science and Pollution Research, 20*(1), 461-468. doi: 10.1007/s11356-012-1144-1 consistent patterns. Therefore, patients were classified as exposed if they lived in a zip code with at least one power plant in it regardless of the type of fuel used. After adjusting for age, sex, race, median household income, and rural/urban residence, the research team found significantly elevated rates of hospitalization for asthma (11 percent increase), acute respiratory infection (15 percent increase), and chronic obstructive pulmonary disease (17 percent increase) among New Yorkers living near at least one fuel-fired power plant.[1255]

- October 20, 2011 – Emergency room visits and hospital admissions in elderly people living close to a new gas-fired power plant in Italy were counted and related to levels of air pollution both before and after the plants became operational. The results showed that ambient levels of nitrogen oxides and particulate matter rose after the plant started operations. Further, despite the fact that pollutants were below the limits set by the European legislation, there was a positive correlation between number of emergency room visits and daily concentrations of these air pollutants among nearby residents aged 70 or older.[1256]

- April 5, 2010 – Most new fossil fuel power plants are gas-powered. In this study, a research team estimated the number of premature deaths from fine particulate matter that would result from bringing 29 proposed fossil-fuel power plants in Virginia on line. Their modelling predicted that, were all 29 plants made operational, concentrations of fine particulate air pollution would rise in 271 counties across 19 states. Over a six-year period, 104 cumulative excess deaths would occur due to operations of these proposed plants.[1257]

[1255] Liu, X., Lessner, L., & Carpenter, D. O. (2012). Association between residential proximity to fuel-fired power plants and hospitalization rate for respiratory diseases. *Environmental Health Perspectives, 120*(6), 807–810. doi: 10.1289/ehp.1104146

[1256] Di Ciaula, A. (2012). Emergency visits and hospital admissions in aged people living close to a gas-fired power plant. *European Journal of Internal Medicine*, *23*(2), e53-e58. Advance online publication. doi: 10.1016/j.ejim.2011.09.013

[1257] Hermann, R. P., Divita Jr, F., & Lanier, J. O. (2010). Predicting premature mortality from new power plant development in Virginia. *Archives of Environmental Health, 59*(10). doi: 10.1080/00039890409605170

Inaccurate jobs claims, increased crime rates, threats to property values and mortgages, and local government burden

According to multiple studies in multiple states, the oil and gas industry's promises of job creation from drilling for natural gas have been greatly exaggerated. Many of the jobs are short-lived, have gone to out-of-area workers, and, increasingly, are lost to automation. With the arrival of drilling and fracking operations, communities have experienced steep increases in rates of crime, variously including assault, rape, sex trafficking, larceny, and auto theft. In the Marcellus Shale region, violent crime increased 30 percent in counties that experienced a fracking boom compared to those without fracking. Aggravated and sexual assaults were the crimes primarily responsible for this increase. Crime rates have increased even with additional allocation of funds for public safety. Financial and other strains on municipal services include those on law enforcement, road maintenance, emergency services, and public school district administration. In Texas alone, road damage and other transportation impacts costs an estimated $1.5-$2 billion a year. In shale boom areas across the United States, school districts report heightened stress, regardless of whether student funding increased or decreased. Economists are increasingly quantifying community quality of life impacts and the unequal distribution of costs and benefits associated with drilling and fracking. Drilling and fracking pose an inherent conflict with mortgages and property insurance due to the hazardous materials used and the associated risks. With the departure of drilling and fracking operations from these communities, some of the challenges are eased. However, such departures can also lead to additional economic harms, such as by sharp upticks in foreclosures, late car and mortgage payments, empty housing units, and failed or diminished local businesses.

- March 14, 2019 – A Canadian team reviewed the research published between 2009–2018 on the impacts on communities of "the whole suite of technologies that aid in the exploration, extraction, and transportation" of natural gas. This first review of impacts across the supply chain found most of the studies addressed upstream communities (those adjacent to the gas extraction), and that midstream and downstream communities were understudied. Midstream communities were those located in transportation corridors, such as near pipelines, and downstream communities were those near processing and shipping facilities. The study identified 28 community impacts across four broad categories: environmental impacts; impacts to infrastructure and service delivery; impacts on policy, regulation, and participation in decision-making; and socioeconomic impacts. In each area, the reviewers identified common findings, mixed results across studies, and research gaps. For social service delivery, for example, the review found significant effects from the boom and bust cycles. In the boom cycle these included "increased pressure on limited infrastructure, affordable housing and daycare, recreational and child/youth programs, and social services to address alcohol and drug addictions, domestic violence, and crime." In the bust cycle there is a continued need for social services, especially as created by unemployment, economic hardship, local business closures, dropping property values, and out-migration. In this period though, there may be cuts to social services, and "peer-reviewed articles rarely focused on the capacity of local governments to address impacts before, during, and after they happen."[1258]

- December 10, 2018 – Although Pennsylvania has been able to realize modest short-term economic growth from fracking, policy researchers found that the state has also allowed costs to be externalized to public health, the environment, and community integrity. Despite emerging evidence on adverse public health effects, there remain significant uncertainties about these externalized costs, especially with regard to the long term. Research done in the state has shown "significant remaining uncertainties in detecting and attributing responsibility for groundwater contamination" associated with fracking. Intensive gas extraction in Pennsylvania can strain communities by several pathways: increased demand for emergency medical and mental health services; loss of housing for low income residents displaced by temporary, out-of-state workers; and increased traffic violations and arrests for driving under the influence. Emergencies at fracking sites can also strain or exceed the capabilities of local emergency response organizations. At the state level, policy weaknesses include failure to mandate the disclosure of fracking chemicals, failure to exercise adequate inspection and enforcement, and failure to institutionalize "stewardship of rents extracted from a nonrenewable resource for future generations."[1259]

- November 21, 2018 – The presence of drilling and fracking operations is linked with fewer visits to overnight recreation sites in National Forests in western states. As part of a USDA Forest Service study that analyzed visitor use data from 27 National Forests with 722 overnight use areas, researchers found that, on average, each additional oil or gas well within a five-kilometer radius of a site was linked to six fewer visits annually. Within a five-kilometer radius, the distance between the well and the campground was not a significant factor. The researchers did not speculate on the overall user experience but wrote that their results do "suggest that the presence of oil and gas development may have a significant enough effect on the user experience to motivate users to recreate elsewhere."[1260]

- October 28, 2018 – In 15 states between 2000 and 2013, intensive shale oil and gas drilling activity was linked with 41,760 fewer students enrolled in school per year in grades 11 and 12. This phenomenon was greatest in states with a younger compulsory schooling age (16 years of age instead of 17 or 18), in states with a lower effective tax rate on oil and gas production, and in rural counties with traditional mining or persistent poverty.[1261] The results of the study, conducted by a team of economists, aligned with

[1258] Buse, C. G., Sax, M., Nowak, N., Jackson, J., Fresco, T., Fyfe, T., & Halseth, G. (2019). Locating community impacts of unconventional natural gas across the supply chain: A scoping review. *The Extractive Industries and Society, 6*(20), 620-629. doi: 10.1016/j.exis.2019.03.002
[1259] Chalfant, B. A., & Corrigan, C. C. (2019). Governing unconventional oil and gas extraction: The case of Pennsylvania. *Review of Policy Research, 36*(1). Advance online publication. doi: 10.1111/ropr.12319
[1260] Rasch, R., Reeves, M., & Sorenson, C. (2018). Does oil and gas development impact recreation visits to public lands? A cross-sectional analysis of overnight recreation site use at 27 national forests with oil and gas development. *Journal of Outdoor Recreation and Tourism. 24,* 45-51. doi: 10.1016/j.jort.2018.11.001
[1261] Zuo, N., Schieffer, J., & Buck, S. (2019). The effect of the oil and gas boom on schooling decisions in the U.S. *Resource and Energy Economics, 55*, 1-23. doi: 10.1016/j.reseneeco.2018.10.002

historical evidence from the 1970s energy boom as well as complementary research from the 2000s, both showing that oil and gas booms "can discourage educational attainment by increasing the opportunity cost for students to stay in school." (See entry below for July 2015.)

- September 24, 2018 – An *E&E* investigation examined cities in North Dakota, Pennsylvania, and Oklahoma that are experiencing lingering financial and social disruptions following oil and gas booms. In Oklahoma, "the state Legislature is trying to fix what some viewed as a string of bad fiscal decisions that led to cuts in education and other services." In Pennsylvania, communities are still roiled by "a series of bitter disputes about whether local landowners were getting their fair share of royalties from gas drilling." In North Dakota, the debt held by the city of Williston was high for a town its size, with its manageability dependent on continuing oil tax income from the state.[1262]

- August 22, 2018 – Marking a decade since Marcellus Shale fracking began in earnest, a five-university research team presented a review of impacts to people, policy, and culture in the greater mid-Atlantic region of the United States. The review's geographic and thematic sections address a range of impacts on Pennsylvania communities and a discussion of the less-studied communities in West Virginia and Ohio undergoing fracking. Economic impacts in Pennsylvania, contrary to what political and business interests typically tout, are mixed. Employment data showed that positive effects for local residents "are relatively small and temporary, in large part because much of the employment benefits from the activity goes to workers living outside the host communities." Further, among local residents, economic benefits were unequally distributed based on land ownership. In Pennsylvania, about half of lease and royalty dollars accrue to the top 10 percent of local landowners who owned the most acreage, while the bottom 70 percent of landowners collectively receive only 2.8 percent of all such dollars. "The vast majority of local residents were not rural landowners and thus were unable to take advantage of gas leasing for revenue." For poorer residents in fracking areas, "radically tightening housing markets, coupled with skyrocketing housing costs," presented fundamental economic hardships.[1263]

- June 6, 2018 – Uneven distribution of economic/service-related benefits and social/environmental costs characterize the Barnett and the Eagle Ford shale plays in Texas, according to an analysis of shale energy development in the southern United States that included both objective and perceived effects. Transportation-related hazards, deemed "the big one," were seen as the primary concern to community leaders and residents. Multiple sources and study types corroborated the objective transportation trends and harms. For example, a survey of county and city public officials in the 15-county Eagle Ford Shale region concluded that increasing transportation demands resulting from fracking "have not been met with needed state resources to maintain

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[1262] Lee, M., & King, P. (2018, September 24). These places rode out the boom and bust. Now what? *E&E News.* Retrieved from https://www.eenews.net/stories/1060099341

[1263] Jacquet, J. B., Junod, A. N., Bugden, D., Wildermuth, G., Fergen, J. T., Jalbert, K., . . . Ladlee, J. (2018). A decade of Marcellus Shale: Impacts to people, policy, and culture from 2008 to 2018 in the Greater Mid-Atlantic region of the United States. *The Extractive Industries and Society, 5,* 596-609. doi: 10.1016/j.exis.2018.06.006

and/or upgrade transportation facilities to meet the increased volume and weight of vehicles using the transportation system in local communities.” An Academy of Medicine, Engineering and Science of Texas Task Force on Environmental and Community Impacts of Shale Development in Texas likewise concluded, “the level of funding to address the impacts to the transportation infrastructure and traffic safety in the oil and gas industry area is low relative to the magnitude of the impact.” This analysis also described uneven distribution of benefits. For example, individuals and energy companies located outside of the region held 96 percent of Eagle Ford mineral wealth.[1264]

- March 4, 2018 – Local governments in highly rural regions experiencing large-scale growth in oil and gas activity faced the greatest fiscal challenges, according to a study evaluating the effects of this development in 21 U.S. regions during boom and bust periods. “Increased crime, vehicle accidents, and other public safety issues were major challenges,” and “the scale of these challenges tended to track the scale of population growth and a region's rurality.” Though revenues from property and sales taxes and other sources resulted in a net gain for many local governments, the volatility of industry activity and population growth created especially difficult challenges for some municipalities. In a rural western Colorado city, for example, residents were faced with increased taxes, as well as increased water and wastewater fees to service the debt incurred by needed upgrades.[1265]

- February 13, 2018 – Economists found that Oklahoma home prices in 2006 to 2014 declined by three to four percent after experiencing a moderate earthquake. Further, sale prices for the properties affected by the most intense earthquakes were estimated to have declined from 3.5-10.3 percent. The study also found that houses were on the market significantly longer following earthquake exposure. The intensity of a quake for each property was determined by linking earthquake magnitude to the distance of the home from its epicenter. The researchers wrote, “Oklahoma provides an exceptional case study as the state most affected by sudden changes in seismic frequency and intensity,” and that although the exact proportion of earthquakes induced by oil and gas activity is not certain, “the Oklahoma Geological Survey has recognized that the majority of earthquakes are likely to be induced.” They concluded that the rise in earthquake activity “has inflicted substantial costs on homeowners in Oklahoma.”[1266]

- January 25, 2018 – In the Marcellus Shale region, counties experiencing a fracking boom suffered a 30 percent increase in violent crime, compared to those with no gas boom. Aggravated and sexual assaults were the crimes primarily responsible for this increase. This research took advantage of “natural experiment” conditions in the region, with a prohibition on fracking in New York State and a fracking boom across the border in Pennsylvania. The study used 2004 to 2012 county-level data from New York and

[1264] Theodori, G. L. (2018). Shale energy development in the Southern United States: A review of perceived and objective social impacts. *The Extractive Industries and Society, 5,* 610-618. doi: 10.1016/j.exis.2018.05.006
[1265] Newell, R. G., & Raimi, D. (2018). The fiscal impact of increased U.S. oil and gas development on local governments. *Energy Policy, 117,* 14-24. doi: 10.1016/j.enpol.2018.02.042
[1266] Cheung, R., Wetherell, D., & Whitaker, S. (2018). Induced earthquakes and housing markets: Evidence from Oklahoma. *Regional Science and Urban Economics, 69,* 153-166. doi: 10.1016/j.regsciurbeco.2018.01.004

Pennsylvania Marcellus Shale regions, on unconventional gas wells drilled, and on seven "FBI Index I" offenses. The offenses were violent crimes (aggravated assault, rape, robbery, and murder) and property crimes (larceny, burglary, and auto theft). While violent crimes increased in fracking boom areas, property crimes did not. The research featured many controls to isolate the effects of the fracking economy on crime rates. In addition, "victimization costs" were estimated to be $8.1 million per year in high fracking counties. "Policymakers along with oil and natural gas proponents often cite the benefits in terms of jobs and income that are created in a community. However, the welfare costs of victims of crimes, among other issues, should also be considered to make optimal policy decisions."[1267]

- January 24, 2018 – The nearest full-time fire department to a deadly Quinton, Oklahoma natural gas rig explosion was nearly 30 miles away, according to an *E&E* investigation focusing on emergency response. "The deaths highlight a crucial fact of the drilling boom—much of it has occurred in rural areas where small-town police officers, sheriff's deputies and volunteer firefighters are often the first responders."[1268]

- January 13, 2018 – Sex trafficking in oil boomtowns remains a huge problem, according to interviews with 185 health and social service professionals, criminal justice personnel, industry and community representatives, and victims of violence in the Bakken oil field region. These results are reflective of the growing literature on the topic. Interviewees shared information on increases in domestic violence, dating violence, sexual assault, stalking, and sex trafficking, Findings demonstrated that sex trafficking was linked to "a confluence of underlying forces including big oil money, an increase in drug cartels and drug use, degradation of women in a male-dominated workforce, increased access to weapons, and a rise in transient populations." A noteworthy contribution of this study was the documentation that participants felt unprepared to address the needs of victims of sex trafficking, having very few resources, and limited background and experience with these problems.[1269]

- December 12, 2017 – Fracking is unlikely to be a panacea for economically marginalized rural, suburban, or urban areas, and economic optimism regarding fracking tends to be overgeneralized, according to a study analyzing national data on socioeconomic wellbeing for the years 2000 to 2011. Researchers noted that large profits for industry and economic development "may not trickle down to residents living in high-production counties," but instead often benefit a relative few, over a temporary time period. The study measured percentage of families below the poverty line in each county, average earnings, median household income, and employment status, to understand these socioeconomic impacts of oil and gas booms. Their literature review also uncovered a disparity in findings: "industry-funded studies have found substantial economic windfalls

[1267] Komarek, T. M. (2018). Crime and natural resource booms: Evidence from unconventional natural gas production. *The Annals of Regional Science, 61,* 113-137. doi: 10.1007/s00168-018-0861-x
[1268] Lee, M., & Soraghan, M. (2018, January 24). Rig wreckage probed for cause of deadly Okla. blast. *E&E News.* Retrieved from https://www.eenews.net/stories/1060071777
[1269] Heitkamp, T. (2018, January 13). Sex trafficking in the Bakken Oil Fields. Presented at Society for Social Work and Research, Washington, DC. Retrieved from https://sswr.confex.com/sswr/2018/webprogram/Paper32717.html

related to extraction… but the peer-reviewed literature suggests mixed or modest effects."[1270]

- September 26, 2017 – The partial abandonment of the Eagle Ford Shale dramatically hurt small business owners, according to a report by *Bloomberg.* "As the shale drillers moved on to richer fields, the South Texas landscape became pockmarked with abandoned structures. This nimbleness—the ability to just pack up and leave at a moment's notice—may give U.S. oil companies a competitive advantage against their more rigid state-run OPEC rivals, but there is a human cost to it all." Concerning one tool and supply company in the region, the investigation found: "During the height of the Eagle Ford boom, R. Katz was supplying as many as 52 rigs and employing as many as 18 people in its office outside Cuero's main strip. Today, it's got 11 rig clients and three employees."[1271]

- August 10, 2017 – Researchers from the independent, nonpartisan economic research group Resources for the Future studied the impacts of unconventional oil and gas booms on public school districts in the oil- and gas-producing states Pennsylvania, Ohio, West Virginia, North Dakota, Montana, and Colorado between 2000 and 2013. Using quantitative data analysis as well as extensive interviewing with parents and students in the districts, the study addressed the effects of recent oil and gas booms on student enrollment, teachers, public education finances, and student achievement metrics. Though divergent trends were found between school districts in the eastern versus western U.S., "nearly all boom districts reported heightened stress from financial volatility." Though some districts had a statistically positive increase in per student funding while others had a decline, "the study found that greater revenues do not always translate into increased educational outcomes…. One western Colorado school district had to operate on a four-day-a week schedule and cut academic programs because of increased economic volatility."[1272] As reported in *U.S. News and World Report*, "the boom-and-bust cycle of the industry was found to create overwhelming stress on local districts as students and teachers were moving in and out of a region to meet the economic demands of drilling."[1273]

- June 18, 2017 – A Shale Task Force of the Academy of Medicine, Engineering and Science of Texas (TAMEST) developed the report, *Environmental and Community Impacts of Shale Development in Texas*, a "first-of-its-kind, comprehensive review of scientific research and related findings regarding impacts of shale oil and gas production

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[1270] Mayer, A., Olson-Hazboun, S. K., & Malin, S. (2018). Fracking fortunes: Economic wellbeing and oil and gas development along the urban-rural continuum. *Rural Sociology, 83*(3), 532-567. Advance online publication. doi: 10.1111/ruso.12198

[1271] Murtaugh, D. (2017, September 26). The oil ghost towns of Texas. *Bloomberg.* Retrieved from https://www.bloomberg.com/news/features/2017-09-26/the-oil-ghost-towns-of-texas

[1272] Ratledge, N., & Zachary, L. (2017). *Impacts of unconventional oil and gas booms on public education: A mixed-methods analysis of six producing states.* Retrieved from http://www.rff.org/research/publications/impacts-unconventional-oil-and-gas-booms-public-education-mixed-methods

[1273] Englert, E. (2017, August 10). Fracking brings challenges to local school systems. *U.S. News and World Report.* Retrieved from https://www.usnews.com/news/national-news/articles/2017-08-10/fracking-brings-challenges-to-local-school-systems in Texas." Transportation impacts included road damage costing Texas an estimated $1.5 to $2 billion a year, and rural crashes involving commercial vehicles increasing over 75 percent in some drilling regions. The number of fatal collisions in the Permian Basin doubled from 94 during 2006 to 2009, to 183 from 2010 to 2013. The report also noted that Texas is the only major oil and gas producing state without a "surface damage act" to protect landowners, who do not own the mineral rights on their land and have little control over oil and gas operations. The report, which also addressed topics such as seismicity, air, and water, noted that the various impacts of oil and gas development "can't be studied or addressed in isolation." Authors continued, "[t]hese connections are important and pervasive, but are not well-studied yet." TAMEST includes all of the state's Nobel Laureates, plus Texas-based members of the National Academies of Sciences, Engineering, and Medicine.[1274]

- April 6, 2017 – The economic impacts of fracking at the advent of the Marcellus Shale boom is an understudied topic. The onset of fracking was so rapid that academics were challenged to provide accurate and timely information to policymakers, and the one major paper that did appear in 2011 did not clearly disclose its industry sponsorship. A Pennsylvania Department of Community & Economic Development-funded study set out to investigate those early years. In addition to scrutinizing available data, the authors conducted a survey of 1,000 landowners in Bradford and Tioga counties, the two counties with the most fracked wells in Pennsylvania at the start of the boom. From the 501 returned surveys, they determined residents saved more than half of their earliest royalty and lease income, which "may or may not ultimately be spent within Pennsylvania." Hence, the windfalls from mineral rights created "little economic impact during the year received." Further, the study's overall "lower-bound" estimate of economic impacts for 2009 found that fully 15.4 percent of these mineral rights were owned by non-residents. At the same time, survey results showed that 37 percent of the workforce consisted of non-residents with only half of their income staying in the state. This study's upper-bound jobs count for 2009 was substantially lower than the estimates that made at the time. In addition, the study urged caution regarding future jobs predictions, as the sharp decline between 2011 and 2013 "was totally unexpected" and was not captured in a 2010 forecast for jobs in 2020.[1275]

- April 5, 2017 – Economists at Colorado State University quantified the "substantial environmental costs associated with hydraulic fracturing," as part of an analysis of the market and non-market costs and benefits of fracking in 14 U.S. states. These costs were "dominated by $27.2 billion ($12.5–$41.95 billion) health damages from air pollution." They also found costs including "$3.8 billion ($1.15–$5.89 billion) in greenhouse gas emissions, $4 billion ($3.5–$4.45 billion) in wildlife habitat fragmentation, and $1 billion ($0.5–$1.6 billion) in pollution of private drinking water wells." Results also showed a disconnect between those reaping economic rewards from fracking and those paying the

[1274] The Academy of Medicine, Engineering and Science of Texas. (2017. *Environmental and Community Impacts of Shale Development in Texas.* Retrieved from http://tamest.org/shale-task-force/
doi: 10.25238/TAMESTstf.6.2017

[1275] Hoy, K. A., Kelsey, T. W., & Shields, M. (2017). An economic impact report of shale gas extraction in Pennsylvania with stricter assumptions. *Ecological Economics, 138,*178-185. doi: 10.1016/j.ecolecon.2017.03.037

price: the "benefits" (mostly in the form of lower natural gas prices to residential, commercial, and industrial consumers) were geographically dispersed while the costs tended to concentrate in localized areas where drilling took place. Although the most comprehensive economic study to date, this analysis was not able to fully quantify all costs, including those related to water contamination (beyond surface-spill related costs for damage to private wells); diminishment of open spaces and aesthetics for community members; and seismic activity. The authors concluded that costs might well outweigh the benefits for suburban dwellers near fracking operations, as exemplified by Denton, Texas, where "nearly all the royalty money was flowing to mineral owners living elsewhere…rather than to adjacent homeowners."[1276]

- February 19, 2017 – The *New York Times* reported on the oil and gas industry's embrace of automation and its threat to preserving and bringing back jobs. Executives interviewed as part of the investigation were straightforward in their intentions to shrink their work forces. "'We want to transform our work force to the point where we need to hire fewer people,' said Joey Hall, Pioneer's executive vice president for Permian Operations." In 2016 Pioneer Natural Resources added 240 wells in West Texas without adding any new employees. A vice president at a Pennsylvania manufacturer of drilling rigs stated, "If it's a repetitive task, it can be automated, and I don't need someone to do that. I can get a computer to do that."[1277]

- February 1, 2017 – Stanford University earth science professor Robert Jackson and two professors of law assessed how a new type of "conservation easement," an established kind of legal agreement, could enable landowners to restrict fracking on their properties. A mineral estate conservation easement (MECE) can serve as a private landowner response to the demonstrable threats of fracking to property and community: "Accompanying the rise of high-volume hydraulic fracturing has been a suite of environmental and social concerns, including potential water and air contamination, greenhouse gas emissions, health effects, and community disruptions." "We support the exploration of MECEs as an additional tool for landowners to exercise their rights and responsibilities," the team concluded.[1278]

- January 26, 2017 – Automation is reducing the size of drilling crews and will lessen the number of jobs added nationally with any upturn in oil and gas operations, according to a piece on OilPrice.com. The author described predictions, including:

[1276] Loomis, J., & Haefele, M. (2017). Quantifying market and non-market benefits and costs of hydraulic fracturing in the United States: A summary of the literature. *Ecological Economics, 138,* 160-167. doi: 10.1016/j.ecolecon.2017.03.036
[1277] Krauss, C. (2017, Feburary 19). Texas oil fields rebound from price lull, but jobs are left behind. *New York Times*. Retrieved from https://www.nytimes.com/2017/02/19/business/energy-environment/oil-jobs-technology.html?_r=0
[1278] Jackson, R. B., Owley, J., & Salzman, J. (2017). Mineral estate conservation easements: A new policy instrument to address hydraulic fracturing and resource extraction. *Environmental Law Reporter*, *47*(2). 10112-10120. Retrieved from https://elr.info/news-analysis/47/10112/mineral-estate-conservation-easements-new-policy-instrument-address-hydraulic-fracturing-and-resource-ext

Automated drilling rigs may be able in the future to reduce the number of persons in a drilling crew by almost 40 percent, from 25 workers to 15 workers, *Houston Chronicle*'s Jordan Blum writes, quoting industry analysts.

Drilling company Nabors Industries expects that it may be able to reduce the size of the crew at each well site to around 5 people from 20 workers now if more automated drilling rigs are used, Bloomberg's David Wethe says.[1279]

- December 22, 2016 – Researchers with the Energy Policy Institute at the University of Chicago measured the costs and benefits of fracking in local communities across nine U.S. shale basins. They found that, despite contributions to local economies with the arrival of fracking, residents experienced decreases in local quality of life. Spikes in crime were the most directly measurable of these effects. "Despite local governments' efforts to improve public safety—allocating 20 percent more funding—the crime rates still marginally increased." The study also found unequal distribution of benefits. Students, the elderly, and those who don't own mineral rights did not benefit at all. Their analysis found an average gain of about $1,300 to $1,900 per household per year, but these gains were offset by a reduction in the typical household's quality of life, which the authors computed at about $1,000 to $1,600 per year.[1280]

- December 21, 2016 – Economists from the University of Anchorage and Montana State University studied the impact of regional shale energy booms on crime rates across U.S. counties from 2000 to 2013, documenting increased rates of many types of crime, including assault, rape, larceny, and auto theft. In 2013, they pegged the average monetary cost of these additional crimes at $2 million per county. Researchers emphasized these results represented short-term costs only, as they could not predict how crimes rates and attendant costs will accrue over longer periods of time, as, for example, if criminal behavior and labor migration facilitate a slow drain of human and physical capital from the region and propagate "a long-term resource curse." The study also found "that registered sex offenders moved in disproportionate numbers to boom towns in North Dakota," and "that income inequality increased as the shale boom progressed."[1281]

- May 24, 2016 – In 327 U.S. counties previously at the center of the fracking boom, overdue car loans approached their highest level in five years, and late mortgage payments also rose, according to a report by the *Financial Times* that examined data from the Federal Reserve Bank of New York. These trends stood in stark contrast to lowered overdue debt rates in the rest of the U.S. This surge in late car payments in intensely fracked areas of the United States has "exposed the damage done by the collapse in

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[1279] Paraskova, T. (2017, January 26). Robots over roughnecks: Next drilling boom might not add many jobs. *OilPrice.com.* Retrieved from https://oilprice.com/Energy/Energy-General/Robots-Over-Roughnecks-Next-Drilling-Boom-Might-Not-Add-Many-Jobs.html

[1280] Bartik, A. W., Currie, J., Greenstone, M., & Knittel, C. R. (2016). *The local economic and welfare consequences of hydraulic fracturing.* Energy Policy Institute at the University of Chicago. Retrieved from https://epic.uchicago.edu/research/publications/local-economic-and-welfare-consequences-hydraulic-fracturing

[1281] James, A., & Smith, B. (2016). There will be blood: Crime rates in shale-rich U.S.counties. *Journal of Environmental Economics and Management, 84,* 125–152. doi: 10.1016/j.jeem.2016.12.004

drilling activity and marred broadly positive trends for late debt payments by American consumers."[1282]

- May 8, 2016 – With the downturn in the fracking industry, Wisconsin's sand mining sector, which provides silica sand for fracking operations, has also slumped and prompted significant layoffs and job losses in both 2015 and 2016, according to a report by Eau Claire's *Leader-Telegram*. "This is what the bust part of the boom-and-bust cycle of the energy sector looks like, and it's something west-central Wisconsin residents, who are mostly new to the industry, aren't used to seeing." Other companies that supply goods and services to sand mining operations in the region have also experienced a downturn.[1283]

- March 8, 2016 – A DeWitt County, Texas judge estimated it will cost his county $432 million to rebuild its roads, noting that if a road "leads to a rig site, it's bound to be a broken road." The judge stated that ultimately the companies would pay a large share.[1284]

- February 22, 2016 – *Inside Energy* investigated oil-industry related wage theft claims in the West, finding "a growing number of oil workers are turning to the courts, saying they weren't paid fairly even when times were good." Between 2010 and 2015, wage theft suits against oil and gas companies in Colorado increased by a factor of nine, and in Texas nearly ten times. The investigation found that oil and gas companies were consistently among the top violators of wage laws—especially in failure to pay overtime. A federal investigation of the industry led to the recovery of $40 million dollars in unpaid wages. One of the officers involved in the investigations is quoted saying, "We have found cases where workers were not even paid the minimum wage, because they're working so many hours…. So the idea that they're being highly compensated, in some cases, they're not."[1285]

- January 13, 2016 – A fire on a fracking site in Grady County, Oklahoma that consumed 22 oil tankers required the response of six regional fire departments.[1286]

- December 15, 2015 – The value of homes that rely on well water in Pennsylvania dropped an average of $30,167 when fracking took place within 1.5 kilometers, according to a study by Duke University researchers published in the *American Economic Review*. For these groundwater-dependent homes, a fracking well located within one kilometer was linked to a 13.9 percent average decrease in values; homes with wells at

[1282] Fleming, S. (2016, May 24). US fracking bust sparks surge in car debt. *Financial Times.* Retrieved from http://www.ft.com/cms/s/0/a4cb1270-21c2-11e6-aa98-db1e01fabc0c.html
[1283] Lindquist, E. (2016, May 8). Silent sandbox: Once booming frac sand industry continues major downturn. *Leader-Telegram.* Retrieved from http://www.leadertelegram.com/News/Front-Page/2016/05/08/Silentsandbox.html
[1284] Callahan, C. (2016, March 8). Fracking fall-off leaves South Texas roads a mess. *KSAT.com*. Retrieved from http://www.ksat.com/web/ksat/news/fracking-fall-off-leaves-south-texas-roads-a-mess
[1285] Boyce, D. (2016, February 22). Wage theft claims surge as oil prices fall. *Inside Energy.* Retrieved from http://insideenergy.org/2016/02/22/wage-theft-claims-surge-as-oil-prices-fall/
[1286] KFOR-TV, Querry, K., & Fultonberg, L. (2016, January 13). Firefighters extinguish damaging Grady Co. fracking fire. *KFOR.com*. Retrieved from http://kfor.com/2016/01/13/all-lanes-of-traffic-shut-down-due-to-large-oil-rig-fire/

least two kilometers away maintained their value. The study was based on home sales between 1995 and 2012 in 36 counties. Researchers stated that their figures may not fully reflect the total costs associated with groundwater contamination risk, as, for example, when homeowners purchase expensive home water filtration systems. Though their study does not incorporate data on actual contamination, concerns about contamination can significantly affect property values. Researchers found "strong evidence of localized costs borne particularly by groundwater-dependent homes."[1287]

- December 8, 2015 – Even as housing prices in shale gas-areas of Pennsylvania have dropped along with fracking activity, many seniors and people living on low incomes are still being priced out of the market, *StateImpact* reported. Pennsylvania still lacks a quarter million affordable rental homes for people in poverty despite a 2012 law requiring gas companies to pay well fees intended to offset the costs of affordable housing programs in communities where drilling is occurring.[1288]

- December 2, 2015 – "The local economy is feeling the pinch" of the downturn of activity in Pennsylvania's gas fields, according to a Reuters report. The late 2015 slump marked a turning point in Marcellus Shale fracking. Regional economic effects reported include empty hotel rooms and foreclosure notices in Lycoming County at their highest since data were first collected.[1289]

- October 7, 2015 – Vehicular collisions and Texas fracking activity are closely linked, according to a report by the Texas A&M University Transportation Institute. Researchers analyzed the number of crashes and injuries across Texas during the period from 2006 to 2009, when drilling and fracking operations were intensive over the Barnett Shale, as well as from 2010 to 2013, when activity increased in the Permian Basin in West Texas and the Eagle Ford Shale in South Texas, and decreased in the Barnett. Collisions increased where shale gas activity increased and decreased where it slowed down.[1290] Quoted in the *Texas Tribune*, report co-author Cesar Quiroga said, "The two trends correlated so well, and they were perfectly aligned ….We could use this as a predictive model."[1291] Further, the increase was greater in South Texas, the region that relies most heavily on horizontal, hydraulic fracking requiring millions of gallons of water and sand to be trucked in, compared to West Texas which does use fracking but also more simple, vertical wells. The comprehensive cost of these collisions was estimated to be about $2

[1287] Muehlenbachs, L., Spiller, E., & Timmins, C. (2015). The housing market impacts of shale gas development. *American Economic Review*, *105*(12), 3633–3659. doi: 10.1257/aer.20140079
[1288] Cusick, M. (2015, December 8). Despite drilling slowdown, rents still high in fracking boomtowns. *StateImpact.* Retrieved from https://stateimpact.npr.org/pennsylvania/2015/12/08/despite-drilling-slowdown-rents-still-high-in-fracking-boomtowns/
[1289] McAllister, E. (2015, December 2). America's biggest gas field finally succumbs to downturn. *Reuters.com*. Retrieved from http://www.reuters.com/article/us-usa-marcellus-decline-insight-idUSKBN0TL0CY20151202#W0DRBI8eM4MKscSV.97
[1290] Quiroga, C. & Tsapakis, J. (2015). *Oil and gas energy developments and changes in crash trends in Texas.* Texas A&M Transportation Institute, PRC 15-35 F. Retrieved from http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/PRC-15-35-F.pdf
[1291] Malewitz, J. (2015, October 7). Report: Energy boom-related traffic crashes cost billions. *Texas Tribune*. Retrieved from https://www.texastribune.org/2015/10/07/report-shows-huge-toll-energy-boom-traffic-crashes/

billion more from 2010 to 2013—in both the Eagle Ford and Permian Basin—compared to the previous period.

- September 30, 2015 – The North Dakota Bureau of Criminal Investigation was set to hire nine new agents, reported the *Billings Gazette*, "…allowing for more attention to cases of human trafficking and organized crime in western North Dakota … as increased oil production resulted in growing populations."[1292]

- September 29, 2015 – "New residential units sit empty as gas production falls," *HousingWire Magazine* wrote, following up on their earlier reporting describing the link between the drilling boom and the real estate boom in the Bakken shale region of North Dakota. Economic data indicate that Bakken drilling is not lasting long enough to sustain the building explosion.[1293]

- September 9, 2015 – Most local governments in Western North Dakota and Eastern Montana's Bakken region have experienced net negative fiscal effects, according to a Duke University analysis published by the National Bureau of Economic Research. These trends were also seen in municipalities in rural Colorado and Wyoming, which also struggled to manage fiscal impacts during recent oil and gas booms, but in these two states the fiscal impact eased as drilling activity slowed.[1294] Referencing the report, *McClatchyDC* wrote, "North Dakota cities and counties have been slammed." Municipal challenges have included providing water and sewer infrastructure, substantial damage to roads, soaring housing prices, and strained emergency services.[1295]

- August 27, 2015 – Fracking in or near public parks could cause tourists to stay away and lead to a decline in park use, according to a report published by a team of tourism, recreation, and sport management researchers from the University of Florida, North Carolina State University, and Florida State University. Using data collected from 225 self-identified park users from Pennsylvania, Ohio, West Virginia, Kentucky, and Tennessee, researchers reported that only one-third of participants were willing to participate in recreational activities near fracking operations, compared to 38 percent unwilling, and 29 percent neutral. Forty-six percent of respondents supported a ban on fracking on public lands, while 20 percent agreed with promoting fracking on public lands.[1296]

[1292] McCleary, M. (2016, September 30). North Dakota to hire 9 more criminal investigation agents. *Billings Gazette*. Retrieved from http://billingsgazette.com/news/state-and-regional/montana/north-dakota-to-hire-more-criminal-investigation-agents/article_a4192344-c9b0-51cc-9693-5a4335f5be05.html

[1293] Lane, N. (2015, September 29). Is fracking about to bust housing in North Dakota? *HousingWire Magazine.* Retrieved from http://www.housingwire.com/articles/35196-is-fracking-about-to-bust-housing-in-north-dakota

[1294] Newell, R. G., & Raimi, D. (2015). *Shale public finance: Local government revenues and costs associated with oil and gas development.* The National Bureau of Economic Research, Working Paper No. 21542. doi: 10.3386/w21542

[1295] Cockerham, S. (2015, September 9). Oil boom a loser for North Dakota cities, counties, study finds. *McClatchyDC.* Retrieved from http://www.mcclatchydc.com/news/nation-world/national/economy/article34552824.html

[1296] Kellison, T. B., Bunds, K. S., Casper, J. M., & Newman, J. I. (2015). Fracking & parkland: Understanding the impact of hydraulic fracturing on public park usage. Retrieved from http://plaza.ufl.edu/tkellison/_/Fracking.html

- July 1, 2015 – Britain's Department for Environment, Food & Rural Affairs released previously redacted sections of a report on the impacts of drilling and fracking. The report found that housing prices near fracking wells would likely fall up to seven percent for houses within a mile of wells. Furthermore, properties within one to five miles of fracking sites could incur additional insurance costs. The report warned of environmental damages, including from leakage of fracking waste fluids, and found that public health could be affected indirectly through consumption of contaminated wildlife, livestock, or agricultural products. The report also found potential for some benefits, such as job growth.[1297]

- July 2015 – A working paper by researchers with the National Bureau of Economic Research found that fracking resulted in an increase in male teen high school dropout rates. "Our estimates imply that, absent fracking, the male-female gap in high school dropout rates among 17- 18-year olds would have narrowed by about 11 percent between 2000 and 2013 instead of remaining unchanged." The authors explained that by increasing the demand for low-skilled labor, fracking could slow growth in educational attainment. They noted that the relative wage boost from fracking may be only temporary. Indeed, by the end of the sample period, the benefits had started to wane as the labor demand from fracking appeared to no longer favor dropouts. Thus, the fracking boom may be inhibiting educational achievement among young men who "would already be near the bottom of the skill distribution, with possible implications for future productivity and the social safety net."[1298, 1299]

- March 20, 2015 – The U.S. Attorney for Western New York linked a rise in production of methamphetamine to use among workers in the fracking fields of northern and western Pennsylvania. Surging demand for the drug, which allows users to stay awake for 48 to 72 hours, may be related to the extremely long working hours that employees in the gas industry must endure.[1300]

- January 4, 2015 – A documentary by Forum News Service, "Trafficked Report," revealed that sex trafficking, including of children, in the Bakken oil fields of North Dakota was a significant problem.[1301] The dynamics of the oil boom, with an influx of out-of-state and

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[1297] Vaughan, A. & Mason, R. (2015, July 1). Fracking could hurt house prices, health and environment, official report says. *Guardian*. Retrieved from http://www.theguardian.com/environment/2015/jul/01/fracking-could-hurt-house-prices-health-and-environment-official-report-says

[1298] Cascio, F. U., & Narayan, A. (2015, July). *Who needs a fracking education? The educational response to low-skill biased technological Change.* National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w21359

[1299] Chandra, S. (2015, July 14). Fracking jobs encouraged American teens to become high school dropouts. *Bloomberg Business*. Retrieved from: http://www.bloomberg.com/news/articles/2015-07-14/fracking-jobs-encouraged-american-teens-to-become-high-school-dropouts

[1300] Newberg, R. (2015, March 20). Meth use tied to fracking workers in Pennsylvania. *WIVB 4*. Retrieved from http://wivb.com/2015/03/20/meth-use-tied-to-fracking-workers-in-pennsylvania/

[1301] Dalrymple, A., & Lymn, K. (2015, January 4). Trafficked Report: Sex for sale in the Bakken. *Forum News Service*. Retrieved from http://www.traffickedreport.com/?p=15 primarily male workers far from their families, created an increase in demand for prostitution.[1302]

- December 28, 2014 – The *New York Times* profiled the impacts of oil drilling and fracking on the Fort Berthold Indian Reservation in North Dakota, finding corruption, crime, and negative environmental impacts. Aside from a significant rise in jobs, which often go to transient workers, many residents "see deterioration rather than improvement in their standard of living. They endure intense truck traffic, degraded roads, increased crime, strained services and the pollution from spills, flares and illegal dumping." According to the *Times*' calculation, the reservation had seen 850 oil-related environmental incidents from 2007 through mid-October 2014, which generally went unpunished.[1303]

- December 26, 2014 – Examining Pennsylvania Department of Transportation data, Ohio's *Star Beacon* newspaper found that fracking poses a safety threat on rural roads. The paper found that Pennsylvania's five busiest drilling counties recorded 123 more heavy truck crashes in 2011 than before the gas boom began—a 107 percent increase. The paper noted the burden drilling and fracking placed on local communities and governments, including the strain on local emergency responders.[1304]

- December 17, 2014 – Heavy drilling and fracking (defined as 400 or more wells drilled within a county over 5-8 years) was positively correlated with increased crime, sexually transmitted diseases, and traffic fatalities, according to a report by the Multi-State Shale Research Collaborative.[1305] The report looked at the impacts in Pennsylvania, Ohio, and West Virginia, primarily finding statistically significant impacts in six heavily drilled counties in Pennsylvania. In those six counties, violent crime increased 17.7 percent—corresponding to about 130 more violent crimes in those counties in 2012—compared to a decrease in violent crime rates in both urban and rural non-drilling communities. Property crime increased 10.8 percent in those six counties, drug abuse rates rose 48 percent, and drunk-driving offenses rose 65 percent compared to 42 percent in rural areas with no drilling. The report found a statistically significant increase of 24 percent to 27 percent in rates of sexually transmitted diseases across drilling counties in all three states. Motor vehicle fatalities increased 27.8 percent in Pennsylvania's six high-drilling

[1302] Gaines, J. (2015, March 9). The oil boom in North Dakota now has a serious sex-trafficking problem. *Business Insider*. Retrieved from http://www.businessinsider.com/north-dakota-sex-trafficking-prostitution-oil-boom-police-raid-2015-3

[1303] Sontag, D., & McDonald B. (2014, December 28). In North Dakota, a tale of oil, corruption and death. *The New York Times*. Retrieved from http://www.nytimes.com/2014/12/29/us/in-north-dakota-where-oil-corruption-and-bodies-surface.html

[1304] Finnerty, J. (2014, December 26). Fracking's biggest safety threat is on rural roads. *Star Beacon*. Retrieved from http://www.starbeacon.com/news/fracking-s-biggest-safety-threat-is-on-rural-roads/article_bc48687a-8caf-11e4-b4d9-6382c924a6f9.html

[1305] Price, M., Basurto, L., Herzenberg, S., Polson, D.,Ward, S., & Wazeter, E.(2014, December). *The shale tipping point: The relationship of drilling to crime, traffic fatalities, STDs, and rents in Pennsylvania, West Virginia, and Ohio.* The Multi-State Shale Research Collaborative. Retrieved from http://www.multistateshale.org/shale-tipping-point counties. The report found a modest increase in jobs, but noted that an influx of out-of-state workers at least partially explained the increases in traffic and crime.[1306]

- December 15, 2014 – A report written in French by Quebec's Advisory Office of Environmental Hearings concluded that the environmental costs of fracking in the St. Lawrence Lowlands would outweigh the potential economic benefits. In a press release, the Advisory Office of Environmental Hearings concluded that fracking "would not be advantageous for Quebec because of the magnitude of the potential costs and externalities, compared to royalties that would be collected by Quebec. Other concerns also remain, including plans of social acceptability, legislation, and a lack of knowledge, particularly with respect to water resources."[1307]

- October 30, 2014 – The *New York Times* profiled the profound impact heavy drilling has had on Glasscock County, Texas, including its farming community. Farmers described increases in trash, traffic accidents, clashes around farmers selling groundwater to drillers, and economic detriment. In many cases, acres of farmland around a drill site "will probably never be suitable for fertile farming again," and farmers are "at the mercy" of what drillers want to pay for damages. The county itself receives revenue, but most of that additional money "is being used to repair roads damaged by oil field truck activity. Overall, the gains from drilling are not viewed as worth the drawbacks in a county long dominated by cotton farming."[1308]

- September 28, 2014 – A *Washington Post* investigation reported on heroin and methamphetamine addiction—and associated violent crime—among Native American communities located within the Bakken Shale oil fields. According to a chief judge for the Mandan, Hidatsa, and Arikara Nation, "The drug problem that the oil boom has brought is destroying our reservation."[1309]

- September 11, 2014 – An editor for the *Washington Post* examined jobs and manufacturing data in Youngstown, Ohio, to demonstrate that drilling and fracking are not resulting in a revitalization of the Rust Belt as some proponents and a prominent *New York Times* story asserted. The *Post* determined that in Youngstown, Ohio, the manufacturing sector has lost jobs by the tens of thousands in the last twenty years and the oil and gas industry has created approximately two thousand jobs since the recession

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[1306] McKelvey, W. (2014, December 17). Fracking brought spikes in crime, road deaths and STDs to Pa.: Report. *Patriot News*. Retrieved from http://www.pennlive.com/midstate/index.ssf/2014/12/fracking_brought_spikes_in_vio.html

[1307] McCarthy, S. (2014, December 15). Fracking dealt another setback by Quebec report. *Globe and Mail.* Retrieved from http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/bape-says-shale-gas-production-not-advantageous-for-quebec/article22096203/

[1308] Batheja, A. (2014, October 30). A county resents oil drilling, despite the money it brings in. *The New York Times*. Retrieved from http://www.nytimes.com/2014/10/31/us/a-county-resents-oil-drilling-despite-the-money-it-brings-in.html?ref=earth&_r=1

[1309] Horwitz, S. (2014, September 28). Dark side of the boom: North Dakota's oil rush brings cash and promise to reservation along with drug-fueled crime. *The Washington Post.* Retrieved from http://www.washingtonpost.com/sf/national/2014/09/28/dark-side-of-the-boom/

ended. Six years prior, there were 13,000 more jobs in the Youngstown metro area than there were in summer 2014.[1310]

- September 9, 2014 – A study by researchers at Colorado State University examined the political economy of harm and crime associated with the oil and gas industry in rural Colorado, particularly around the rise of fracking. The researchers looked at complaints that citizens filed with the state, and also conducted interviews and examined other data. They found 2,444 complaints between November 2001 and June 2013 covering a range of issues including water, environment, noise, air quality, land use, and more. They characterized citizen complaints as "extensive and complex" and concluded that, regardless of the nature of the harm, most were "persistent and omnipresent" rather than short-lived, isolated problems.[1311]

- September 6, 2014 – In Williams County, North Dakota, in the Bakken Shale, increases in crime have corresponded with the flow of oil. The infusion of cash has attracted career criminals who deal in drugs, violence, and human sex trafficking. The *Williston Herald* portrayed, in a "reader's discretion advised" article, the rapid rise of "index crimes"—"violent crimes that result in the immediate loss of an individual's property, health or safety, such as murder, larceny and rape." With fewer than 100 law enforcement personnel, crime in Williams County "has risen in kind with the county's population, but funding, staffing and support training for law enforcement has not."[1312]

- September 2014 – Reporting on the social, environmental, health and safety, and economic burdens endured by localities from fracking, the magazine *Governing: The States and Localities* found that "fracking, in many cases, negatively impacts property values, which in turn depresses property tax revenue. For property owners who own the rights to the oil and gas on their land, the effects of drilling can be offset by royalty payments. But localities have no revenue offset if properties lose value."[1313]

- August 26, 2014 – The U.S. Justice Department Office on Violence Against Women awarded three million dollars to five rural and tribal communities to prosecute crimes of violence against women and provide services to victims of sexual assault, domestic violence, and stalking in the Bakken Region of North Dakota and Montana.[1314] Rationale documented by tribal leaders, law enforcement, and the FBI included, "rapid

[1310] Tankersley, J. (2014, September 11). Fracking hasn't restored the Rust Belt's lost jobs. *The Washington Post*. Retrieved from http://www.washingtonpost.com/news/storyline/wp/2014/09/11/fracking-hasnt-restored-the-rust-belts-lost-jobs/

[1311] Opsal, T., & Shelley T. O. (2014). Energy crime, harm, and problematic state response in Colorado: A case of the fox guarding the hen house? *Critical Criminology, 22* (4), 561-577.

[1312] Bell, T. (2014, September 6). Modernized slavery. *Williston Herald.* Retrieved from http://www.willistonherald.com/news/modernized-slavery/article_84e257d8-3615-11e4-a4f8-001a4bcf887a.html

[1313] Shafroth, F. (2014, September). Fracking's financial losers: local governments. *Governing: The States and Localities.* Retrieved from http://www.governing.com/columns/public-money/gov-frackings-financial-losers.html

[1314] U.S. Department of Justice. (2014, August 26). Associate Attorney General West announces $3 million in grants to address violence against women in rural and tribal communities in the Bakken Region. *Justice News*. Retrieved from http://www.justice.gov/opa/pr/associate-attorney-general-west-announces-3-million-grants-address-violence-against-women development of trailer parks and modular housing developments often referred to as 'man camps;' abrupt increase in cost of living, especially housing; rapid influx of people, including transients, in a previously rural and stable community; constant fear and perception of danger; and a lost way of life. Local and tribal officials and service providers reported that these changes have been accompanied by a rise in crime, including domestic and sexual violence."[1315]

- May 27, 2014 – A *Bloomberg News* analysis of 61 shale-drilling companies found that the economic picture of shale oil and gas is unstable. Shale debt has almost doubled over the last four years while revenue has gained just 5.6 percent. For the 61 companies in their analysis, *Bloomberg News* reported: "In a measure of the shale industry's financial burden, debt hit $163.6 billion in the first quarter." Further, *Bloomberg* noted that drillers are caught in a bind because they must keep borrowing to pay for exploration needed to "offset steep production declines typical of shale wells…. For companies that can't afford to keep drilling, less oil coming out means less money coming in, accelerating the financial tailspin."[1316]

- May 5, 2014 – An Associated Press analysis found that traffic fatalities have spiked in heavily drilled areas of six states, whereas most other roads in the nation have become safer even as population has grown. In North Dakota drilling counties, for instance, traffic fatalities have increased 350 percent.[1317]

- April 16, 2014 – A comprehensive article in the *Albany Law Review* concluded that the risks inherent with fracking are not covered by homeowner's insurance, not fully insured by the oil and gas industry, and threaten mortgages and property value.[1318]

- April 2014 – A report by the Multi-State Shale Research Collaborative, "Assessing the Impacts of Shale Drilling: Four Community Case Studies," documented economic, community, government, and human services impact of fracking on four rural communities. The study found that fracking led to a rapid influx of out-of-state workers and, although some new jobs were created, these were accompanied by additional costs for police, emergency services, road damage, and social services. In addition, increased rents, and a shortage of affordable housing accompanied the fracking boom.

[1315] U.S. Department of Justice. (2014). OVW Fiscal Year 2014 Violence Against Women Bakken Region Initiative: Enhanced response to victims application guidelines. Retrieved from http://www.justice.gov/sites/default/files/ovw/legacy/2014/04/25/fy2014-initative-for-the-bakken-region-enhanced-services-for-victims.pdf

[1316] Loder, A. (2014, May 27). Shakeout threatens shale patch as frackers go for broke. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2014-05-26/shakeout-threatens-shale-patch-as-frackers-go-for-broke.html

[1317] Begos, K., & Fahey, J. (2014, May 5). AP impact: Deadly side effect to fracking boom. *Associated Press*. Retrieved from http://bigstory.ap.org/article/ap-impact-deadly-side-effect-fracking-boom-0

[1318] Radow, E. L. (2014). At the intersection of Wall Street and Main: Impacts of hydraulic fracturing on residential property interests, risk allocation, and implications for the secondary mortgage market. *Albany Law Review, 77*(2), 673-704.

Unemployment rose after one county's boom ended; in another county, unemployment stayed above the state average throughout.[1319]

- March 27, 2014 – A report by researchers at Rand Corporation determined that each shale gas well in Pennsylvania causes between $5,400 and $10,000 in damage to state roads. The report did not calculate damage to local roads, which is also significant. Researchers used estimates of truck trips that are significantly below the number estimated for New York by the New York State Department of Environmental Conservation (NYS DEC).[1320, 1321]

- February 15, 2014 – The *Los Angeles Times* detailed steep increases in crime that have accompanied fracking in parts of the Eagle Ford Shale in Texas, including sexual assaults and thefts.[1322]

- February 14, 2014 – Pennsylvania landowners with fracking leases rallied in Bradford County against gas companies for precipitous drops in royalty payments.[1323]

- December 20, 2013 – The National Association of Realtors' *RealtorMag* summarized a growing body of research, including a University of Denver survey and a *Reuters* analysis, that shows threats property values from fracking and gas drilling.[1324]

- December 12, 2013 – A *Reuters* analysis discussed how oil and gas drilling has made making some properties "unsellable" and researched the link between drilling and property value declines. The analysis highlighted a Duke University working paper that finds shale gas drilling near homes can decrease property values by an average of 16.7 percent if the house depends on well water.[1325]

[1319] Multi-State Shale Research Collaborative. (2014, April 10). *Assessing the impacts of shale drilling county case studies* (Rep.). Retrieved from https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxtdWx0aXN0YXRlc2hhbGV8Z3g6NGU4MjIyNWU5ZjFhZjM4Yg

[1320] Cusick, M. (2014, March 27). Report finds each Marcellus gas well costs thousands in road damage. *StateImpact*. Retrieved from http://stateimpact.npr.org/pennsylvania/2014/03/27/report-finds-each-marcellus-gas-well-costs-thousands-in-road-damage/

[1321] Abramzon, S., Samaras, C., Curtright, A., Litovitz, A., & Burger, N. (2014). Estimating the consumptive use costs of shale natural gas extraction on Pennsylvania roadways. *Journal of Infrastructure Systems*. *20*(3). doi: 10.1061/(ASCE)IS.1943-555X.0000203, 06014001

[1322] Hennessy-Fiske, M. (2014, February 15). Fracking brings oil boom to south Texas town, for a price. *Los Angeles Times.* Retrieved from http://www.latimes.com/nation/la-na-texas-oil-boom-20140216%2C0%2C7621618.story#ixzz30Iw9FXoz

[1323] Marshall, J. (2014, February 14). Landowners rally for royalties from gas companies. Retrieved from http://www.wbng.com/news/local/Landowners-rally-for-245596511.html

[1324] Daily Real Estate News. (2013, December 20). 'Fracking' sparks concern over nearby home values. *National Association of Realtors*. Retrieved, from http://realtormag.realtor.org/daily-news/2013/12/20/fracking-sparks-concern-over-nearby-home-values#.UrmdIlPmVu8.twitter

[1325] Conlin, M. (2013, December 12). Gas drilling is killing property values for some Americans. *Reuters*. Retrieved from http://www.businessinsider.com/drilling-can-make-some-properties-unsellable-2013-12#ixzz2nMgFv8FU

- December 10, 2013 – Pennsylvania's *Daily Review* reported that more gas companies are shifting costs to leaseholders and that royalty payments are drastically shrinking. The story quoted Bradford County Commissioner Doug McLinko saying that some gas companies "are robbing our landowners" and that the problem of royalty payments being significantly reduced by deductions for post-production costs "is widespread throughout our county."[1326]

- November 30, 2013 – The *New York Times* reported striking increases in crime in Montana and North Dakota where the oil and gas boom is prevalent, as well as challenges faced by local residents from the influx of out-of-area workers and the accompanying costs. The *New York Times* reported, "'It just feels like the modern-day Wild West,' said Sgt. Kylan Klauzer, an investigator in Dickinson, in western North Dakota. The Dickinson police handled 41 violent crimes last year, up from seven only five years ago."[1327]

- November 21, 2013 – The Multi-State Shale Research Collaborative released a six-state collaborative report demonstrating that the oil and gas industry has greatly exaggerated the number of jobs created by drilling and fracking in shale formations. The report found that far from the industry's claims of 31 direct jobs created per well, only four jobs are created for each well. It also demonstrated that almost all of the hundreds of thousands of 'ancillary' jobs that the drilling industry claims are related to shale drilling existed before such drilling occurred. As Frank Mauro, Executive Director Emeritus of the Fiscal Policy Institute put it, "Industry supporters have exaggerated the jobs impact in order to minimize or avoid altogether taxation, regulation, and even careful examination of shale drilling."[1328]

- November 12, 2013 – *The American Banker* reported that the "Fracking Boom Gives Banks Mortgage Headaches," with a number of financial institutions refusing to make mortgages on land where oil and gas rights have been sold to an energy company. The article stated that the uniform New York state mortgage agreement used by Fannie Mae and Freddie Mac requires that homeowners not permit any hazardous materials to be used or located on their property. Fracking is therefore a problem because it is just such a hazardous activity with use of hazardous materials.[1329]

- September 25, 2013 – A report found that fracking is linked to significant road damage, increased truck traffic, crime, and strain on municipal and social services. Data from the

[1326] Loewenstein, J. (2013, December 10). Shrinking royalty checks. *Thedailyreview.com*. Retrieved from http://thedailyreview.com/news/shrinking-royalty-checks-1.1598195
[1327] Healy, J. (2013, November 30). As oil floods plains towns, crime pours in. *The New York Times*. Retrieved from http://www.nytimes.com/2013/12/01/us/as-oil-floods-plains-towns-crime-pours-in.html?smid=tw-share&_r=0
[1328] Campbell, J. (2013, November 21). Report: Industry-backed studies exaggerate fracking job estimates. *Politics on the Hudson*. Retrieved from http://polhudson.lohudblogs.com/2013/11/21/report-industry-backed-studies-exaggerate-fracking-job-estimates/
[1329] Peters, A. (2013, November 12). Fracking boom gives banks mortgage headaches. *American Banker*. Retrieved from http://www.americanbanker.com/issues/178_218/fracking-boom-gives-banks-mortgage-headaches-1063561-1.html

past ten years on the social costs of fracking including truck accidents, arrests, and higher rates of sexually transmitted diseases are all causes for alarm.[1330]

- September 12, 2013 – In a feature titled "Pa. fracking boom goes bust," *The Philadelphia Inquirer* presented data from the independent Keystone Research Center detailing "flat at best" job growth and declines in production and royalty payments.[1331]

- August 22, 2013 – A University of Denver study in the *Journal of Real Estate Literature* found a 5-15 percent reduction in bid value for homes near gas drilling sites.[1332]

- August 21, 2013 – *The Atlantic Cities* and *MSN Money* reported that fracking operations may be damaging property values and may impair mortgages or the ability to obtain property insurance.[1333, 1334]

- August 13, 2013 – A *ProPublica* investigative analysis found that Chesapeake Energy is coping with its financial difficulties in Pennsylvania by shifting costs to landowners who are now receiving drastically reduced royalty payments.[1335]

- August 4, 2013 – In a survey of West Virginia landowners with shale wells on their property, more than half reported problems including damage to the land, decline in property values, truck traffic, and lack of compensation by the oil and gas company.[1336]

- May 24, 2013 – Pennsylvania Department of Transportation Secretary Allen D. Biuhler and Pennsylvania State Police Commissioner Frank Pawlowski said that gas drilling has led to increases in truck traffic, traffic violations, crime, demand for social services, and the number of miles of roads that are in need of repairs. They noted that drilling companies that committed to repairing roads have not kept pace with the roads they

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[1330] Gibbons, B. S. (2013, September 25). Environmental groups calculate social cost of natural gas boom. *The Times-Tribune*. Retrieved from http://thetimes-tribune.com/news/environmental-groups-calculate-social-cost-of-natural-gas-boom-1.1558186

[1331] Bunch, W. (2013, September 12). Pa. fracking boom goes bust. *Philly.com*. Retrieved from http://articles.philly.com/2013-09-12/news/41974274_1_fracking-boom-penn-state-marcellus-center-marcellus-shale

[1332] Downing, B. (2013, April 22). Survey says home values hurt by fracking at drill sites. *Ohio.com*. Retrieved from http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/survey-says-home-values-hurt-by-fracking-at-drill-sites-1.422838

[1333] Drouin, R. (2013, August 19). How the fracking boom could lead to a housing bust. *Citylab*. Retrieved from http://www.theatlanticcities.com/politics/2013/08/how-fracking-boom-could-lead-housing-bust/6588/

[1334] Notte, J. (2013, August 21). Fracking leaves property values tapped out. *MSN Money*. Retrieved from http://money.msn.com/now/post--fracking-leaves-property-values-tapped-out

[1335] Lustgarten, A. (2013, August 13). Unfair share: How oil and gas drillers avoid paying royalties. *ProPublica*. Retrieved from http://www.propublica.org/article/unfair-share-how-oil-and-gas-drillers-avoid-paying-royalties

[1336] Collins, A. R., & Nkansah, K. (2013, August 4). *Divided rights, expanded conflict: The impact of split estates in natural gas production* [Scholarly project]. Retrieved from http://ageconsearch.umn.edu/bitstream/150128/2/Collins_Nkahsah_Split%20estate.pdf damage. Commissioner Pawlowski reported that 56 percent of 194 trucks checked were over the legal weight limit and 50 percent were also cited for safety violations.[1337]

- May 4, 2013 – Pennsylvania's *Beaver County Times* asked, "What boom?" in pointing to Keystone Research Center data showing that the number of jobs numbers created by shale gas extraction do not add up to what the gas industry claims, noting that unemployment has increased and the state actually fell to 49th in the nation for job creation.[1338]

- April 2, 2013 – The *New York Times* reported that manufacturing jobs resulting from an abundance of shale gas have not appeared. "The promised job gains, other than in the petrochemical industry, have been slow to materialize," The *New York Times* reported. The article suggested that increased automation has made it unlikely that manufacturers will add many jobs.[1339]

- March 19, 2013 – The *Wall Street Journal* reported that the shale gas boom has not had a big impact on U.S. manufacturing because lower energy prices are only one factor in a company's decision on where to locate factories, and not always the most important factor. "Cheap energy flowing from the U.S. shale-gas boom is often touted as a 'game changer' for manufacturing," the *Journal* reported. "Despite the benefits of lower energy costs, however, the game hasn't changed for most American manufacturers."[1340]

- February 2013 – A peer-reviewed analysis of industry-funded and independent studies on the economics of fracking found that it is unlikely that fracking will lead to long-term economic prosperity for communities. The analysis noted that shale gas development brings a number of negative externalities including the potential for water, air, and land contamination; negative impacts on public health; wear and tear on roads and other infrastructure; and costs to communities due to increased demand for services such as police, fire departments, emergency responders, and hospitals.[1341]

[1337] PR Newswire. (2014, May 24). Increased gas drilling activities bringing new challenges to local governments in Pennsylvania. *PR Newswire*. Retrieved from http://www.prnewswire.com/news-releases/increased-gas-drilling-activities-bringing-new-challenges-to-local-governments-in-pennsylvania-94774764.html

[1338] Morgan, R. (2013, May 4). Beaver County Times: What boom? Industry pundits claim thousands of jobs will be created, but numbers don't quite add up. *Keystone Research Center*. Retrieved from http://keystoneresearch.org/media-center/media-coverage/beaver-county-times-what-boom-industry-pundits-claim-thousands-jobs-will

[1339] Schwartz, N. D. (2013, April 01). Rumors of a cheap-energy jobs boom remain just that. *The New York Times*. Retrieved from http://www.nytimes.com/2013/04/02/business/economy/rumors-of-a-cheap-energy-jobs-boom-remain-just-that.html?_r=0

[1340] Hagerty, J. R. (2013, March 19). Shale-gas boom alone won't propel U.S. industry. *The Wall Street Journal*. Retrieved from http://online.wsj.com/news/articles/SB10001424127887324392804578362781776519720

[1341] Barth, J. M. (2013). The economic impact of shale gas development on state and local economies: Benefits, costs, and uncertainties. *New Solutions: A Journal of Environmental and Occupational Health Policy, 23*(1), 85-101. doi: 10.2190/NS.23.1.f

- November 16, 2012 – A Duke University study showed a drop in home values near fracking for properties that rely on groundwater. [1342]

- September 27, 2012 – The *New York Times* reported that the prospect of fracking has hindered home sales in the Catskills and raised concerns about drops in property values, according to real estate agents and would-be buyers.[1343]

- August 17, 2012 – A study by the state agencies, the Montana All Threat Intelligence Center and the North Dakota State and Local Intelligence Center, found that crime rose by 32 percent since 2005 in communities at the center of the oil and gas boom.[1344]

- October 30, 2011 – A comprehensive article in the *New York State Bar Association Journal* concluded that the risks inherent with fracking threaten mortgages.[1345]

- October 26, 2011 – The Associated Press reported that areas with significant fracking activity, including Pennsylvania, Wyoming North Dakota and Texas, are "seeing a sharp increase in drunken driving, bar fights and other hell-raising."[1346]

- October 19, 2011 – A *New York Times* investigation found that fracking can create conflicts with mortgages, and that "bankers are concerned because many leases allow drillers to operate in ways that violate rules in landowners' mortgages," and further that "[f]earful of just such a possibility, some banks have become reluctant to grant mortgages on properties leased for gas drilling. At least eight local or national banks do not typically issue mortgages on such properties, lenders say."[1347]

- September 7, 2011 – The NYS DEC estimated that 77 percent of the workforce on initial shale gas drilling projects would consist of transient workers from out of state. Not until the thirtieth year of shale gas development would 90 percent of the workforce be comprised of New York residents.[1348]

[1342] Muoio, D. (2012, November 16). Duke researchers show dip in home value caused by nearby fracking. *The Chronicle*. Retrieved from http://www.dukechronicle.com/articles/2012/11/16/duke-researchers-show-dip-home-value-caused-nearby-fracking

[1343] Navarro, M. (2012, September 27). Gas drilling jitters unsettle Catskills sales. *The New York Times*. Retrieved from http://www.nytimes.com/2012/09/30/realestate/fracking-fears-hurt-second-home-sales-in-catskills.html?pagewanted=1

[1344] Montana All Threat Intelligence Center, & North Dakota State and Local Intelligence Center. (2012, August 17). *Impact of population growth on law enforcement in the Williston Basin region* (Rep.). Retrieved from http://www.ag.nd.gov/reports/JOINTPRODUCTFINAL.pdf

[1345] Radow, E. N. (2011). Homeowners and gas drilling leases: Boon or bust? *New York State Bar Association Journal, 83*(9). Retrieved from http://www.s-oacc.org/resources/NYSBA_Journal_nov-dec2011_lead_article_with_reprint_info.pdf

[1346] Levy, M. (2011, October 26). Towns see crime, carousing surge amid gas boom. *Associated Press*. Retrieved from http://news.yahoo.com/towns-see-crime-carousing-surge-amid-gas-boom-135643480.html

[1347] Urbina, I. (2011, October 19). A rush to sign leases for gas runs into mortgage restriction. *The New York Times*. Retrieved from http://www.nytimes.com/2011/10/20/us/rush-to-drill-for-gas-creates-mortgage-conflicts.html?_r=2&hp&

[1348] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal*

- August 15, 2011 – The *Pittsburgh Post-Gazette* reported that increases in crime followed the Pennsylvania gas drilling boom, noting, for instance, that drunken driving arrests in Bradford County were up 60 percent, DUI arrests were up 50 percent in Towanda, and criminal sentencing was up 35 percent in 2010.[1349]

- July 26, 2011 – A New York State Department of Transportation document estimated that fracking in New York could result in the need for road repairs and reconstruction costing $211 million to $378 million each year.[1350]

- June 20, 2011 – A Keystone Research Center study found that the gas industry's claim of 48,000 jobs created between 2007 and 2010 as a result of natural gas drilling in Pennsylvania is a far cry from the actual number of only 5,669 jobs—many of which were out-of-state hires.[1351]

- May 9, 2011 – A study in the *Journal of Town & City Management* found that shale gas development can impose "significant short- and long-term costs" to local communities. The study noted that shale gas development creates a wide range of potential environmental hazards and stressors, all of which can adversely impact regional economies, including tourism and agriculture sectors.[1352]

- November 30, 2010 – The *Dallas Morning News* featured a story, "Drilling Can Dig into Land Value," reporting that the Wise County Central Appraisal District Appraisal Review Board found that a drilling company had caused an "extraordinary reduction" in property value, by 75 percent.[1353]

- November 28, 2010 – The Texas *Wise County Messenger* reported that some landowners near fracking operations experience excessive noise, exposure to diesel fumes, and problems with trespassing by workers.[1354]

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drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs (6-233, 234, Rep.).

[1349] Needles, Z. (2011, August 15). Must crime follow Pennsylvania's gas drilling boom? *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/stories/business/legal/must-crime-follow-pennsylvanias-gas-drilling-boom-310373/

[1350] Reilly, S. (2011, July 26). Document estimates fracking's toll on N.Y. roads. *Pressconnects.com*. Retrieved from http://www.pressconnects.com/article/20110726/NEWS01/107260384/Document-estimates-fracking-s-toll-N-Y-roads

[1351] Herzenberg, S. (2011). Drilling deeper into job claims. Keystone Research Center. Retrieved from http://keystoneresearch.org/sites/keystoneresearch.org/files/Drilling-Deeper-into-Jobs-Claims-6-20-2011_0.pdf

[1352] Christopherson, S. & Rightor, N. (2011). How shale gas extraction affects drilling localities: Lessons for regional and city policy makers. *Journal of Town & City Management, 2*(4), 1-20. Retrieved from http://www.greenchoices.cornell.edu/downloads/development/shale/Economic_Effects_on_Drilling_Localities.pdf

[1353] Heinkel-Wolfe, P. (2010, September 18). Drilling can dig into land value. *Dallas News*. Retrieved from http://www.dallasnews.com/incoming/20100918-Drilling-can-dig-into-land-value-9345.ece

[1354] Evans, B. (2010, November 28). Rising volume: 'Fracking' has bolstered economies, but noise still echoes around drilling. *WCMessenger.com*. Retrieved from http://www.wcmessenger.com/2010/news/rising-volume-fracking-has-bolstered-economies-but-noise-still-echoes-around-drilling/

Inflated estimates of oil and gas reserves and profitability

Industry projections of oil and gas reserves and profitability of drilling have proven undependable. Over time, well production has become increasingly short-lived, which has led companies drilling shale to reduce the value of their assets by billions of dollars, creating shortfalls that are largely filled through asset sales and mounting debt load. Throughout the ten-year fracking boom, the industry as a whole has spent more money drilling wells than selling oil and gas. Beginning in 2014, a fall in oil and gas prices led to a two-year downturn in fracking operations. As interest payments consumed the revenue of many smaller companies, more than 70 U.S. oil and gas companies declared bankruptcy, and the number of oil and gas rigs declined by 75 percent or more. When companies abandoned operations, they also abandoned the wells they drilled, raising questions about who serves as the custodian of inactive wells and their associated infrastructure, now and hereafter.

Beginning in 2017, a modest recovery in prices brought renewed industry enthusiasm for fracking. However, because of the rapid depletion of individual shale wells and the falling output of major shale basins, including the Bakken and the Marcellus, operators must reinvest profits to drill new wells at an increasingly rapid pace just to maintain the same level of extraction. More than half of all U.S. oil is now produced by wells that are two years old or younger, and they are pumping less oil than forecast. In the first half of 2018, despite rising oil prices, fracking-focused companies continued to lose cash.

The need to stabilize economic fundamentals by increasing production and lower costs is contributing to the shift toward "mega-fracking," with ever-longer laterals to allow one well to access more oil or gas—and with requirements for higher volumes of water, sand, and chemicals per well.

- January 2, 2019 – An analysis by the *Wall Street Journal* comparing productivity estimates provided to investors with third-party projections revealed that thousands of shale wells are pumping considerably less oil and gas than owners were forecasting. Two-thirds of projections made by fracking companies between 2014-2017 in Texas and North Dakota oil basins were overly optimistic. All together, these companies are on track to extract 10 percent less oil and gas than they predicted. "The Journal's findings suggest current production levels may be hard to sustain without greater spending because operators will have to drill more wells to meet growth targets."[1355]

- October 17, 2018 – A research brief jointly published by the Institute for Energy Economics and Financial Analysis and the Sightline Institute tracked cash flow for 33 leading fracking companies. It found that fracking-focused companies continued to lose cash through the first half of 2018. Specifically, between January and June 2018, in spite

[1355] Olson, B., Elliott, R., & Matthews, C. M. (2019, January 2). Fracking's secret problem—oil wells aren't producing as much as forecast. *Wall Street Journal*. Retrieved from https://www.wsj.com/articles/frackings-secret-problemoil-wells-arent-producing-as-much-as-forecast-11546450162 of rising oil prices, fracking companies spent $3.9 billion more on drilling than they generated by selling oil and gas.[1356]

- September 20, 2018 – Confronted with falling prices and mounting debt, Southwest Energy sold off its assets in Arkansas' Fayetteville Shale, placing fracking on hold.[1357]

- June 4, 2018 – A macroeconomic study using a simulation model found that economies that depend on fossil fuel extraction could be gravely harmed if global demand for fossil fuels declines in the face of innovations in energy efficiency and renewable technologies and public policy that promotes them. "Russia, the United States or Canada…could see their fossil fuel industries nearly shut down. ... The United States is worse off if it continues to promote fossil fuel production and consumption than if it moves away from them. This is due to the way global fossil fuel prices are formed. If the rest of the world reduces fossil fuel consumption and there is a sell-out, then lower fuel prices will make much US production non-viable, regardless of its own policy, meaning that its assets become stranded."[1358]

- June 16, 2017 – Because of a persistent slump in gas prices and the declining productivity of many of its Marcellus Shale wells, the revenue from gas drilling fees fell for a third straight year in Pennsylvania. The annual fee revenue goes to county and municipal governments, roadway repairs, and infrastructure upgrades, among other things.[1359]

- April 3, 2017 – A British team of researchers assessed the physical footprint of well pads in Europe and the United Kingdom if shale gas development goes forward. When they included proposed setbacks for the UK—the minimal distance well pads have to be away from existing homes and other infrastructure—they found that recoverable oil and gas would be limited by 74 percent.[1360]

- March 25, 2017 – The *Economist* took shale fracking to task for its unstable finances and inability to turn a profit. "Shale firms are on an unparalleled money-losing streak. About $11bn was torched in the last quarter, as capital expenditures exceeded cashflows. The

[1356] Institute for Energy Economics and Financial Analysis, & Sightline Institute. (2018, October 17). *Energy market update: Red flags on U.S. fracking, disappointing financial performance continues.* Retrieved from http://ieefa.org/wp-content/uploads/2018/10/Red-Flags-on-U.S.-Fracking_October-2018.pdf
[1357] Breen, D. (2018, September 20). Fayetteville Shale assets sold off, fracking still on hold. *Arkansas Public Media.* Retrieved from https://www.arkansaspublicmedia.org/post/fayetteville-shale-assets-sold-fracking-still-hold
[1358] Mercure, J.-F., Pollitt, H., Viñuales, J. E., Edwards, N. R., Holden, P. B., Chewpreecha, U., . . . Knobloch, F. (2018). Macroeconomic impact of stranded fossil fuel assets. *Nature Climate Change, 8*, 588-593. doi: 10.1038/s41558-018-0182-1
[1359] Carlson, C. (2017, June 16). Pennsylvania gas drilling fee revenue falls for third year. *WENY.com.* Retrieved from http://www.weny.com/story/35680098/pennsylvania-gas-drilling-fee-revenue-falls-for-third-year?utm_medium=social&utm_source=twitter_WENYTV
[1360] Clancy, S. A., Worrall, F., Davies, R. J. & Gluyas, J. G. (2018). An assessment of the footprint and carrying capacity of oil and gas well sites: The implications for limiting hydrocarbon reserves. *Science of the Total Environment, 618*, 586-594. Advance online publication. doi: 10.1016/j.scitotenv.2017.02.160

cash-burn rate may well rise again this year. . . . The oil bulls of Houston have yet to prove that they can pump oil and create value at the same time."[1361]

- March 21, 2017 – An MIT study questioned the U.S. Energy Information Administration's rosy projections on the abundance and availability of shale gas and oil. Analyzing field data on oil wells in North Dakota's Williston Basin, the authors found that advances in fracking technology, such as the shift to longer laterals per well, have had a more modest impact on boosting oil and gas production than the agency had estimated. At the same time, the attraction of operators to the most productive areas of basins has had a greater impact. As time goes by, the prime drilling spots with the easy-to-extract oil or gas will get used up, the authors argued, and technology may not be able to compensate.[1362, 1363]

- July 7, 2016 – "Oil-field-services companies are depleted after slashing prices and laying off workers, and their slow recovery could crimp the energy industry's overall ability to bounce back from the oil bust," according to the *Wall Street Journal*. Almost 70 percent of fracking equipment in the United States has been idled, and 60 percent of field workers involved in fracking have been laid off. Halliburton alone has laid off over 28,500 workers, which is one third of its workforce. More than 70 oilfield services companies have filed for bankruptcy since the beginning of 2015.[1364]

- June 15, 2016 – Billions of dollars of proven reserves have become unproven this year, as "59 U.S. oil and gas companies deleted the equivalent of 9.2 billion barrels, more than 20 percent of their inventories," according to *Bloomberg*. In 2009, the Securities and Exchange Commission (SEC) made it easier for the companies to include in their proven reserves undeveloped acreage and wells that wouldn't be drilled for years on the grounds that "shale prospects are predictable across wide expanses." Since then, the SEC has become more strict about inflated reserves estimates.[1365]

- May 16, 2016 – *CNN Money* reported on the two latest U.S. oil and gas bankruptcies: SandRidge Energy's Chapter 11 filing was based on roughly $4 billion of debt and came the week after the biggest such bankruptcy to date—that of Linn Energy with more than $10 billion in debt. There had been at least 29 U.S. oil and gas bankruptcies in 2016 at the date of the article's publication, bringing the 2015-2016 total to at least 64. "The industry has historically been full of wildcatters and speculators. It's not surprising we're

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[1361] America's shale firms don't give a frack about financial returns. (2017, March 25). *Economist.* Retrieved from https://www.economist.com/news/business-and-finance/21719436-exploration-and-production-companies-are-poised-go-another-investment-spree-americas

[1362] Montgomery, J. B., & O'Sullivan, F. M. (2017). Spatial variability of tight oil well productivity and the impact of technology. *Applied Energy, 195,* 344–355. doi: 10.1016/j.apenergy.2017.03.038

[1363] Marshall, C. (2017, October 6). Studies attack conventional wisdom on natural gas. *E&E News.* Retrieved from https://www.eenews.net/stories/1060062933

[1364] Sider, A. (2016, July 7). Revving up oil fields won't be so easily done. *Wall Street Journal.* Retrieved from http://www.wsj.com/articles/revving-up-oil-fields-wont-be-so-easily-done-1467883807

[1365] Loder, A. (2016, June 15). Why billions in proven shale oil reserves suddenly became unproven. *Bloomberg.* Retrieved from http://www.bloomberg.com/news/articles/2016-06-15/shale-drillers-paper-wells-draw-sec-scrutiny-before-vanishing going through this boom-and-bust cycle," the article quoted the managing director at oil restructuring firm SOLIC Capital, George Koutsonicolis, as saying.[1366]

- May 9, 2016 – "The pace of oil patch bankruptcies is picking up," a *Forbes* piece read, listing the 15 biggest such bankruptcies to date. "All told, 69 oil and gas producers with $34.3 billion in cumulative secured and unsecured debt have gone under."[1367]

- March 25, 2016 – Oil and gas borrowers "feasted on what Bloomberg estimates was $237 billion of easy money without scrutinizing whether the loans could endure a drastic downturn," according to a *Washington Post* piece focusing on one company, Swift Energy, which itself was $1.349 billion in debt and had entered bankruptcy. Despite having been cautious prior to the Texas fracking boom, "[a]s the company began to frack more often, the amount it spent on exploration and drilling skyrocketed by hundreds of millions of dollars." Those expenses combined with global developments led to its failure, along with over 40 other oil and gas companies in 2015. "The consequences are far-reaching. The U.S. oil industry, having grown into a giant on par with Saudi Arabia's, is shrinking, with the biggest collapse in investment in energy in 25 years. More than 140,000 have lost energy jobs. Banks are bracing for tens of billions of dollars of defaults, and economists and lawyers predict the financial wreckage will accelerate this year."[1368]

- March 10, 2016 – Crude oil production is not falling as quickly as predicted, given the sharp decline in prices and the drop-off in new drilling and fracking operations. As reported by Reuters, this disconnect is due to refracking of older wells, along with other unconventional techniques such as "choking" and "lifting," which can extend the productive lives of wells or otherwise capture more product from them.[1369]

- March 1, 2016 – An analysis of fracking trends in the journal *Nature* concluded that a European shale gas boom was unlikely due to disappointing early yields (Poland, Lithuania and Denmark), links to earthquakes (United Kingdom), and intense public opposition in densely populated areas throughout the continent.[1370]

- June 19, 2015 – A *Bloomberg Business* analysis of the 62 drilling companies in the Bloomberg Intelligence North America Independent Exploration and Production Index found that the companies' debt continued to be a major problem. For 27 of the 62 companies, interest payments were consuming more than 10 percent of revenue. Drillers' debt rose to $235 billion at the end of the first quarter, a 16 percent increase over the year

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[1366] Egan, M. (2016, May 16). Oil bankruptcies mount despite crude rebound. *CNN Money.* Retrieved from http://money.cnn.com/2016/05/16/investing/sandridge-energy-oil-bankruptcy/

[1367] Helman, C. (2016, May 9). The 15 biggest oil bankruptcies (so far). *Forbes.* Retrieved from http://www.forbes.com/sites/christopherhelman/2016/05/09/the-15-biggest-oil-bankruptcies-so-far/#7c765e10739b

[1368] Harlan, C. (2016, March 25). The big bust in the oil fields. *The Washington Post.* Retrieved from https://www.washingtonpost.com/news/wonk/wp/2016/03/25/the-big-bust-in-the-oil-fields/

[1369] Gopinath, S., & Gayathri, A. (2016, March 10). Forget fracking. Choking and lifting are latest efforts to stem U.S. shale bust. *Reuters*. Retrieved from http://www.reuters.com/article/us-usa-shale-analysis-idUSKCN0WB1AI

[1370] Inman, M. (2016). Can fracking power Europe? *Nature, 531,* 22-24. Retrieved from http://www.nature.com/news/can-fracking-power-europe-1.19464 prior. *Bloomberg Business* expressed concern that shale drillers have "consistently spent money faster than they've made it, even when oil was $100 a barrel." S&P assigned speculative, or junk, ratings to 45 of the 62 companies in Bloomberg's index.[1371]

- April 7, 2015 – A Moody's Investors Service analysis of liquefied natural gas (LNG) prospects found that lower oil prices were causing suppliers to defer or cancel most proposed LNG projects. Moody's found that this was due in part to the drop in international oil prices relative to U.S. natural gas prices, thus removing the economic advantage of U.S. LNG projects. Moody's stated, "LNG is a capital-intensive infrastructure business prone to periodic construction cycles that lead to overcapacity, which we expect will continue for the rest of the decade."[1372]

- March 20, 2015 – A study by the Energy Watch Group in Germany found that the costs of allowing fracking in Germany would outweigh the benefits, noting in part that natural gas trading in the United States has been declining since 2009. The study also noted the costs of infrastructure, environmental and health risks and pointed to the need to expand renewable energy.[1373]

- December 19, 2014 – An International Energy Agency (IEA) report projected that U.S. domestic oil supplies, dominated by fracking, face challenges, and oil output from shale formations output, will level off and decline in the early 2020s.[1374] IEA Chief Economist Fatih Birol said, "A well-supplied oil market in the short-term should not disguise the challenges that lie ahead."[1375]

- August 29, 2014 – Andrew Nikiforuk, a Canadian energy analyst, reported on diminishing returns and the higher-cost, higher-risk nature of fossil fuel extraction by fracking. Nikiforuk wrote, "Most of the world's oil and gas firms are now pursuing extreme hydrocarbons because the cheap and easy stuff is gone…. That means industry will spend more good money chasing poor quality resources. They will inefficiently mine and frack ever larger land bases at higher environmental costs for lower energy returns."[1376]

[1371] Loder, A. (2015, June 18). The shale industry could be swallowed by its own debt. *Bloomberg Business*. Retrieved from http://www.bloomberg.com/news/articles/2015-06-18/next-threat-to-u-s-shale-rising-interest-payments

[1372] Moody's Investors Service. (2015, April 7). Lower oil prices cause suppliers of liquefied natural gas to nix projects. Retrieved from https://www.moodys.com/research/Moodys-Liquefied-natural-gas-projects-nixed-amid-lower-oil-prices--PR_322439

[1373] Sagener, N. (2015, March 26). Fracking costs outweigh benefits for Germany and Europe, study says. *EurActiv*. Retrieved from http://www.euractiv.com/sections/energy/fracking-costs-outweigh-benefits-germany-and-europe-study-says-313087

[1374] International Energy Agency. (2014, December). World Energy Outlook 2014 Executive Summary. Retrieved from http://www.iea.org/publications/freepublications/publication/WEO_2014_ES_English_WEB.pdf

[1375] Dimick, D. (2014, December 19). How long can the U.S. oil boom last? *National Geographic*. Retrieved from http://news.nationalgeographic.com/news/2014/12/141219-fracking-oil-supply-price-reserves-profits-environment/

[1376] Nikiforuk, A. (2014, August 29). A big summer story you missed: Soaring oil debt returns diminish as energy companies resort to higher-cost, higher-risk hydrocarbons. *The Tyee.* Retrieved from http://thetyee.ca/Opinion/2014/08/29/Soaring-Oil-Debt-Summer/

- July 29, 2014 – According to the U.S. Energy Information Administration, energy companies are incurring increasing debt and selling assets to continue drilling in shale. "Based on data compiled from quarterly reports, for the year ending March 31, 2014, cash from operations for 127 major oil and natural gas companies totaled $568 billion, and major uses of cash totaled $677 billion, a difference of almost $110 billion. This shortfall was filled through a $106 billion net increase in debt and $73 billion from sales of assets . . ."[1377]

- July 2014 – Researchers at the Washington, DC-based Environmental Law Institute and Washington & Jefferson College in Pennsylvania collaborated to produce a report designed in part to help communities avoid the "boom and bust" cycles of extractive industries. Authors warned, "While resource extraction has long been regarded as an economic benefit, a body of academic literature suggests that long term growth based chiefly on resource extraction is rare." Confounding factors include transience of the workforce, localized inflation, widening disparities in royalties and impact fee disbursement, commodity price volatility, and communities overspending on infrastructure.[1378]

- June 19, 2014 – Energy analyst Deborah Lawrence Rogers outlined the spiraling debt and severe deterioration of the assets of five major shale gas drillers over the last five years. She concluded, "This is not sustainable. It could be argued that it is not even moral. It is a failed business model of epic proportion. While companies could make the argument at one time that this was a short term downtrend, that no longer holds water because this pattern is long term."[1379]

- April 10, 2014 – A report by a petroleum geologist and petroleum engineer concluded the 100-year supply of shale gas is a myth, distinguished between what is technically recoverable and economically recoverable shale gas, and asserted that at current prices, New York State has no economically recoverable shale gas.[1380]

- February 28, 2014 – Maria van der Hoeven, Executive Director of the IEA, said in an interview with *The Christian Science Monitor* that there is only a decade left in the U.S. shale oil and gas boom, noting that her agency's analysis predicts that production will soon flatten out and, by 2025, begin to decline.[1381]

[1377] US Energy Information Administration. (2014, July 29). As cash flows flatten, major energy companies increase debt, sell assets. *Today in Energy.* Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=17311

[1378] Environmental Law Institute, & Washington & Jefferson College. (2014, July). Getting the boom without the bust: Guiding Southwestern Pennsylvania through shale gas development. Retrieved from http://www.eli.org/sites/default/files/eli-pubs/getting-boom-final-paper-exec-summary-2014-07-28.pdf

[1379] Rogers, D. L. (2014, June 19). Huge CAPEX = free cash flow? Not in shales. *Energy Policy Forum.* Retrieved from http://energypolicyforum.org/2013/06/19/huge-capex-free-cash-flow-not-in-shales/

[1380] Labyrinth Consulting Services, Inc., Berman, A., & Pittinger, L. (2014). Resource Assessment of Potentially Producible Natural Gas Volumes From the Marcellus Shale, State of New York. Retrieved from: http://www.lwvny.org/

[1381] Unger, D. J. (2014, February 28). IEA chief: Only a decade left in US shale oil boom. *Christian Science Monitor*. Retrieved from http://www.csmonitor.com/Environment/Energy-Voices/2014/0228/IEA-chief-Only-a-decade-left-in-US-shale-oil-boom

- December 18, 2013 – A University of Texas study in *Proceedings of the National Academy of Sciences* found that fracking well production drops sharply with time, which undercuts the oil and gas industry's economic projections.[1382] In an interview about the study with *StateImpact NPR* in Texas, Tad Patzek, Chair of the Department of Petroleum and Geosystems Engineering at University of Texas at Austin, noted that fracking "also interferes now more and more with daily lives of people. Drilling is coming to your neighborhood, and most people abhor the thought of having somebody drilling a well in their neighborhood."[1383]

- August 18, 2013 – *Bloomberg News* reported that low gas prices and disappointing wells have led major companies to devalue oil and gas shale assets by billions of dollars.[1384]

- October 21, 2012 – The *New York Times* reported that many gas drilling companies overproduced natural gas backed by creative financing and now "are committed to spending far more to produce gas than they can earn selling it." "We are all losing our shirts today," said Exxon CEO Rex Tillerson in the summer of 2012.[1385]

- July 13, 2012 – *The Wall Street Journal* reported that ITG Investment Research, at the request of institutional investors, evaluated the reserves of Chesapeake Energy Corporation's shale gas reserves in the Barnett and Haynesville formations and found them to be only 70 percent of estimates by Chesapeake's engineering consultant for the company's 2011 annual report. Chesapeake and its consultant defended their figures.[1386]

- August 23, 2011 – The U.S. Geological Survey (USGS) cut the government's estimates of natural gas in the Marcellus Shale from 410 trillion cubic feet to 84 trillion cubic feet, equivalent to a reduction from approximately 16 years of U.S. consumption at current levels of natural gas use, to approximately 3.3 years of consumption. The USGS's updated estimate was for natural gas that is technically recoverable, irrespective of economic considerations such as the price of natural gas or the cost of extracting it.[1387]

[1382] Patzek, T. W., Male, F., & Marder, M. (2013). Gas production in the Barnett Shale obeys a simple scaling theory. *Proceedings of the National Academy of Sciences, 110*(49), 19731-19736. doi: 10.1073/pnas.1313380110
[1383] Buchele, M. (2013, December 18). New study shows how gas production from "fracked" wells slows over time. *StateImpact*. Retrieved from http://stateimpact.npr.org/texas/2013/12/18/new-study-shows-how-gas-production-from-fracked-wells-slows-over-time/
[1384] Monks, M., Penty, R., & De Vynck, G. (2013, August 18). Shale grab in U.S. stalls as falling values repel buyers. *Bloomberg*. Retrieved from http://www.bloomberg.com/news/2013-08-18/shale-grab-in-u-s-stalls-as-falling-values-repel-buyers.html
[1385] Krauss, C., & Lipton, E. (2012, October 20). After the boom in natural gas. *The New York Times*. Retrieved from http://www.nytimes.com/2012/10/21/business/energy-environment/in-a-natural-gas-glut-big-winners-and-losers.html?pagewanted=all
[1386] Wirz, M. (2013, July 13). Chesapeake reserve doubted. *Wall Street Journal*. Retrieved from http://online.wsj.com/news/articles/SB10001424052702303644004577523411723501548
[1387] United States Geological Survey. (2011, August 23). USGS releases new assessment of gas resources in the Marcellus shale, Appalachian Basin. *USGS Newsroom*. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=2893&from=rss_home#.Uok0mGRO_GA.

- June 26-27, 2011 – As reported in two *New York Times* stories, hundreds of emails, internal documents, and analyses of data from thousands of wells from drilling industry employees, combined with documents from federal energy officials, raised concerns that shale gas companies were overstating the amount of gas in their reserves and the profitability of their operations.[1388, 1389, 1390] The *New York Times*' public editor criticized the stories, but offered no evidence that the major findings were wrong.[1391] The *New York Times*' news editors publicly defended both stories against the public editor's criticism.[1392, 1393]

[1388] Urbina, I. (2011, June 25). Insiders sound an alarm amid a natural gas rush. *The New York Times*. Retrieved from http://www.nytimes.com/2011/06/26/us/26gas.html?pagewanted=all
[1389] U.S. Energy Information Administration. (2014, May 30). *U.S. Natural Gas Summary.* Retrieved from http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm
[1390] Urbina, I. (2011, August 24). Geologists sharply cut estimate of shale gas. *The New York Times*. Retrieved from http://www.nytimes.com/2011/08/25/us/25gas.html
[1391] Brisbane, A. S. (2011, July 16). Clashing views on the future of natural gas. *The New York Times*. Retrieved from http://www.nytimes.com/2011/07/17/opinion/sunday/17pubed.html?gwh=7D408242717755A0E06B0D265498E177&gwt=pay&assetType=opinion&_r=0
[1392] Brisbane, A. S. (2011, July 17). Times editors respond to my shale gas column. *The New York Times*. Retrieved from http://publiceditor.blogs.nytimes.com/2011/07/17/times-editors-respond-to-my-shale-gas-column/
[1393] Brisbane, A. S. (2011, July 30). Times editors respond to column on redactions. *The New York Times*. Retrieved from http://publiceditor.blogs.nytimes.com/2011/07/30/times-editors-respond-to-column-on-redactions/

Disclosure of serious risks to investors

A snapshot of the dangers posed by natural gas drilling and fracking can be found in the annual Forms 10-K that oil and natural gas companies are required to file with the U.S. Securities and Exchange Commission (SEC). The information so contained in these reports, which provide a comprehensive summary of a company's financial performance, provides a window into the harms and risks of fracking that are otherwise shielded from view by "gag order" clauses in court settlements, non-disclosure agreements between industry and landowners, and trade secret claims in regards to the chemical ingredients of fracking fluid. In this way, the Form 10-K can serve as an imperfect surrogate for right-to-know data. Recently, Forms 10-K have been used to warn investors about risks from climate change lawsuits.

Federal law requires that companies offering stock to the public disclose in their Form 10-K, among other things, the "most significant factors that make the offering speculative or risky."[1394] In a review of Forms 10-K spanning the past decade available on the SEC's website, oil and natural gas companies have routinely warned of drilling's serious risks. In the words of Exxon Mobil Corporation's subsidiary XTO Energy, "our operations are subject to hazards and risks inherent in drilling."[1395] In the language of Range Resources Corporation: "development and exploratory drilling and production activities are subject to many risks."[1396]

Such hazards and risks include leaks, spills, explosions, blowouts, environmental damage, property damage, injury, and death. Chesapeake Energy Corporation has stated that "horizontal and deep drilling activities involve greater risk of mechanical problems than vertical and shallow drilling operations."[1397] Over the past 15 years, companies have combined horizontal drilling with hydraulic fracturing to tap natural gas and oil in shale formations.

The companies also routinely warn of inadequate insurance to cover drilling harms. According to XTO Energy, "we are not fully insured against all environmental risks, and no coverage is maintained with respect to any penalty or fine required to be paid by us."[1398] Range Resources states, "we can provide no assurance that our coverage will

[1394] See 17 C.F.R. § 229.503(c) (companies must disclose the "most significant" risks); 17 C.F.R. § 230.405 ("the term material, when used to qualify a requirement for the furnishing of information as to any subject, limits the information required to those matters to which there is a substantial likelihood that a reasonable investor would attach importance in determining whether to purchase the security registered"); 17 C.F.R. § 240.10b-5 (it is illegal "to make any untrue statement of a material fact or to omit to state a material fact . . . in connection with the purchase or sale of any security); 17 C.F.R. 249.310 (requiring Form 10-K, "for annual and transition reports pursuant to sections 13 or 15(d) of the Securities Exchange Act of 1934.")
[1395] XTO Energy Corp., Annual Report (Form 10-K) (Feb. 25, 2010) at 25.
[1396] Range Resources Corp., Annual Report (Form 10-K) (Feb. 24, 2015) at 22.
[1397] Chesapeake Energy Corp., Annual Report (Form 10-K) (Feb. 27, 2015) at 18.
[1398] XTO Energy Corp., Annual Report (Form 10-K) (Feb. 25, 2010) at 17.

adequately protect us against liability from all potential consequences, damages and losses."[1399]

Houston-based Noble Energy provides a representative example of the risks that at least several drilling companies include in their annual reports. Noble states:

> Our operations are subject to hazards and risks inherent in the drilling, production and transportation of crude oil, natural gas and NGLs [natural gas liquids], including:
>
> - injuries and/or deaths of employees, supplier personnel, or other individuals;
> - pipeline ruptures and spills;
> - fires, explosions, blowouts and well cratering;
> - equipment malfunctions and/or mechanical failure on high-volume, high-impact wells;
> - leaks or spills occurring during the transfer of hydrocarbons from an FPSO [floating production storage and offloading vessels] to an oil tanker;
> - loss of product occurring as a result of transfer to a rail car or train derailments;
> - formations with abnormal pressures and basin subsidence which could result in leakage or loss of access to hydrocarbons;
> - release of pollutants;
> - surface spillage of, or contamination of groundwater by, fluids used in operations;
> - security breaches, cyber attacks, piracy, or terroristic acts;
> - theft or vandalism of oilfield equipment and supplies, especially in areas of active onshore operations;
> - hurricanes, cyclones, windstorms, or "superstorms," which could affect our operations in areas such as the Gulf Coast, deepwater Gulf of Mexico, Marcellus Shale or Eastern Mediterranean;
> - winter storms and snow which could affect our operations in the DJ Basin [Denver-Julesburg Basin in Colorado] or Marcellus Shale;
> - extremely high temperatures, which could affect third party gathering and processing facilities in the DJ Basin;
> - volcanoes which could affect our operations offshore Equatorial Guinea;
> - flooding which could affect our operations in low-lying areas;
> - harsh weather and rough seas offshore the Falkland Islands, which could limit certain exploration activities; and
> - pandemics and epidemics, such as the Ebola virus, which is ongoing in certain regions of West Africa and may adversely affect our business operations through travel or other restrictions.
>
> Any of these can result in loss of hydrocarbons, environmental pollution and other damage to our properties or the properties of others.[1400]

Noble has language similar to that found in other companies' annual reports about inadequate insurance and adds, "we do not have insurance for gradual pollution nor do

[1399] Range Resources Corp., Annual Report (Form 10-K) (Feb. 24, 2015) at 26.
[1400] Noble Energy, Annual Report (Form 10-K) (Feb. 19, 2015) at 38.

we have coverage for penalties or fines that may be assessed by a governmental authority."[1401]

Forms 10-K are also a tool of disclosure for risks concerning climate change beyond specific negative impacts on operations (hurricanes, flooding, etc.) listed, for example, in Noble Energy's annual report cited above. In 2016, Chevron became the first major oil company to warn investors in its Form 10-K about the risk of climate change lawsuits: "Increasing attention to climate change risks has resulted in an increased possibility of governmental investigations and, potentially, private litigation against the company."[1402] Also in 2016, the SEC began investigating Exxon Mobil for valuing its assets in ways that do not account for the possible depreciation of oil and gas under a policy framework that shifts investments in energy away from fossil fuels and toward renewable sources.[1403] Under pressure from investors, Exxon agreed in December 2017 to disclose more details about climate risks by filing with the SEC, in a Form 8-K, a statement that said the company would no longer resist motions from shareholders seeking this information.[1404]

At this writing, it is not clear whether, under the current Administration, the SEC will continue its push toward investor disclosure of climate change risks.[1405] Nevertheless, the unsolved problem of methane leaks is increasingly recognized as a rising risk for oil and gas investors concerned that methane emissions are not transparently managed, may negate the claim that natural gas is more climate-friendly than coal, and hence pose a risk to their investments.[1406, 1407]

The risks identified by these oil and gas companies are not just hypothetical. Many, if not all of these risks are reflected in the evidence compiled in other sections of this Compendium.

1401 Noble Energy. Annual Report (Form 10-K) (Feb 19, 2015) at 79.

1402 Romm, J. (2017, March 2). Chevron is first oil major to warn investors of risks from climate change lawsuits. *ThinkProgress.* Retrieved from https://thinkprogress.org/chevron-admits-climate-lawsuits-threaten-profits-33937dd562fd/#.56j1qq4h3

1403 Olson, B., & Viswanatha, A. (2016, September 20). SEC probes Exxon over accounting for climate change. *Wall Street Journal*. Retrieved from https://www.wsj.com/articles/sec-investigating-exxon-on-valuing-of-assets-accounting-practices-1474393593

1404 Cushman, Jr., J. H., & Hasemyer, D. (2017, December 12). Exxon agrees to disclosure climate risks under pressure from investors. *InsideClimate News*. Retrieved from https://insideclimatenews.org/news/12122017/exxon-climate-risk-disclosure-sec-shareholder-investigation-pressure

1405 Griffen, P., & Jaffe, A. M. (2017, February 15). Are fossil fuel companies telling investors enough about the risks of climate change? *The Conversation.* Retrieved from https://theconversation.com/are-fossil-fuel-companies-telling-investors-enough-about-the-risks-of-climate-change-72562

1406 Connan, M.-S. (2016, December 1). *Methane: The next frontier for fossil fuel emissions.* Retrieved from https://us.allianzgi.com/en-us/insights/capital-markets-and-economics/methane-the-next-frontier-for-fossil-fuel-emissions

1407 Gilblom, K. (2017, December 19). Insidious gas leaks are casting doubts over Shell's clean credentials. *Bloomberg.* Retrieved from https://www.bloomberg.com/news/articles/2017-12-20/as-shell-gambles-on-gas-leaks-cast-cloud-over-clean-credentials

Medical and scientific calls for more study, reviews confirming evidence for harm, and calls for increased transparency and science-based policy

With increasing urgency, groups of medical and other health professionals and scientists are issuing calls for comprehensive, long-term study of the full range of potential health and ecosystem effects of drilling and fracking. These appeals underscore the accumulating evidence of harm, point to the major knowledge gaps that remain, and decry the atmosphere of secrecy and intimidation that continues to impede the progress of scientific inquiry. Published reviews and international governmental reports underscore the mounting evidence of health risks including developmental, neurological, carcinogenic, respiratory, reproductive, and psychological. Health professionals and scientists in the United States and around the world increasingly call for the suspension of unconventional gas and oil extraction activities in order to limit, mitigate, or eliminate its serious, adverse public health hazards, including health threats from climate change.

- March 29, 2019 – Doctors for the Environment Australia announced the reinforcement of its position that no new gas extraction of any kind should occur in Australia. Its position was largely informed by the wealth of literature from the United States documenting adverse health findings.[1408] The organization's review found growing evidence of direct health impacts as well as a clear potential for indirect impacts of gas and oil mining on essential environmental determinants of health. "These concerns include risks to a stable climate, air quality, water quality, water security, food security, community cohesion and, in some locations, geological stability. The cumulative impacts of these industries on the wider requirements for good health and wellbeing are extremely concerning."[1409]

- February 1, 2019 – Natural gas extraction via fracking is associated with "preterm birth, high-risk pregnancy, and possibly low birth weight; three types of asthma exacerbations; and nasal and sinus, migraine headache, fatigue, dermatologic, and other symptoms," according to a review covering research through mid-2017.[1410] The Johns Hopkins Bloomberg School of Public Health scientists cited the methodological robustness of these studies and the biological plausibility of the links found. Further, they included in their review the contribution of fracking to climate change and its further health impacts. Authors expressed serious doubt that the risks of fracking can be managed. "Some have suggested that regulations will prevent health impacts, but no health studies provide guidance on what regulations, if any, will get the health effects to go away." The authors further noted that the fracking boom has, in many regions, outpaced the ability of science

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[1408] Haswell, M., & Shearman, D. (2019, March 29). Expanding gas mining threatens our climate, water and health. *The Conversation.* Retrieved from https://theconversation.com/expanding-gas-mining-threatens-our-climate-water-and-health-113047

[1409] Haswell, M., & Shearman, D. (2019). The implications for human health and wellbeing of expanding gas mining in Australia: Onshore oil and gas policy background paper. College Park, South Australia: Doctors for the Environment Australia. Retrieved from https://www.dea.org.au/wp-content/uploads/2018/12/DEA-Oil-and-Gas-final-28-11-18.pdf

[1410] Gorski, I., & Schwartz, B. S. (2019). Environmental health concerns from unconventional natural gas development. *Oxford Research Encyclopedia of Global Public Health*. doi: 10.1093/acrefore/9780190632366.013.44

to document health impacts with long latencies, such as cancer and neurodegenerative diseases. The review concluded that the results of early health studies "should give pause" about whether and how shale gas fracking should proceed and referenced the several U.S. states and nations that have disallowed fracking, citing health concerns.

- December 12, 2018 – "The healthcare community has a professional mandate to protect society from harm to human health. We have a responsibility to help society move away from fossil fuels and accelerate the transition to renewable energy," wrote a team of medical professionals in an editorial for the *British Medical Journal*. Citing the "overwhelming" evidence that fossil fuels pose serious threats to public and planetary health, the group identified divestment from fossil fuel corporations as a strategy that increasing numbers of medical professional groups are taking, as part of fulfilling that professional mandate.[1411]

- December 4, 2018 – In a review of 63 studies in 20 countries, a University of Southern California medical research team concluded that the potential public health effects of "upstream oil extraction" include cancer, liver damage, immunodeficiency, and neurological damage. Collectively, onshore operations that bring crude oil to the surface affect nearly six million people that live or work nearby. Community health, worker health, and animal health in oil-drilling regions were addressed in this review, as well as effects on soil, air, surface water, and drinking water quality. In their analysis, the authors included both conventional or unconventional extraction techniques but noted that, in the United States, hydraulic fracturing accounted for 50 percent of total oil production in 2015—up from less than two percent in 2000.[1412]

- August 16, 2018 – The closer one lives to fracking sites, the more likely one is to experience toxic exposures and a related number of health impacts. Setbacks less than one quarter mile (1,320 feet) from drilling and fracking operations are not sufficient to protect public health, and additional setbacks are needed to protect vulnerable groups and settings, according to an expert panel assembled in Pennsylvania. "Vulnerable groups were defined by the panelists as children, neonates, fetuses, embryos, pregnant women, elderly individuals, those with pre-existing medical or psychological conditions, and those with pre-existing respiratory conditions. Vulnerable settings were defined as schools, day care centers, hospitals, and long-term care facilities. The panel, which consisted of 18 health care providers, public health practitioners, environmental advocates, and researchers/scientists, was brought together to compare existing minimum setback requirements against research about the health impacts of living near fracking activity. The panel was unable to come to agreement on a minimum safe setback distance between one quarter and two miles. It also noted that the failure to achieve consensus on this issue reflects uncertainties based on limited data of real-time toxic emissions from

[1411] Law, A., Duff, D., Saunders, P., Middleton, J., & McCoy, D. (2018). Medical organisations must divest from fossil fuels. *British Medical Journal, 363*, k5163. doi: 10.1136/bmj.k5163

[1412] Johnston, J. E., Lim, E., & Roh, H. (2018). Impact of upstream oil extraction and environmental public health: A review of the evidence. *Science of the Total Environment, 657,* 187-199. doi: 10.1016/j.scitotenv.2018.11.483

drilling and fracking operations, the limited number of scientific studies available, and the potential for episodically recurrent periods of high exposures.[1413]

- June 5, 2018 – The exacerbation of climate change caused by shale gas development is sufficient grounds to confirm that "the risks clearly and considerably outweigh any possible benefits," according to two public health scholars who published their editorial in the *British Medical Journal*.[1414]

- May 9, 2018 – With the objective of making practical recommendations for primary care providers, researchers sought to identify all published peer-reviewed studies examining evidence of direct relationships between high-volume hydraulic fracturing and human health harms. As a scoping review, the study purpose was to examine the extent and breadth of research and identify research gaps. Their criteria for inclusion were "narrow" and included peer-reviewed journal articles from the United States, in English, published between 2000 and September 2017. Among the 18 studies selected, 10 showed a positive correlation to the negative health outcome, six showed a mixed relationship, and two found no relationship. The authors wrote, "The health impacts found in the limited studies in this scoping review should encourage health care providers to maintain a high index of suspicion with patients who live or have lived near [drilling and fracking] activity or who have worked in oil and gas fields."[1415]

- April 4, 2018 – Two scholars critiqued the wide-ranging consultation on unconventional gas extraction, including fracking, which was commissioned by the Scottish government and published in November 2016.[1416] Noting that the Scottish assessment is more comprehensive than assessments conducted in the United States and elsewhere, the authors wrote, "The public health impact assessment in particular is underpinned by what appears to be a rigorous and transparent examination of existing scientific literature drawing on external peer review at some stages." However, they also went on to say that some of the conclusions drawn "appear to be optimistic readings of data and experience. For example, assessments of the ability of industry and regulators to control fracking effects on public health do not stand up to scrutiny." They identified several other ways in which the health impact assessment's conclusions were not always supported by the evidence it reviewed and if the assessment had overlooked areas of concern. For example, the literature on social impact assessments, as well as health research addressing questions of well-being and mental health, were neglected. Nevertheless, these scholars recommended the Scottish consultation as a research and policy tool.

[1413] Lewis, C., Greiner, L. H., & Brown, D. R. (2018). Setback distances for unconventional oil and gas development: Delphi study results. *PlosOne, 13*(8), e0202462. doi: 10.1371/journal.pone.0202462
[1414] McCoy, D., & Saunders, P. (2018). Fracking and health. *British Medical Journal, 361,* k2397. doi: 10.1136/bmj.k2397
[1415] Wright, R., & Muma, R. D. (2018). High-volume hydraulic fracturing and human health outcomes: A scoping review. *Journal of Occupational and Environmental Medicine, 5*, 424–429. doi: 10.1097/JOM.0000000000001278
[1416] Watterson, A., & Dinan, W. (2018). Public health and unconventional oil and gas extraction including fracking: Global lessons from a Scottish government review. *International Journal of Environmental Research and Public Health, 15*(4), pii: E675. doi: 10.3390/ijerph15040675

- February 12, 2018 – The Los Angeles County Department of Public Health reviewed the public health and safety risks of oil and gas facilities and identified "next steps." These included an increase in setback distances, continuous air monitoring systems around oil and gas operations, increased local oversight, a comprehensive Community Safety Plan, and Emergency Preparedness Plans. For this report, authors reviewed epidemiological literature, environmental and health impact assessments, neighborhood health investigations, and consultations with various jurisdictions regarding oil and gas ordinances.[1417] At the time of the report preparation, there were 3,468 active and 1,850 inactive oil and gas wells countywide. Conditions varied widely. Among the most egregious was an active well that was located 60 feet from a multi-unit housing complex and that shared borders with a local high school and a college dormitory. "The potential public health impacts of oil and gas sites located in densely populated areas are concerning, particularly to those who experience disproportionate economic and health inequities." Recommendations for some individual neighborhoods included offering temporary relocation assistance. "The report was ordered by the city of Los Angeles after complaints of headaches, eye and throat irritation, nausea and vomiting were received from residents of South Los Angeles, Wilmington and unincorporated county areas in the past several years."[1418]

- December 12, 2017 – Commissioned by the Australian government, the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory released its Draft Final Report. Tasked with identifying and assessing the risks of shale gas fracking for Australia's remote Northern Territory—and with making recommendations to mitigate those risks where possible—the Inquiry describes a multiplicity of risks, including many that are ill-defined and understudied[1419] Most notably, it recommends a halt on all fracking production licenses until a two-to-three-year study can be launched to further understand the nature of the risks for the particular ecology and culture of the region."[1420] Fracking is currently prohibited in the Northern Territory, which is estimated to hold over one-third of Australia's shale gas.

- November 7, 2017 – In a commentary published in *JAMA*, two South Dakota physicians reviewed the data on the potential public health implications of fracking, including asthma, water contamination, exposures to fracking fluid, and exposure of workers to

[1417] Butler, K., Tayour, C., Batikian, C., Contreras, C., Bane, M., Rhoades, E., . . . Rangan, C. (2018). Public health and safety risks of oil and gas facilities in Los Angeles County. Los Angeles County Department of Public Health. Retrieved from http://publichealth.lacounty.gov/eh/docs/PH_OilGasFacilitiesPHSafetyRisks.pdf

[1418] Scauzillo, S. (2018, February 27). Living near oil wells can cause health problems, LA County believes it has solutions. *Los Angeles Daily News.* Retrieved from https://www.dailynews.com/2018/02/27/living-near-oil-wells-can-cause-health-problems-la-county-believes-it-has-solutions/

[1419] Scientific Inquiry into Hydraulic Fracturing in the Northern Territory. (2017). *Draft final report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory.* Retrieved from https://frackinginquiry.nt.gov.au/inquiry-reports/draft-final-report

[1420] Reuters staff. (2017, December 12). Study seen needed before lifting fracking ban in remote Australia. *Reuters.* Retrieve from https://www.reuters.com/article/us-australia-fracking/study-seen-needed-before-lifting-fracking-ban-in-remote-australia-idUSKBN1E60TL silica dust. They voiced specific concerns about parkinsonism, neuropathy, and kidney disease, and called for prospective toxicity studies.[1421]

- October 25, 2017 – Scientists and physicians (including two co-authors of this *Compendium*) reviewed the body of evidence on the potential of unconventional oil and natural gas (UOG) development and operations to contribute to neurological and developmental harm via increased air and water pollution in the surrounding communities where it takes place. Highlighting data gaps and research limitations (such as the nondisclosure by industry of chemical mixtures), they nevertheless pinpointed evidence in the existing literature showing that "the chemicals that are used in or are byproducts of UOG operations have been linked to serious neurodevelopmental health problems in infants."[1422] Interviewed by the *Guardian,* a co-author said, "Given the profound sensitivity of the developing brain and the central nervous system, it is very reasonable to conclude that young children who experience frequent exposure to these pollutants are at particularly high risk for chronic neurological problems and disease."[1423] The research team concluded that there is "a need for public health prevention techniques, well-designed studies, and stronger state and national regulatory standards."

- October 23, 2017 – A Yale University research team reported that carcinogens involved in fracking operations have the potential to contaminate both air and water in nearby communities in ways that may increase the risk of childhood leukemia. The team identified 55 known or possible carcinogens that may be released into air and water from fracking operations. Of these, 20 are linked to leukemia or lymphoma.[1424] "This analysis creates a priority list of carcinogens to target for future exposure and health studies."[1425]

- July 31, 2017 – A review by a team of medical, psychological, occupational, and environmental health professionals concluded, "there appears to be an array of levels of psychosocial functioning that are deleteriously affected by the fracking process and industries and their aftermath." Though much of the research they identified linking fracking to psychological functioning was preliminary, documented impacts included: individual-level impacts, such as feelings of stress and powerlessness; community-level impacts, such as disrupted social fabric and new gender/sex imbalances in the community; collective trauma such as caused by a boom-and-bust cycle; and worker impacts, such as psychosocial impacts of being a transient worker. The review provided

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[1421] Wilke, R. A., & Freeman, J. W. (2017). Potential health implications related to fracking. *JAMA, 318*(17), 1645-1646. doi: 10.1001/jama.2017.14239

[1422] Webb, E., Moon, J., Dyrszka, L., Rodriguez, B., Cox, C., Patisaul, H., … London, E. (2017). Neurodevelopmental and neurological effects of chemicals associated with unconventional oil and natural gas operations and their potential effects on infants and children. *Reviews on Environmental Health.* Advance online publication. doi: 10.1515/reveh-2017-0008

[1423] Davis, N. (2017, October 25). Pollutants from fracking could pose health risk to children, warn researchers. *Guardian.* Retrieved from https://www.theguardian.com/environment/2017/oct/25/pollutants-from-fracking-could-pose-health-risk-to-children-warn-researchers

[1424] Elliot, E. G., Trihn, P., Ma, X., Leaderer, B. P., Ward, M. H., & Deziel, N. C. (2017). Unconventional oil and gas development and risk of childhood leukemia. *Science of the Total Environment, 576*. doi: 10.1016/j.scitotenv.2016.10.072

[1425] Yale News. (2016, October 24). Fracking linked to cancer-causing chemicals, new YSPH study finds. Retrieved from https://publichealth.yale.edu/news/article.aspx?id=13714 "an important first step in understanding the psychological toll that this energy development strategy has on fracking communities and sets the stage for advancements in research, clinical and policy, that will help us to better understand, assist, and advocate for those affected by fracking."[1426]

- May 1, 2017 – The Southwest Pennsylvania Environmental Health Project established a voluntary public health registry "aimed at tracking and eventually analyzing the impacts of shale gas development on people living near wells, impoundments, compressor stations and pipelines." According to a spokesperson, "The point is that the vast majority of independent science is looking at [shale gas development] and saying something's not good there. We need to know more… The findings of this registry will allow the health care community to be more informed about what problems people are experiencing when they walk into their offices. It will give the doctors some idea of what they should be looking for."[1427]

- April 28, 2017 – Portuguese and Brazilian reviewers identified the issue of water resources "as one of the most sensitive to negative impacts by shale gas exploration and exploitation," in their examination of scientific articles published between 2010 and 2015. They pointed to "expected" new legislation and industry practices for impact reductions but continued on to say that there are "no indications of a solution in the near future" for the problems of wastewater and greenhouse gas emissions.[1428]

- February 8, 2017 – Addressing the community health and safety harms linked with camps that house temporary workers in extractive industries, the British Columbia Ministry of Aboriginal Relations and Reconciliation funded a research project carried out in consultation with Indigenous nations. The premise, that "Indigenous women and youth can experience negative impacts of resource extraction at every phase of resource development," was borne out by the project's community dialogues and literature review. "Increased domestic violence, sexual assault, substance abuse, and an increased incidence of sexually transmitted infections (STIs) and HIV/AIDS due to rape, prostitution, and sex trafficking are some of the recorded negative impacts of resource extraction projects, specifically as a result of the presence of industrial camps and transient work forces." The objectives of the project were to stimulate dialogue and to develop detailed protective steps for Nations, government, and industry in advance of the initiation of planned extraction projects in the region, such as the TransCanada and Spectra Energy pipelines,

[1426] Hirsch, J. K., Smalley, K. B., Selby-Nelson, E. M., Hamel-Lambert, J. M., Rosmann, M. R., Barnes, T. A., . . . LaFromboise, T. (2017). Psychosocial impact of fracking: A review of the literature on the mental health consequences of hydraulic fracturing. *International Journal of Mental Health and Addiction.* doi: 10.1007/s11469-017-9792-5

[1427] Hopey, D. (2017, May 1). Registry will study health impact from living near shale gas wells. *Pittsburgh Post-Gazette*. Retrieved from http://powersource.post-gazette.com/powersource/consumers-powersource/2017/05/01/Registry-will-study-health-impact-from-living-near-shale-gas-wells/stories/201705010018

[1428] Costa, D., Jesus, J., Branco, D., Danko, A., & Fiúza, A. (2017). Extensive review of shale gas environmental impacts from scientific literature (2010–2015). *Environmental Science and Pollution Research, 24,* 14579–14594. doi: 10.1007/s11356-017-8970-0 in order to prevent violence against women and other life changing negative effects linked to the industrial camps.[1429]

- February 8, 2017 – Los Angeles County health officials criticized as insufficient the allocation of only one million dollars by the Southern California Gas Company to fund an independent health study in the aftermath of the massive methane leak at Aliso Canyon that lasted from October 2015 until February 2016. "'It's a study, but not a health study,' said Angelo Bellomo, the Los Angeles County deputy director for health protection. 'It is not responsive to addressing the health needs and concerns to this community. More importantly, it's inconsistent with advice given to [South Coast Air Quality Management District] by health officials.'" Health experts from across the state had suggested a design "that was comprehensive and larger in scope as well as consistent with a state Senate bill introduced last year that estimated such a design would cost $13 million in the first three years, and up to $40 million to complete."[1430]

- January 19, 2017 – An epidemiologist at Brown University reviewed studies to date on health outcomes in communities living close to unconventional natural gas development, and identified areas requiring further study. "Future epidemiologic studies should implement personal exposure assessments to examine associations between individual contaminants and relevant health outcomes, particularly to explain associations seen with respiratory and birth outcomes," the author concluded."[1431]

- December 5, 2016 – A team of British scientists wrote a 156-paper review on the risks and harms of fracking that attempts to "capture, review and interpret the published literature across all the accepted domains of public health in a systematic way and consider specific implications for the UK." They concluded that shale gas fracking "unequivocally presents an exposure hazard," and that further studies were needed to address exposure and health outcome data, noting the lack of before, during, and after exposure data for both air and water around drilling and fracking sites. Authors also noted that the claims that shale gas is less harmful to the climate than coal are not backed by lifecycle analyses. This team called for more research and a delay on any proposed drilling and fracking activity in the United Kingdom.[1432]

[1429] Gibson, G., Yung, K., Chisholm, L., & Quinn, H., with Lake Babine Nation and Nak'azdli Whut'en. (2017). *Indigenous Communities and Industrial Camps: Promoting healthy communities in settings of industrial change.* Retrieved from http://www.thefirelightgroup.com/thoushallnotpass/wp-content/uploads/2016/03/Firelight-work-camps-Feb-8-2017_FINAL.pdf

[1430] Gazzar, B., & Abram, S. (2017, February 8). $1 million health study 'shortchanges' Porter Ranch gas leak victims, critics say. *Los Angeles Daily News*. Retrieved from https://www.dailynews.com/2017/02/08/1-million-health-study-shortchanges-porter-ranch-gas-leak-victims-critics-say/

[1431] Stacy, S. L. (2017). A review of the human health impacts of unconventional natural gas development. *Current Epidemiology Reports, 4,* 38–45. doi: 10.1007/s40471-017-0097-9

[1432] Saunders, P.J., McCoy, D., Goldstein, R., Saunders, A. T., & Munroe, A. (2018). A review of the public health impacts of unconventional natural gas development. *Environmental Geochemistry and Health, 40*(1), 1-57. Advance online publication. doi: 10.1007/s10653-016-9898-x

- November 1, 2016 – The government of Scotland released a health impact assessment that reconfirmed the evidence for potential contamination of air and water, threats to worker health from silica dust exposure, and risks to the health of nearby residents.[1433]

- October 23, 2016 – In a unanimous vote of the society's 300-member House of Delegates, the Pennsylvania Medical Society called for a moratorium on new shale gas drilling and fracking in Pennsylvania and an initiation of a health registry in communities with pre-existing operations.[1434, 1435]

- October 11, 2016 – A group of health care professionals in Massachusetts called for an immediate moratorium on major new natural gas infrastructure until the impact of these projects on the health of the communities affected can be adequately determined through a Comprehensive Health Impact Assessment.[1436] The group noted that the operation of natural gas facilities risks human exposures to toxic, cancer-causing, and radioactive pollution due to the presence of naturally co-occurring contaminants, toxic additives to the hydraulic fracturing process, and through the operation of transmission pipelines.[1437]

- September 15, 2016 – A systematic review of 45 studies, primarily but not exclusively addressing conventional oil and gas activities, showed an emerging body of evidence documenting harm to reproductive health from residential and occupational exposure to these operations. The strongest evidence existed for increased risk of miscarriage, prostate cancer, birth defects, and decreased semen quality. Authors state that there is "ample evidence for disruption of the estrogen, androgen, and progesterone receptors with individual chemicals and waste products related to oil and gas extraction," and "impacts from unconventional oil and gas activities will likely be greater, given that unconventional activities have many similarities to conventional ones and employ dozens of endocrine-disrupting chemicals in the process of hydraulic fracturing."[1438]

- September 14, 2016 – In a commentary about fracking in the *American Journal of Public Health*, Weill Cornell Medicine physicians wrote, "mounting empirical evidence shows harm to the environment and to human health . . . and we have no idea what the long-

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[1433] Health Protection Scotland. (2016). *A health impact assessment of unconventional oil and gas in Scotland, Vol. 1*. Retrieved from http://www.hps.scot.nhs.uk/resourcedocument.aspx?resourceid=3102
[1434] Pennsylvania Medical Society (2016, October 23). Resolution 16-206: Pennsylvania Medical Society support for a moratorium on fracking. Retrieved from https://www.pamedsoc.org/PAMED_Downloads/HODAEC/16-206.pdf
[1435] Hopey, D. (2016, October 28). Doctors call for a state ban on drilling and fracking. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/local/region/2016/10/27/Doctors-group-calls-for-moratorium-on-fracking-in-Pennsylvania/stories/201610270226
[1436] Massachusetts Health Care Professionals Against Fracked Gas (2016, October). Call for a moratorium on natural gas projects undergoing construction or review in the Commonwealth of Massachusetts. Retrieved from http://mhcpafg.org/
[1437] Massachusetts Health Care Professionals Against Fracked Gas. (2016, February 20). The role of comprehensive health impact assessment in evaluating natural gas infrastructure proposals in Massachusetts. Retrieved from http://mhcpafg.org/
[1438] Balise, V. D., Meng, C-X., Cornelius-Green, J. N., Kassotis, C. D., Kennedy, R., & Nagel, S. C. (2016). Systematic review of the association between oil and natural gas extraction processes and human reproduction. *Fertility and Sterility, 106*(4). doi: 10.1016/j.fertnstert.2016.07.1099

term effects might be. . . . Ignoring the body of evidence, to us, is not a viable option anymore."[1439]

- July 7, 2016 –The UK health professional organization Medact released an updated assessment of the potential health impacts of shale fracking in England that confirm the findings of its 2015 report, *Health and Fracking*. The new report, *Shale Gas Production in England,* concluded, "Our view that the UK should abandon its policy to encourage [shale gas production] remains unchanged." The new report included hundreds of new academic papers addressing impacts on air and water quality, health, climate change, social wellbeing, economics, noise and light pollution, and seismic events. Still, authors wrote, "the absence of an independent social, health and economic impact assessment of [shale gas production] at scale is a glaring omission. Given the availability of alternative sources of energy, these are grounds for placing an indefinite moratorium on SGP (a position adopted by many jurisdictions across the world) until such time that there is greater clarity and certainty about the relative harms and benefits of shale gas."[1440]

- May 31, 2016 – "There are too many science, technology and risk-assessment gaps to green-light fracking in western Newfoundland," according to a panel that studied the question. In an interview with Canada's *Globe and Mail*, panel leader and engineering professor Ray Gosine said, "The science, the studies that have been done, have been somewhat limited – certainly limited compared to what we'd expect to have done in order to plan this kind of operation…. There are a number of gaps and deficiencies that are significant."[1441]

- May 13, 2016 – Physicians for Social Responsibility called for a ban on hydraulic fracturing, pointing both to the irremediable climate harm caused by methane emissions as well to the multiple health risks from industrial-scale water consumption, air pollution, seismic effects, the generation of large quantities of toxic liquid waste, and long-term impacts on drinking water aquifers. "We cannot stay healthy in an unhealthy environment. Nor can we survive indefinitely on a planet growing hotter and more prone to extreme, unpredictable and destructive weather. These factors impel PSR to call for a ban on fracking and for a rapid transition to cleaner, healthier, carbon-free sources of energy."[1442]

- March 27, 2016 – Noting that many chemicals used in fracking fluids are known or suspected endocrine disruptors, a group of public health researchers called for an endocrine-centric component for health assessments in areas impacted by oil and gas operations. The team outlined a series of recommendations to assess the "potential

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[1439] Finkel, M. L., & Law, A. (2016). The rush to drill for natural gas: a five-year update. *American Journal of Public Health, 106*(10). doi: 10.2105/AJPH.2016.303398

[1440] McCoy, D. & Munro, A. (2016). *Shale gas production in England: An updated public health assessment.* Retrieved from http://www.medact.org/wp/wp-content/uploads/2016/07/medact_shale-gas_WEB.pdf

[1441] Bailey, S. (2016, May 31). Too many gaps to recommend fracking in Newfoundland: Panel. *Globe and Mail*. Retrieved from http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/too-many-unknowns-to-recommend-fracking-in-western-newfoundland-panel/article30216746/

[1442] Physicians for Social Responsibility (2016, May 13). PSR position statement calling for a ban on hydraulic fracturing. Retrieved from http://www.psr.org/assets/pdfs/psr-fracking-policy.pdf endocrine-related risks from chemical exposures associated with oil and natural gas operations. We present these recommendations in light of the growing body of information regarding both chemical concentrations in the environment and adverse health outcomes reported in humans and wildlife."[1443]

- January 6, 2016 – A Yale University team of epidemiologists called for a systematic evaluation of chemicals in fracking fluid and wastewater for reproductive and development toxicity. While basic toxicity information is lacking for more than three-quarters of the more than 1,000 chemicals known to be used in fracking fluid, many of the remainder, the authors note, are linked to reproductive and developmental harm. "Therefore, carefully designed, rigorous exposure, and epidemiologic studies are urgently needed to investigate public health uncertainties…. The 67 chemicals we identified as possibly associated with either reproductive or developmental toxicity with a current or proposed federal drinking water standard or health-based guideline represent a feasible starting point for evaluation in future drinking water exposure studies or human health studies…."[1444]

- November 24, 2015 – A Harvard University team identified a trend toward increasing chemical secrecy and less transparency by examining 96,000 chemical disclosure forms filed by fracking companies between March 2011 and April 2015. These forms were submitted to the Fracfocus website, a chemical disclosure portal for the fracking industry that operates on a voluntary basis but for which reporting in mandated in more than 20 states. Fracfocus is the largest public database on chemicals used in U.S. fracking operations.[1445] Companies involved in fracking withheld chemical data at significantly higher rates in 2015 (16.5 percent) as compared to 2011-2013 (11 percent). The research team also found that withholding drops by a factor of four when companies report aggregate data without attribution to the specific products in the fracking fluid. The authors called for state governments to retain authority in requiring disclosure of "product-specific ingredient lists."[1446]

- August 7, 2015 – While acknowledging the "dramatic increase in the number of peer-reviewed published studies" on environmental and health impacts of fracking, Weill Cornell Medical College's Dr. Madelon Finkel and co-author PSE Healthy Energy's Jake Hays called for more well-designed longer-term epidemiologic studies to quantify the connections between fracking-related risk factors and health outcomes. Without such studies it is challenging to capture, for example, outcomes such as cancer that take many

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[1443] Kassotis, C. D., Tillitt, D. E., Lin, C-H., Mcelroy, J. A., & Nagel, S. (2016). Endocrine-disrupting chemicals and oil and natural gas operations: Potential environmental contamination and recommendations to assess complex environmental mixtures. *Environmental Health Perspectives, 124*(3). doi: 10.1289/ehp.1409535

[1444] Elliot, E. G., Ettinger, A. S., Leaderer, B. P., Bracken, M. B., & Deziel, N. C. (2016). A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. *Journal of Exposure Science and Environmental Epidemiology.* Advance online publication. doi: 10.1038/jes.2015.81

[1445] Song, L. (2015, Nov. 24). What chemicals are used in fracking? Industry discloses less and less. *InsideClimate News.* Retrieved from https://insideclimatenews.org/news/24112015/fracking-natural-gas-drilling-chemicals-frac-focus-study

[1446] Konschnik, K., & Dayalu, A. (2016). Hydraulic fracturing chemicals reporting: Analysis of available data and recommendations for policymakers. *Energy Policy, 88*. doi: 10.1016/j.enpol.2015.11.002

years to present. The authors described several important studies that are currently underway that will add to the body of knowledge in the future.[1447]

- June 9, 2015 – Information on individual exposures and local environmental conditions prior to the commencement of fracking in a given area is often "unavailable or hard to obtain. These and other data gaps have hindered the kind of large-scale epidemiological studies that can link exposures to actual health outcomes, with valid comparison groups," wrote public health journalist David Tuller in the journal *Health Affairs*.[1448] In an interview with *Michigan Radio*, Tuller noted that, because well development happens quickly, there was generally a lack of pre-drilling baseline studies.[1449]

- April 17, 2015 – Using sophisticated Geographic Information Systems (GIS) tools to examine distribution of fracking wells compared to distribution of vulnerable populations, Clark University researchers found consistent evidence that, in the Pennsylvania Marcellus Shale region, census tracts with potential exposure to pollution from fracking wells contained "significantly higher" percentages of poor people. They also found clusters of vulnerable populations concentrated near drilling and fracking in all three states they studied: Pennsylvania (for poverty and elderly population), West Virginia (for poverty, elderly population, and education level) and Ohio (for children). Researchers also reported difficulty in accessing high quality and consistent unconventional well data in all three states, demonstrating an "urgent need" for common data collection and reporting.[1450] Another GIS-based study sought to begin to fill this gap in data on spatially distributed risks of fracking, identifying Pennsylvania populations at "very high" and "high" risk in over a dozen counties. The author called for more focus on those areas to understand the impacts of fracking.[1451]

- March 30, 2015 – The UK medical organization Medact published a report, *Health & Fracking: The Impacts and Opportunity Costs*, which concluded that fracking poses significant risks to public health and called for an immediate moratorium to allow time for a full and comprehensive health and environmental impact assessment to be completed.[1452] The report was supported by a letter published in the *British Medical Journal* calling for shale gas development to be put on hold, signed by the Climate and Health Council and over a dozen senior health professionals. The letter stated, "The arguments against fracking on public health and ecological grounds are overwhelming.

[1447] Finkel, M. L. & Hays, J. (2015). Environmental and health impacts of 'fracking': Why epidemiological studies are necessary. *Journal of Epidemiology and Community Health*. Advance online publication. doi: 10.1136/jech-2015-205487

[1448] Tuller, D. (2015). As fracking booms, dearth of health risk data remains. *Health Affairs, 34* (6), 903-906.

[1449] Williams, R. (June 9, 2015). Why there are gaps in public health studies on fracking. *Michigan Radio.* Retrieved from http://michiganradio.org/post/why-there-are-gaps-public-health-studies-fracking#stream/0

[1450] Ogneva-Himmelberger, Y., & Huang, L. (2015). Spatial distribution of unconventional gas wells and human populations in the Marcellus Shale in the United States: Vulnerability analysis. *Applied Geography, 60*. 165-174.

[1451] Meng, Q. (2015). Spatial analysis of environment and population at risk of natural gas fracking in the state of Pennsylvania, USA. *Science of the Total Environment, 515-516.* 198-206.

[1452] Medact. (2015). *Health & fracking: The impacts and opportunity costs.* London: McCoy, D. & Saunders, P.

There are clear grounds for adopting the precautionary principle and prohibiting fracking."[1453]

- February 17, 2015 – Writing in the *Canadian Medical Association Journal*, a public health scientist and medical doctor briefly reviewed the human health risks of fracking documented to date and made the case for a health care worker role in insisting on improved understanding. They cited worker and community safety issues as the biggest short-term risks, but emphasized that more needs to be known "before health care providers can definitively respond to their patients' and communities' concerns.… Physicians may wish to advocate delaying new development activities until the potential health effects are better understood."[1454]

- January 22, 2015 –The acting head of research at the Cancer Association of South Africa, Carl Albrecht, said that known carcinogenic chemicals used in fracking could lead to an epidemic of cancer in South Africa's Karoo desert. As South Africa was poised to publish draft regulations, Albrecht said that the effect of fracking on human health was ignored.[1455]

- January 19, 2015 – In an article that reviewed research and research gaps, a team of British and U.S. medical and scientific professionals urged the United Kingdom and other nations to engage in science before engaging in fracking. They warned that even strong regulations may not effectively address air pollution from fracking, and that "permanent, adverse environmental, climatic, and population health impacts" may exist in some cases.[1456]

- December 17, 2014 – In an editorial, Rutgers University environmental exposure expert Paul J. Lioy (now deceased) highlighted fracking as an area in which accurate exposure monitoring and risk assessment did not yet exist. Lioy emphasized that the relevant research was compartmentalized and fragmented and that exposures and health outcomes around unconventional natural gas development need to be systematically addressed through "well-defined exposure studies in communities and workplaces."[1457]

- December 5, 2014 – A team of medical and scientific researchers, including from the Institute for Health and Environment at the State University of New York (SUNY) at

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[1453] Stott, R., Atkinson, S., Montgomery, H., Rao, M., McKee, M., Gerada, C., . . . Popay, J. (2014). Public Health England's draft report on shale gas extraction. *BMJ, 348.* Retrieved from http://www.bmj.com/content/348/bmj.g2728/rr

[1454] Bharadwaj, L. & Goldstein, B. D. (2015). Shale gas development in Canada: What are the potential health effects? *CMAJ, 187*(3), E99-E100.

[1455] Vecchiatto, P. (January 22, 2015). Chemicals used in fracking 'could cause cancer.' *Business Day BDlive.* Retrieved from http://www.bdlive.co.za/business/energy/2015/01/22/chemicals-used-in-fracking-could-cause-cancer

[1456] Hays, J., Finkel, M. L., Depledge, M., Law, A., & Shonkoff, S. B. C. (2015). Considerations for the development of shale gas in the United Kingdom. *Science of the Total Environment, 512–513,* 36–42. doi: 10.1016/j.scitotenv.2015.01.004

[1457] Lioy, P.J. (2015). Exposure science and its places in environmental health sciences and risk assessment: Why is its application still an ongoing struggle in 2014? *Journal of Exposure Science and Environmental Epidemiology, 25,* 1-3. doi: 10.1038/jes.2014.59

Albany, reviewed the scientific evidence that both adult and early life—including prenatal—exposure to chemicals from fracking operations can result in adverse reproductive health and developmental effects. These include: endocrine-disrupting chemicals potentially increasing risk for reproductive problems, breast cancer, abnormal growth and developmental delays, and changes in immune function; benzene, toluene and xylene (BTX chemicals) increasing risk for impaired sperm quantity and quality in men and menstrual and fertility problems in women; and heavy metals increasing the risk of miscarriage and/or stillbirths. Potential exposures occur through both air and water. Based on their review, the authors concluded, "Taken together, there is an urgent need for the following: 1) biomonitoring of human, domestic and wild animals for these chemicals; and 2) systematic and comprehensive epidemiological studies to examine the potential for human harm."[1458] Lead author Susan Nagel said in an accompanying interview, "We desperately need biomonitoring data from these people. What are people actually exposed to? What are the blood levels of people living in these areas? What are the levels in the workers?"[1459]

- November 12, 2014 – A team of Australian researchers reviewed the strength of evidence for environmental health impacts of fracking based on publications from 1995 to 2014. They noted that the rapid expansion of fracking had outstripped the pace of science and that most studies focused on short-term, rather than long-term, health. Hence, "very few studies examined health outcomes with longer latencies such as cancer or developmental outcomes." Noting that no evidence exists to rule out health impacts, the team called for direct and clear public health assessments before projects are approved, longitudinal studies that include baseline data, and government and industry transparency.[1460]

- September 15, 2014 – Researchers led by University of Rochester's Environmental Health Sciences Center conducted interviews in New York, North Carolina, and Ohio to evaluate community health concerns about unconventional natural gas development. They identified many areas where more study is needed, including baseline measures of air quality, ongoing environmental monitoring, and health impact assessments. They noted that other areas where data are lacking involve the assessment of drilling and fracking impacts on vulnerable populations such as very young children, and the potential consequences of interactions between exposures resulting from shale gas extraction operations. Researchers suggested incorporating the input of potentially affected community members into the development of the research agenda.[1461]

[1458] Webb, E., Bushkin-Bedient, S., Cheng, A., Kassotis, C. D., Balise, V., & Nagel, S. C. (2014). Developmental and reproductive effects of chemicals associated with unconventional oil and natural gas operations. *Reviews on Environmental Health, 29*(4), 307-318. doi: 10.1515/reveh-2014-0057

[1459] Sample, I. (2014, December 5). Fracking chemicals could pose risks to reproductive health, say researchers. *Guardian.* Retrieved from http://www.theguardian.com/environment/2014/dec/05/fracking-chemicals-could-pose-risks-to-reproductive-health-say-researchers

[1460] Werner, A.K., Vink, S., Watt, K., & Jagals, P. (2015). Environmental health impacts of unconventional natural gas development: A review of the current strength of evidence. *Science of the Total Environment, 505*, 1127–1141. doi: 10.1016/j.scitotenv.2014.10.084

[1461] Korfmacher, K. S., Gray, K. M., & Haynes, E. (2014, September 15). Health impacts of unconventional natural gas development: A comparative assessment of community information needs in New York, North Carolina, and Ohio. *Project Report, UR-UNC-UC Supplement 2012-13.* Retrieved from

- July 21, 2014 – An independent assessment report by Scientists for Global Responsibility and the Chartered Institute of Environmental Health reviewed current evidence across a number of issues associated with shale gas extraction by hydraulic fracturing, including environmental and public health risks, drawing on academic research. Among the report's conclusions: there are major shortcomings in regulatory oversight regarding local environmental and public health risks; there is a large potential for UK shale gas exploitation to undermine national and international efforts to tackle climate change; the water-intensive nature of the fracking process which could cause water shortages in many areas; the complete lack of evidence behind claims that shale gas exploitation will bring down UK energy bills; and concerns that it will impact negatively on UK energy security. Despite claims to the contrary, the report noted that evidence of local environmental contamination from shale gas exploitation is well reported in the scientific literature. It emphasizes that, "[t]here are widespread concerns over the lack of evidence on fracking-related health impacts," and that there is a lack of "substantive epidemiological study for populations exposed to shale gas extraction."[1462]

- July 18, 2014 – A working group of the Environmental Health Sciences Core Centers, supported by the National Institute of Environmental Health Sciences, reviewed the available literature on the potential health impacts of fracking for natural gas. They concluded that further research is urgently needed. Needs identified included: monitoring of air and water quality over the entire lifetime of wells; further epidemiologic research addressing health outcomes and water quality; and research addressing whether air pollution associated with fracking increases the risk of pulmonary and cardiovascular disease. The working group advocated for the participation of potentially affected communities in all areas of research.[1463]

- July 12, 2014 – Eli Avila, Pennsylvania's former Secretary of Health, said that health officials need to be proactive in protecting the public from the health effects of unconventional shale gas extraction. In 2011, funding was approved for a Pennsylvania public health registry to track drilling related complaints and address concerns, but was cut at the last minute. Speaking to the problem posed by the dearth of information, Avila asked, "How can you keep the public safe if you're not collecting data?"[1464]

- June 30, 2014 – The immediate past chair of the Executive Committee of the Council on Environmental Health for the American Academy of Pediatrics, Jerome A. Paulson, MD,

http://www.urmc.rochester.edu/MediaLibraries/URMCMedia/environmental-health-sciences-center/COEC/documents/UNGD-information-needs-asssessment-Final-project-report-091514.pdf

[1462] Harrison, G., Parkinson, S., & McFarlane, G. (2014). Shale gas and fracking: examining the evidence. Published by Scientists for Global Responsibility (SGR) and the Chartered Institute of Environmental Health (CIEH). Retrieved from http://www.cieh.org/WorkArea/showcontent.aspx?id=53520

[1463] Penning, T. M., Breysse, P.N., Gray, K., Howarth, M., & Yan, B. (2014). Environmental health research recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations. *Environmental Health Perspectives, 122*(11), 1155-1159. doi: 10.1289/ehp.1408207

[1464] Associated Press. (2014, July 12). Expert: Pa. didn't address fracking health impacts. *York Dispatch.* Retrieved from http://www.yorkdispatch.com/ci_26135724/expert-pa-didnt-address-fracking-health-impacts called for industry disclosure of all ingredients of fracking fluid; thorough study of all air contaminants released from drilling and fracking operations and their protected dispersal patterns; and study and disclosure of fracking-related water contamination and its mechanisms. In a letter to the Pennsylvania Department of Environmental Protection (PA DEP), Paulson said:

> In summary, neither the industry, nor government agencies, nor other researchers have ever documented that [unconventional gas extraction] can be performed in a manner that minimizes risks to human health. There is now some evidence that these risks that many have been concerned about for a number of years are real risks. There is also much data to indicate that there are a number of toxic chemicals used or derived from the process, known or plausible routes of exposure of those chemicals to humans; and therefore, reason to place extreme limits on [unconventional gas extraction].[1465]

- June 20, 2014 – Highlighting preliminary studies in the United States that suggest an increased risk of adverse health problems among individuals living within ten miles of shale gas operations, a commentary in the British medical journal *The Lancet* called for a precautionary approach to gas drilling in the United Kingdom. According the commentary, "It may be irresponsible to consider any further fracking in the UK (exploratory or otherwise) until these prospective studies have been completed and the health impacts of fracking have been determined."[1466]

- June 20, 2014 – Led by an occupational and environmental medicine physician, a Pennsylvania-based medical and environmental science research team documented "… the substantial concern about adverse health effects of [unconventional natural gas development] among Pennsylvania Marcellus Shale residents, and that these concerns may not be adequately represented in medical records." The teams identified the continued need to pursue environmental, clinical, and epidemiological studies to better understand associations between fracking, medical outcomes, and residents' ongoing concerns.[1467]

- June 17, 2014 – A discussion paper by the Nova Scotia Deputy Chief Medical Officer and a panel of experts identified potential economic benefits as well as public health concerns from unconventional oil and gas development. On the health impacts, they wrote, "uncertainties around long term environmental effects, particularly those related to climate change and its impact on the health of both current and future generations, are considerable and should inform government decision making." The report noted potential dangers including contamination of groundwater, air pollution, surface spills, increased

[1465] Paulson, J.A. (2014, June 30). Letter to the Pennsylvania Department of Environmental Protection. Retrieved from http://concernedhealthny.org/letter-from-dr-jerome-a-paulson-to-the-pennsylvania-department-of-environmental-protection/
[1466] Hill, M. (2014, June 20). Shale gas regulation in the UK and health implications of fracking. *The Lancet*. Advance online publication. doi: 10.1016/S0140-6736(14)60888-6
[1467] Saberi, P., Propert, K. J., Powers, M. Emmett, E., & Green-McKenzie, J. (2014). Field survey of health perception and complaints of Pennsylvania residents in the Marcellus Shale region. *International Journal of Environmental Research and Public Health, 11*(6), 6517-6527. doi: 10.3390/ijerph110606517

truck traffic, noise pollution, occupational health hazards, and the generation of greenhouse gases. It also noted that proximity of potential fracking sites to human habitation should give regulators pause and called for a health impact assessment and study of long-term impacts.[1468] Responding to the report, the Environmental Health Association of Nova Scotia applauded the go-slow approach and called for a 10-year moratorium on fracking.[1469]

- May 29, 2014 – In New York State, more than 250 medical organizations and health professionals released a letter detailing emerging trends in the data on fracking that show significant risk to public health, air quality, and water, as well as other impacts. With signatories including the American Academy of Pediatrics, District II, the American Lung Association in New York, Physicians for Social Responsibility, and many leading researchers examining the impacts of fracking, they wrote, "The totality of the science — which now encompasses hundreds of peer-reviewed studies and hundreds of additional reports and case examples—shows that permitting fracking in New York would pose significant threats to the air, water, health and safety of New Yorkers."[1470, 1471]

- May 9, 2014 – In a peer-reviewed analysis, leading toxicologists outlined some of the potential harm and uncertainty relating to the toxicity of the chemical and physical agents associated with fracking, individually and in combination. While acknowledging the need for more research and greater involvement of toxicologists, they noted the potential for surface and groundwater contamination from fracking, growing concerns about air pollution particularly in the aggregate, and occupational exposures that pose a series of potential hazards to worker health.[1472, 1473]

- May 1, 2014 – A 292-page report from a panel of top Canadian scientists urged caution on fracking, noting that it poses "the possibility of major adverse impacts on people and ecosystems" and that significantly more study is necessary to understand the full extent of the risks and impacts.[1474] The *Financial Post* reported that the panel of experts "found

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[1468] Atherton, F. (2014, June 17). *Discussion paper: Hydraulic fracturing and public health in Nova Scotia.* Nova Scotia Hydraulic Fracturing Independent Review and Public Engagement Process.
[1469] Macdonald, M. (2014, June 17). Nova Scotia expert calls for go-slow approach for hydraulic fracturing. *The Canadian Press*. Retrieved from http://www.calgaryherald.com/health/Health+studies+needed+hydraulic+fracturing+approved+Nova+Scotia/9946368/story.html
[1470] Concerned Health Professionals of New York. (2014, May 29). Letter to Governor Cuomo and Acting Health Commissioner Howard A. Zucker. Retrieved from http://concernedhealthny.org/letters-to-governor-cuomo/
[1471] Hughes, K. (2014, May 29). NY fracking opponents call for moratorium of 3 to 5 years. *Daily Freeman*. Retrieved from http://www.dailyfreeman.com/general-news/20140529/ny-fracking-opponents-call-for-moratorium-of-3-to-5-years
[1472] Society of Toxicology. (2014). Toxicologists outline key health and environmental concerns associated with hydraulic fracturing. *ScienceDaily*. Retrieved from http://www.sciencedaily.com/releases/2014/05/140509172545.htm
[1473] Goldstein, B. D., Brooks, B. W., Cohen, S. D., Gates, A. E., Honeycutt, M. E., Morris, J. B., . . . Snawder, J. (2014). The role of toxicological science in meeting the challenges and opportunities of hydraulic fracturing [Abstract]. *Toxicological Sciences, 139*(2). doi: 10.1093/toxsci/kfu061
[1474] The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction. (2014). Environmental impacts of Hurricane Mitch. *Council of Canadian Academies*. Retrieved from

significant uncertainty on the risks to the environment and human health, which include possible contamination of ground water as well as exposure to poorly understood combinations of chemicals."[1475]

- April 30, 2014 – Medical professionals spoke out on the dearth of public health information collected and lack of long-term study five years into Pennsylvania's fracking boom. Walter Tsou, MD, MPH, past president of the American Public Health Association and former Health Commissioner of Philadelphia commented, "That kind of study from a rigorous scientific perspective has never been done." Other experts added, "There has been more health research involving fracking in recent years, but every study seems to consider a different aspect, and … there is no coordination."[1476]

- April 17, 2014 – In the preeminent *British Medical Journal*, authors of a commentary, including an endocrinologist and a professor of clinical public health, wrote, "Rigorous, quantitative epidemiological research is needed to assess the risks to public health, and data are just starting to emerge. As investigations of shale gas extraction in the US have continually suggested, assurances of safety are no proxy for adequate protection."[1477]

- April 15, 2014 – The *Canadian Medical Association Journal* reported on the increasing legitimacy of concerns about fracking on health: "While scientists and area residents have been sounding the alarm about the health impacts of shale gas drilling for years, recent studies, a legal decision and public health advocates are bringing greater legitimacy to concerns."[1478]

- March 3, 2014 – In the *Medical Journal of Australia*, researchers and a physician published a strongly worded statement, "Harms unknown: health uncertainties cast doubt on the role of unconventional gas in Australia's energy future." They cited knowledge to date on air, water, and soil pollution, and expressed concern about "environmental, social and psychological factors that have more indirect effects on health, and important social justice implications" yet to be understood. They wrote in summary:

  > The uncertainties surrounding the health implications of unconventional gas, when considered together with doubts surrounding its greenhouse gas profile and cost, weigh heavily against proceeding with proposed future developments. While the health effects associated with fracturing chemicals have attracted considerable

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http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/shale%20gas/shalegas_fullreporten.pdf

[1475] Canadian Press. (2014, May 1). Top Canadian scientists urge cautious approach to fracking until more known of impact. *Financial Post*. Retrieved from http://business.financialpost.com/2014/05/01/top-canadian-scientists-urge-cautious-approach-to-fracking-until-more-known-of-impact/?__lsa=3b44-76a1

[1476] Khan, N. (2014, April 30). Health impact of gas fracking left in the dark. *Pocono Record*. Retrieved from http://www.poconorecord.com/apps/pbcs.dll/article?AID=/20140430/NEWS90/404300301/-1/NEWS01

[1477] Law, A., Hays, J., Shonkoff, S. B., & Finkel, M. L. (2014). Public Health England's draft report on shale gas extraction [Abstract]. *BMJ, 1840*. doi: http://dx.doi.org/10.1136/bmj.g2728

[1478] Glauser, W. (2014). New legitimacy to concerns about fracking and health. *Canadian Medical Association Journal, 186*(8), E245-E246. doi: 10.1503/cmaj.109-4725 public attention, risks posed by wastewater, community disruption and the interaction between exposures are of also of concern.[1479]

- March 1, 2014 – In the prestigious British medical journal *The Lancet*, researchers summarized workshops and research about the health impacts of fracking, noting that the scientific study on the health impacts of fracking is "in its infancy." Nevertheless, the existing evidence suggests, said these researchers, that health risks posed by fracking exceed those posed by conventional oil and gas wells due to the sheer number and density of well pads being developed, their proximity to densely populated areas, and the need to transport and store large volumes of materials.[1480]

- February 24, 2014 – In a review of the health effects of unconventional natural gas extraction published in the journal *Environmental Science & Technology*, leading researchers identified a range of impacts and exposure pathways that can be detrimental to human health. Noting how fracking disrupts communities, the review states, "For communities near development and production sites the major stressors are air pollutants, ground and surface water contamination, truck traffic and noise pollution, accidents and malfunctions, and psychosocial stress associated with community change." They concluded, "Overall, the current scientific literature suggests that there are both substantial public concerns and major uncertainties to address."[1481]

- August 30, 2013 – A summary of a 2012 workshop by the Institute of Medicine Roundtable on Environmental Health Sciences, Research, and Medicine featured various experts who discussed health and environmental concerns about fracking and the need for more research. The report in summary of the workshop stated, "The governmental public health system, which retains primary responsibility for health, was not an early participant in discussions about shale gas extraction; thus public health is lacking critical information about environmental health impacts of these technologies and is limited in its ability to address concerns raised by regulators at the federal and state levels, communities, and workers employed in the shale gas extraction industry."[1482]

- June 2013 – A group of three nursing professors published a cautionary review questioning the rollout of new shale-based energy practices at a time when, "anecdotal reports make clear that the removal of fossil fuels from the earth directly affects human health." Although the results of longterm studies are not yet available, the authors point to emerging evidence for negative human and ecologic health effects of fracking.

[1479] Coram, A., Moss, J., & Blashki, G. (2014). Harms unknown: Health uncertainties cast doubt on the role of unconventional gas in Australia's energy future. *The Medical Journal of Australia, 200*(4), 210-213. doi: 10.5694/mja13.11023

[1480] Kovats, S., Depledge, M., Haines, A., Fleming, L. E., Wilkinson, P., Shonkoff, S. B., & Scovronick, N. (2014). The health implications of fracking. *The Lancet, 383*(9919), 757-758. doi: 10.1016/S0140-6736(13)62700-2

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Furthermore, they continue, "sufficient evidence has been presented to the [American Nurses Association], the American Public Health Association, and the American Medical Association's Resident and Fellow Section to result in a call for a moratorium on the issuance of new fracking permits nationally." They urge nurses to contribute to keeping health issues "front and center as we address national energy needs and policies."[1483]

- April 22, 2013 – In one of the first peer-reviewed nursing articles summarizing the known health and community risks of fracking, Professor Margaret Rafferty, Chair of the Department of Nursing at New York City College of Technology wrote, "Any initiation or further expansion of unconventional gas drilling must be preceded by a comprehensive Health Impact Assessment (HIA)."[1484]

- May 10, 2011 – In the *American Journal of Public Health*, two medical experts cautioned that fracking "poses a threat to the environment and to the public's health. There is evidence that many of the chemicals used in fracking can damage the lungs, liver, kidneys, blood, and brain." The authors urged that it would be prudent to invoke the precautionary principle in order to protect public health and the environment.[1485]

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EXHIBIT 17

Existing scientific literature on setback distances from oil and gas development sites

Nicole J. Wong, MPH November 2017 (revised)

Background: Need for an LA Relevant Setback

The current body of peer-reviewed scientific literature has a small but growing set of studies investigating the relationship between the proximity of modern oil and gas extraction nearby communities and health impacts. The published studies that have examined this relationship have considered health outcomes, exposure to toxic health risks, and discussed whether current setback requirements in various states are adequate to ensure the health and safety of people who live, work, play, and learn near these facilities. These studies were conducted primarily in lower population density communities and states. Yet, the majority of these studies find a positive correlation between distance of a home from an active oil or gas well and adverse health outcomes. The closer people live to oil and gas wells, the more likely they will be exposed to toxic air contaminants and the more elevated their risk of associated health effects.[1] Most of these distances are measured at a half-mile to a mile (See Table 2). Distances in Los Angeles are much closer. No peer-reviewed studies to date have investigated the relationship between the proximity of oil and gas development and health outcomes in California, nor have any studied this issue in the U.S. urban context. In Los Angeles alone, about 1.7 million people live within 1 mile of an active oil or gas well, and of that group, more than 32,000 people live within 100 m (about 328 feet) of an oil or gas well.[2]

Overview of Report Contents

> The population density in South Los Angeles is about ***133 times greater*** than the populations investigated in the existing literature.

A total of 14 studies and publications were considered for this report that investigated the health and quality of life impacts and exposures of unconventional natural gas development proximate to residences. Of the 14 studies and publications, 6 considered the distance of an active well to place of residence (Table 1), while the remaining 4 considered the concentration of wells proximate to residences (Table 2). Four of the publications are studies and non-peer reviewed reports that have setback recommendations or relevant considerations for a safe setback margin (included in Table 1). The distances considered in this report range in setback recommendations and findings from 1,500 to 6,600 feet. Among the peer-reviewed studies that specified where samples and data were collected, the average population density was about 150 people per square mile. To compare, the population density for the City of Los Angeles is about 50 times greater at 8,092.3 people per square mile. In neighborhoods like South Los Angeles that is home to several active oil drilling sites, the population densities are up to more than 20,000 people per square mile.[3] The population density in South Los Angeles is about 133 times greater than those of the populations investigated in the existing literature. Table 1 lays out the peer-reviewed studies included in this report, ordered by the safe setback distance each study considered. Advocacy groups in Los Angeles have called for a 2,500-setback law to protect the health and safety of nearby residents. **Based on the current available research, a 2,500-foot setback recommendation is on the lower end**

of the range of distances where research has determined harmful health and quality of life impacts of toxic emissions and exposures.

Oil and Gas Extraction Methods

During much of the early and mid 1900's, conventional methods of extracting oil depleted most of the oil fields throughout the country. In Los Angeles, only 10% of oil field reservoirs can be recovered by conventional means.[2] Now, in order to access resources that are deeper or more difficult to recover than those that have been recovered historically, oil industry has pursued new technologies in "unconventional" or "enhanced oil recovery" methods.[2,5] These methods include steam, water, and/or chemical injection, hydraulic fracturing, acidization, and gravel packing.

Although the existing research has primarily focused on health impacts and toxic emissions from unconventional natural gas development, many of the same chemicals of concern used in so-called unconventional activities are used in routine activities such as well maintenance, well-completion, or rework on both conventional oil and natural gas wells.[6] There are many applications of hazardous chemicals in oil and gas development, and in fact the routine operational chemical use data is less available than that for unconventional chemical use activities.[6]

In Los Angeles, many of the extraction facilities utilize unconventional techniques, such as acidizing with hydrochloric and hydrofluoric acid, directional drilling, and gravel packing which involves use of tons of carcinogenic silica sand. Many of the oil fields in Los Angeles produce both oil and gas at a relatively equal ratio. Among the top ten producing oil fields in the City of Los Angeles, which include Beverly Hills, Wilmington, and Las Cienegas oil fields, the ratio of gas to oil production is about 0.91.[7] Therefore, the existing research in other parts of the country holds relevance for the nature of oil and gas extraction in Los Angeles.

Health and Quality of Life Impacts

The consequences to health from oil and gas activity investigated in the reviewed studies include birth outcomes, asthma, other respiratory and dermal impacts, pediatric sub-chronic non-cancer and chronic hazard indices, unhealthy noise levels, and various associated health symptoms. Among the existing research, the greatest distance to oil and gas activity investigated was 2 km (6,561 feet) where exposure to hydrogen sulfide combined with VOCs were detected.[8] The shortest distance measurement studied was 1,500 feet and this study found significantly more reports of health symptoms in households within 1,500 feet of an active well. The health symptoms included throat irritation, sinus problems, nasal irritation, eye burning, severe headaches, loss of sense of smell, persistent cough, frequent nose bleeds, swollen painful joints.[9] Rabinowitz, et al. (2015) found an increased number of reported upper respiratory symptoms and skin conditions among residents who lived less than 1 km (3,280 feet) from an active well when compared with residents who lived more than 2 km (6,561 feet) from an active well.[10] McKenzie, et al. (2012) found elevated risk of health effects from natural gas development for residents living less than half a mile from wells. They primarily considered the subchronic non-cancer hazard index, which was primarily driven up by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons, and chronic hazard index measurements, which were driven up by benzene exposure.[11]

Another dimension of health impacts related to oil and gas development is noise levels. Boyle, et al. (2017) conducted a pilot study investigating the 24-hour noise levels of a compressor station relative to residential homes both indoors and outdoors.[12] His study determined that homes up to 600m away (about 1,968 feet) experienced outdoor noise levels that exceeded the U.S. Environmental Protection Agency's recommended limit of 55 dBA 100% of the time.[12] In addition to these punctuated periods of noise, the regular day-to-day operations at the site cause what has been described as "buzzing" throughout the night makes it difficult to sleep. Recent studies have increasingly focused on "non-auditory" effects of noise on health including annoyance, sleep disturbance, daytime sleepiness, hypertension, cardiovascular disease, and diminished cognitive performance in school children.[13] Many residents living in close proximity to oil and gas development sites in Los Angeles routinely complain of noise from routine operations.

Air Quality and Toxic Exposure

Three of the studies investigated levels of volatile organic compounds (VOCs) and endocrine disrupting chemicals that exceeded regulatory agency minimum standards. Haley, et al. (2016) discussed how exposures of hydrogen sulfide combined with VOCs could produce potentially new harmful exposures that could be detected at distances up to 2 km (about 6,561 feet).[8] Macey, et al. (2014) investigated several jurisdictions with setback regulations for oil and gas operations and conducted air monitoring sampling to examine if the setbacks were adequate.[14] The findings revealed high concentrations of carcinogenic VOCs at distances greater than the setback regulations, including formaldehyde at 2,591 feet and benzene up to 885 feet away from wells. The study also discussed how health-based risk levels that most regulatory agencies rely on for setting limits on air emissions are very limited in providing a sense of the human health impacts.[14] The risk level standards do not account for more vulnerable subpopulations like children and the elderly. Additionally, the number of compounds that are required for monitoring and toxicity reporting is relatively small when considering the vast number of chemicals required for oil and gas operations.[14] Kassotis, et al. (2014) found elevated levels of endocrine disrupting chemicals in water sources 1 mile away from oil and gas operations with known spills or incidences.[15] The study noted that near one of the investigated facilities contaminated by endocrine disrupting chemicals (EDCs), some of the animals in the area were no longer producing live offspring.

The findings revealed high concentrations of VOCs at greater distances than the setback regulations, including formaldehyde at 2,591 feet and benzene up to 885 feet away from wells.

Explosion Risk and Hazards

Haley, et al. (2016) considered the minimum distance that might be required in case of a blow-out or explosion event by investigating historical evacuation data.[8] For example, an explosion in the Barnett Shale in northern Texas produced a 750-foot burn crater.[16] Their findings determined that the average evacuation zone for such incidences is 0.8 miles, or 4,224 feet. A blowout in Wyoming County, PA required a 1,500 foot evacuation zone, which required the evacuation of only 3 families.[17] Considering that in Wyoming County the population density was only 71.2 people per square mile[1816] compared to a densely populated neighborhood in South Los Angeles with a population density of over 20,000, if a similar event were to happen, the same distance of 1,500 feet would require evacuation of 100,743 people. A very recent example of natural gas pipeline explosion accident comes from rural Colorado. On April 17, 2017, a one-inch abandoned pipeline exploded under a home in Colorado, leveled the house, killed two people and badly burned a third person. The gas well head was located just 178 feet from the home.[19]

Dense Population of the City of Los Angeles and Close Proximity to Oil and Gas Facilities Magnifies Health and Safety Risks

Four studies investigated the relationship between health outcomes and the number of wells within a certain radius of residential homes (Table 3). The studies were concerned with birth outcomes and childhood leukemia and were conducted in Pennsylvania and Colorado. The density measures ranged from 3.36 – 125 wells per square mile. To compare to Los Angeles, the four extraction facilities in South Los Angeles that extract from the Las Cienegas oil field, the 2nd largest gas producing field in Los Angeles, each have 22 to 36 oil and gas wells operating less than 100 feet from residential homes. The Inglewood oil field has over 1000 wells operating well within 1 mile of residential homes, recreation parks, and other sensitive land uses.

The studies that investigated poor birth outcomes found that mothers in the sampling population who lived near the highest density of active wells were 1.3 more likely to give birth to a child who had congenital heart defects (CHD) and 2 times more likely to give birth to a child with neural tube defects (NTD),[22] higher incidences of LBW and SGA,[23] and increased rate of preterm birth.[24] McKenzie, et al. (2017) found that increased well density was associated with increased risk for acute lymphocytic leukemia in people ages 5-24.[25]

Delphi Technique

In addition to peer review studies, a consortium of experts in environmental studies and public health have also assessed and considered policy recommendations to address the health and safety consequences of close proximity to oil and gas development. The Environmental Health Project (EHP) is a public health organization that utilized the Delphi Technique to arrive at an expert consensus on an appropriate setback distance for unconventional oil and gas development from human activity.[21] "The Delphi is an accepted method for reaching convergence of expert opinion about a specific topic," and in this study, consensus was defined as 70% agreement of panelists. The process resulted in an 89% participant agreement that 1 to 1.25-mile distance (6,600 feet) from unconventional oil and gas development is an acceptable minimum to protect human health. Additionally, the study recommends greater setback distances for settings where vulnerable subpopulations might gather, such as schools, day care centers, and hospitals.

…89% participant agreement that **1 to 1.25-mile distance** from unconventional oil and gas development is an acceptable minimum.

Existing setback laws

It is clear that throughout the scientific literature that researchers agree the existing setback laws in various jurisdictions throughout the U.S. are inadequate to protect the health and safety of residents who live, work, and play near oil and gas operations. Existing setback laws range from 150 to 1,500 feet. States like Arkansas,

…**existing setback laws** in various jurisdictions throughout the U.S. **are inadequate** to protect the health and safety of residents who live, work, and play nearby oil and gas operations.

Colorado, and Ohio have varying setback distances from different sensitive land uses.[8,14] Pennsylvania and Texas have state level setback laws for any oil and gas operations near residential land use. Several municipalities in Denton County, Texas, have enforced stronger setback laws. In response to override these municipalities, the Texas state legislature subsequently passed HB40 which preempts regulation of oil and gas operations by municipalities. Haley, et al. (2016) determined that based on historical catastrophic events, thermal modeling, vapor cloud modeling, and air pollution data, these existing setbacks laws are not sufficient to protect potential risks and threats to human health from hydraulic fracturing operations.[8] Macey, et al. (2014) considered the concentration of VOCs in five different states and determined that the setbacks in those states were inadequate to prevent exposure to formaldehyde and benzene.[14] Majority of the established setback laws were typically decided by negotiations between stakeholders, like residents and policymakers, and not supported by scientific, empirical data.[23] The state of Maryland is one example of a jurisdiction that scientifically investigated the health and safety impact of oil and gas operations. In July of 2014, the University of Maryland School of Public Health conducted another study that focused on public health impacts.[26] Among the 52 recommendations that resulted from the investigation, the researchers recommended a minimum 2,000-foot setback between dwellings and well pads and non-electric motor compressor stations. In 2017, Maryland became the second state in the country to ban hydraulic fracturing.[27]

Conclusions

While few studies have investigated the relationship between the proximity of oil and gas operations and human health impacts, this body of literature does highlight a clear public health concern and that existing setback laws are not adequately protecting public health and safety. **The growing body of scientific literature recognizes that a setback distance between oil and gas operations and locations where people live, work, play, and learn are *necessary* to protect human health and safety. Setbacks are especially crucial to protect vulnerable populations, such as children, elderly, and the chronically ill or disabled.** The 2,500-foot setback recommendation incorporates recognition of Los Angeles' population density and the vulnerability of residents, schoolchildren, and the elderly from health hazards and possible disasters related to oil development. The current literature has identified that existing laws are not adequate for low density, rural communities. This finding underscores the need for a stronger setback in Los Angeles' densely populated urban environment. Many of the impacted communities are in close proximity to a large number of wells and other oil and gas development facilities and are already overburdened by exposure to cumulative environmental health impacts from other industrial and transportation sources. These marginalized communities have long endured environmental injustice. **The scientific literature and published reports make a strong case for a far more protective health and safety setback for the City of Los Angeles than currently exists in other jurisdictions, and creates a substantial basis for the 2,500-foot setback proposed by community advocates.**

Table 1. Comparison of studies and reports by distance to active oil and gas wells with consideration to population density.

Blue shaded rows are non-peer reviewed reports. Orange shaded rows are peer reviewed publications that have relevant setback considerations or recommendations.
*Population density values based on 2010 U.S. Census Fact Finder Population density data.

Citation	Health Impact / Exposure Finding	Distance with health / exposure finding impact / recommendation	Converted to feet	Pop Density 2010 of investigated counties/states (residents per sq.mi.)) *
SW Pennsylvania EHP Technical Reports [21]	Delphi Technique	1 to 1.25 mile	6,600 feet	--
Haley, et al., 2016[8]	Exposure to hydrogen sulfide combined with VOCs could produce potentially new set of exposures - detected at distances of 2 km	2 km	6,561 feet	--
Haley, et al., 2016[8] & Heinkel-Wolfe, 2013 [14]	Considered blow-out and evacuation data, average evacuation zone was 0.8 miles. Explosion in Barnett Shale produced a 750-ft burn crater.[14]	0.8 miles	4,224 feet	--
Kassotis, et al., 2014[16]	Elevated levels of endocrine disrupting chemicals in water sources 1 mile from sites that had known spills/incidents - animals no longer produced live offspring… Location: Garfield County, Colorado	1 mile	5,280 feet	19.1
Webb, Ellen, et al. 2017	Literature review on neurodevelopmental and neurological effects of chemicals associated with UOG operations and their potential effects on infants and children. Made a recommended minimum setback of 1.6 km.	1.6 km	5,249 feet	--
Rabinowitz, et al., 2015[10]	Significant respiratory and dermal impacts Location: Washington County, PA	Less than 1 km	3,280 feet	242.5
McKenzie, Witter, Newman, & Adgate, 2012[11]	Significantly increased risk of pediatric sub-chronic non-cancer hazard & Chronic hazard indices	Less than ½ mile	2,640 feet	Rural areas and towns, population <50,000 in 57 counties
Macey, et al., 2014[14]	Monitored high concentrations of VOCs - up to 2,591 ft Location: Counties in 4 states – AR, PA, CO, OH	2,591 ft	2,591 feet	137.45 (average)
2,500 FEET RECOMMENDATION FOR CITY OF LOS ANGELES				8,092.30
University of Maryland School of Public Health 2014[26]	Recommended min setback distance of 2,000 ft from well pads Location: state of MD	1,000 ft	2,000 feet	594.8
Boyle, et al., 2017[12]	Unhealthy noise levels Location: Doddridge County, WV	< 600m	1,969 feet	25.7
Steinzor, Subra, & Sumi, 2013[9]	Significantly higher rates of health symptoms in households within 1,500 ft of an active well Location: 14 counties in PA	1,500 ft	1,500 feet	165.1

Table 2. Studies investigating the relationship of health outcomes and proximity to concentration of wells

Study	Outcome	Measurement	Wells density (per sq mile)	Pop Density 2010 of investigated counties/states (residents per sq.mi.)) *
McKenzie, et al., 2017[25]	In rural Colorado, People ages 5-24 had a 3-4 times higher risk for developing acute lymphocytic leukemia Location: state of Colorado	>33.6 wells in 16.1 km or 10 miles	3.36 wells	48.5
Stacy, et al., 2015[23]	Birth outcomes by concentration of wells. Those with 6+ wells within mile had higher incidence of SGA and LBW in SW Pennsylvania Location: 3 counties in PA (Butler, Washington, Westmoreland	6+ wells per 1 mile	6 wells	277.0 (average)
Casey, et al., 2016[24]	Mothers who lived in the highest exposure quartile were 1.4 times more likely to give birth to children who were considered low birth weight (LBW) and smaller than gestational age (SGA). Location: 40 counties in PA – Using state population density	Highest exposure quartile had 124 wells within 20 km; lowest had 8 wells within 20 km	About 10 wells	283.9
South Los Angeles – Jefferson Drill Site (example for comparison)		36 wells within 1 mile	36 wells	21,848
McKenzie, et al., 2014[22]	In rural Colorado, mothers who lived in higher exposure tertile had 1.3 higher chance of giving birth to a child with congenital heart defect (CHD)2.4 higher chance of having Neural Tube Defect. Even in the 2nd tertile of highest exposure, mothers were 1.2 more likely to give birth to a child with CHD. Location:	Highest exposure tertile had 125-1400 wells within a mile, the next highest tertile had 3.63-125 wells within a mile.	125 wells	Rural areas and towns, population <50,000 in 57 counties

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EXHIBIT 18

Publication No. PR06

2006 ANNUAL REPORT OF THE STATE OIL & GAS SUPERVISOR

California Department of Conservation

Division of Oil, Gas, & Geothermal Resources

STATE OF CALIFORNIA
ARNOLD SCHWARZENEGGER, *Governor*

RESOURCES AGENCY
MIKE CHRISMAN, *Secretary*

DEPARTMENT OF CONSERVATION
BRIDGETT LUTHER, *Director*

dropped slightly from 1,907 in 2006 to 1,895 beginning 2007.

DRILLING ACTIVITY Drilling activity in the district decreased slightly from 2005 levels. Twenty-six wells were drilled or redrilled in 2006, compared with 30 in 2005. The following operators drilled/redrilled wells: Aera Energy LLC - 10 wells in the Ventura field; Berry Petroleum Co. - 7 wells in the Placerita field; Mirada Petroleum, Inc. - 1 well in the Ojai field; Renaissance Petroleum, Inc. - 3 wells in the Cabrillo field; Southern California Gas Co. - 4 wells in the Aliso Canyon field; Vaquero Energy, Inc. - 1 well in the Sespe field.

ACQUISITION OF VINTAGE PETROLEUM WELLS BY OCCIDENTAL PETROLEUM COMPANY In 2006, all the wells operated by Vintage Petroleum Inc. in District 2 were acquired by Vintage Production California LLC (VPC), a subsidiary of Occidental Petroleum Corporation. In addition, VPC acquired Plains Exploration and Production Co. operations in the Oxnard, Saticoy, South Mountain and Pacoima oil fields and the Newhall-Potrero oil field formerly operated by Medallion California Properties Company. Through these acquisitions, VPC owns 1,797 wells in 24 of the 45 active fields in District 2. In 2006, VPC initiated a program to upgrade existing facilities and dismantle out-of-service facilities, with work beginning in the San Miguelito and Rincon oil fields.

ABANDONMENT OF WELL "OJAI" 36 On March 3, 2006, immediately following a seismic event along the San Cayetana fault in the Sespe oil field, idle-well "Ojai" 36, located approximately five miles west along this same fault zone in the Sisar Creek Area of the Ojai oil field, began to flow water at a rate of five barrels per minute. Well records indicated the well penetrated a fault and had encountered a high-pressure water sand. The operator, VPC, contracted with international well-control specialists Boots and Coots to begin emergency operations to secure the well site and bring the well under control. Division staff were on location daily to witness operations. The well was eventually killed with 20 pound-per-gallon mud and permanently plugged and abandoned by May 1st at a cost of approximately $4 million (Photos 1 and 2).

ABANDONMENT OF BARDSDALE OIL FIELD WELLS At the request of the Division, VPC permanently plugged and abandoned 15 long-term idle wells on the "Acorn" and "Bardsdale-Bell" leases in the Bardsdale oil field. Many of these wells were discovered following the October 2003 fires when surrounding dense brush was consumed. The "Acorn" lease was discovered in 1894 and the "Bardsdale-Bell" lease in 1909, with all wells drilled using cable tool rigs and equipment (Photo 3). Most of the well locations were along steep hillsides, which made access extremely challenging and required a significant amount of grading to build locations adequate to accommodate the necessary abandonment equipment (Photos 4 – 7). Most of the wells required two to three times the theoretical volumes of cement to bring cement to surface, probably due to the antiquated landed casing completions.

Photo 1. Well "Ojai" 36. During killing operations, vacuum trucks removed water flowing from the well until kill mud could be injected to help secure the well before abandonment operations could begin. *Photo by D. Kahler.*

Photo 2. Key Energy Services California Inc. rig during abandonment operations on well "Ojai" 36. The Topa Topa Mountains are in the background. *Photo by D. Kahler.*

EXHIBIT 19

On Shaky Ground

FRACKING, ACIDIZING, AND INCREASED EARTHQUAKE RISK IN CALIFORNIA

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On Shaky Ground

FRACKING, ACIDIZING, AND INCREASED EARTHQUAKE RISK IN CALIFORNIA

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Report available at: ShakyGround.org

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Executive Summary

This report analyzes the earthquake risks associated with an increase in wastewater injection that would result from an expansion of fracking and other unconventional oil production in California's Monterey Shale, including:

- the demonstrated connection between the injection of oil and gas wastewater and induced earthquakes,
- significant gaps in current science and inability of regulators to protect Californians from the dangers associated with these quakes, and
- proximity of many active California wastewater injection wells to active faults and major population centers.

To graphically illustrate the risks, the report includes maps from an online interactive tool developed by the FracTracker Alliance, which show the current extent of oil and gas development, including active wastewater injection wells, fracked and acidized wells, fault lines, and communities.

Key Findings:

1. **A majority of California's active oil and gas wastewater injection wells are close to faults.** Our analysis shows that 54 percent of California's 1,553 active and new wastewater injection wells are within 10 miles of a recently active fault (active in the past 200 years), 23 percent are within 5 miles, and 6 percent are within 1 mile. Because the distance from a wastewater injection well to a fault is a key risk factor influencing whether a well may induce an earthquake, these findings raise significant concerns.

Distance of California's Active/New Wastewater Injection Wells to Recently Active Faults	
NUMBER OF ACTIVE/NEW WELLS (PERCENT)	**DISTANCE TO RECENTLY ACTIVE FAULT**
87 wells (6%)	Within 1 mile
350 wells (23%)	Within 5 miles
834 wells (54%)	Within 10 miles

2. **Millions of Californians live in areas at risk for induced earthquakes.** Some of California's major population centers, such as Los Angeles and Bakersfield, are located in regions where high densities of wastewater injection wells are operating very close to active faults.

3. **Research and monitoring are dangerously inadequate.** No studies to date have evaluated the increased risk of induced earthquakes from California's existing wastewater injection wells. There are fundamental knowledge gaps in understanding the risks of induced seismicity from these wells.

4. **Regulations do not protect Californians from the risk of induced earthquakes.** California has no plan to safeguard its residents from the risks of earthquakes induced by Class II injection wells or oil and gas production. Due to significant knowledge gaps, California's Division of Oil, Gas, and Geothermal Resources (DOGGR) cannot safely regulate the risk of induced seismicity from oil and gas production and wastewater disposal.

5. **Oil industry wastewater disposal poses unacceptable risks**. In light of the known environmental and health risks from drilling, well stimulation and wastewater disposal, the link between wastewater injection wells and earthquakes in other states, the potential for a massive expansion of drilling and wastewater production in the Monterey Shale, and the gaps in scientific knowledge regarding induced seismicity, the best way to protect Californians is to halt hydraulic fracturing, acidizing, and other unconventional oil and gas recovery techniques.

In sum, the findings highlight the lack of assurance that fracking and the injection of oil and gas wastewater can be conducted safely, and demonstrate the need for a halt to fracking, acidizing, and other forms of well stimulation.

This report is necessary because California's oil industry may be on the verge of rapidly expanding unconventional oil production of the Monterey Shale, a vast shale oil deposit in the San Joaquin Valley, parts of the Central Coast, and the Los Angeles basin that underlies many communities, important wildlife habitat, and some of the nation's richest farmland.

Oil and gas production results in billions of gallons of contaminated wastewater that is often disposed of in underground injection wells. In many parts of the eastern and central United States where fracking and wastewater injection have boomed, earthquake activity has increased dramatically. Some regions have experienced a 10-fold increase in earthquake activity. A growing body of research has linked wastewater injection wells to increased earthquake activity, including earthquakes that have damaged homes and infrastructure and caused human injuries. Extracting the oil in the Monterey Shale could produce almost 9 trillion gallons of wastewater.

California is uniquely vulnerable to seismic events, with more citizens and infrastructure at risk from earthquakes than any other U.S. state. Seven of the ten U.S. metropolitan areas with the highest estimated annualized losses from earthquake damage are located in the Golden State. An increase in damaging seismic activity would be devastating to California and its economy.

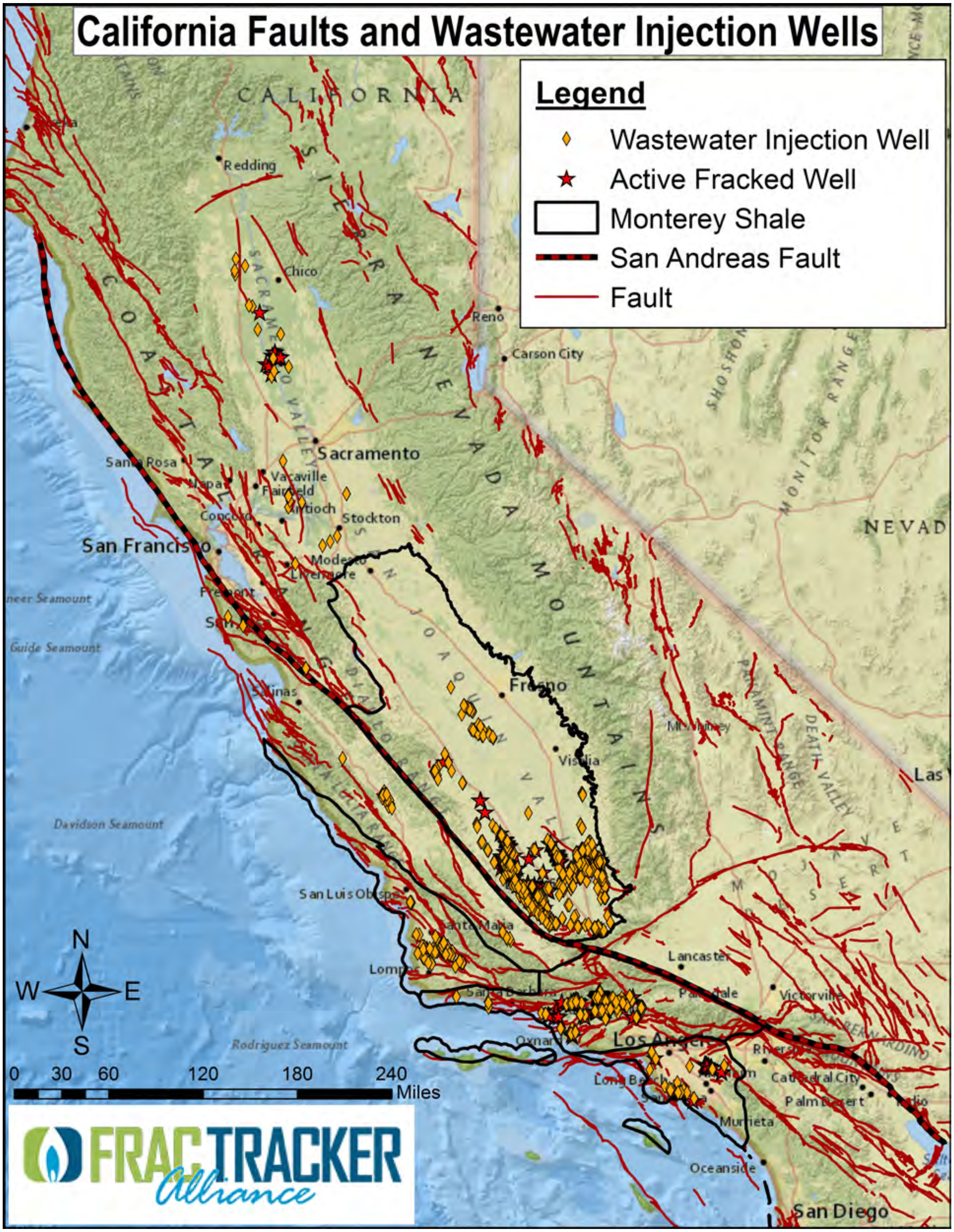

FIGURE 1: California's Faults and Wastewater Injection Wells

Fracking, Wastewater Injection Wells, and Increased Earthquake Risks

1. Fracking and acidizing produce large volumes of contaminated wastewater.

The development of unconventional oil and gas recovery techniques, such as hydraulic fracturing and acidizing, has allowed for a rapid expansion of shale oil and gas development across many parts of the United States. Hydraulic fracturing, or fracking, is a well stimulation technique that releases oil and gas from relatively impermeable formations, such as shale and tight sands, allowing for the extraction of previously unreachable hydrocarbons. Fracking typically involves pumping high volumes of water, sand, and chemicals at high pressures into the rock formation, causing it to crack and release oil and gas.[1]

Although fracking has been done in the U.S. for many years, recent developments, such as directional and horizontal drilling and new chemical fluid mixtures, have facilitated an increase of drilling in previously uneconomic geologic formations.

Acidizing, another well stimulation technique, involves the injection of hydrochloric and/or hydrofluoric acids, along with some of the same fluids used for fracking.[2] These chemicals modify the permeability of a geologic formation, allowing increased hydrocarbon flow. In California, acidizing may be the well stimulation treatment of choice for the oil and gas industry to access the Monterey Shale, due to the highly fractured geology of the state.[3]

Hydraulic fracturing, acidizing and other unconventional well stimulation methods create large quantities of wastewater — called flowback and produced water — that contain contaminants which can reach toxic concentrations. Flowback is the fluid that returns to the surface after fracturing or acidizing is completed, but before oil and gas is recovered from the well. Produced water is primarily composed of the formation fluid that comes to the surface once production of oil and gas has begun. Produced water is associated with all forms of oil and gas production, regardless of the well stimulation technique.

Both flowback and produced water can contain chemicals from the fracking fluid and the fluids rising from deep in the rock formation, which can be harmful to human health. An estimated 15 to 100 percent of fracking fluids return to the surface as wastewater.[4] More than 75 percent of the chemical additives in fracking fluids can affect important organs, and 25 percent can cause cancer.[5] Flowback and produced water are typically very saline and can contain heavy metals such as lead, organic contaminants such as benzene and toluene, and naturally occurring radioactive materials from deep in the formation,[6] which makes treatment and recycling difficult.

Recent estimates report that flowback volumes can range between 420,000 gallons to more than 2.5 million gallons per fracking event, depending on the characteristics of the formation, the amount of fluid injected, and the type of hydrocarbon being extracted.[7] Produced water can reach millions of gallons over the lifetime of the well.[8] In California, oil and gas wells averaged approximately 2.3 million gallons of wastewater per well in 2011.[9]

2. Underground injection wells are the most common method for disposing of oil and gas wastewater in California and many other parts of the U.S.

The wastewater produced during oil and gas extraction is either disposed of or reused for additional oil and gas extraction in a process called "secondary recovery" or "enhanced oil recovery (EOR)." In California and many other parts of the country, the most common wastewater disposal method is trucking or piping the wastewater for injection into deep wastewater injection wells, drilled into porous rock thousands of feet underground.[10] These wastewater injection wells are categorized as Class II Underground Injection Wells by the U.S. Environmental Protection Agency (EPA), which oversees their regulation under the Safe Drinking Water Act's (SDWA) Underground Injection Control (UIC) Program.[11] In California, the Division of Oil Gas and Geothermal Resources (DOGGR) received primacy to directly regulate the state's Class II underground injection wells in 1982.[12]

There are about 30,000 Class II wastewater injection wells in operation in the U.S. that are used for wastewater disposal from oil and gas production.[13] Texas leads the nation with about 7,500 active wastewater injection wells,[14] followed by Oklahoma with an estimated 4,400 active wells.[15]

California has an estimated 2,583 wastewater injection wells, of which 1,553 are currently active.[16] Wastewater injection wells are located throughout the state, from the Chico area in northern California, to Kern County in the Southern San Joaquin Valley, to Los Angeles in the south, and even offshore near Santa Barbara.[17]

California's oil and gas fields produce billions of gallons of contaminated wastewater each year that must be managed — about 15 times more wastewater than oil.[18] In 2012 alone, California's oil and gas industry produced an estimated 124 billion gallons of wastewater.[19] Much of this wastewater is permanently disposed of in wastewater injection wells. According to the most recent data available from the U.S. Department of Energy, in 2007 California's oil and gas industry disposed of 22 percent of the wastewater it produced into injection wells, totaling more than 23 billion gallons[20] — equivalent to about 35,500 Olympic-sized swimming pools. About 69 percent of the wastewater was reused for enhanced recovery,[21] and small amounts are disposed of in unlined percolation ponds, lined evaporation ponds, sewer systems, and surface waters.[22]

In 2012 alone, California's oil and gas industry produced an estimated 124 billion gallons of wastewater.

The amount of wastewater being disposed of in injection wells has skyrocketed in states where fracking has proliferated in recent years.

In Texas, for example, the amount of wastewater injected into disposal wells increased from 1.9 billion gallons in 2005 to nearly 147 billion gallons in 2011 — a 76-fold increase.[23]

California's oil and gas industry may be on the verge of rapidly expanding unconventional oil production in the Monterey Shale, a vast shale deposit in the San Joaquin Valley, parts of the Central Coast and the Los Angeles basin, which holds an estimated 13.7 billion barrels of technically recoverable shale oil.[24] If the oil and gas industry develops the Monterey Shale, the production of wastewater and demand for wastewater injection wells are likely to increase substantially. For example, based on the historically reported ratio of 15 times more wastewater than oil produced in California, extracting the Monterey Shale's estimated 13.7 billion barrels of recoverable oil could produce 8.6 trillion gallons (205.5 billion barrels) of wastewater — enough to fill almost 13 million Olympic-sized swimming pools.

3. Scientists have long documented that wastewater injection wells can induce earthquakes.

The underground injection of wastewater has long been documented to induce earthquakes. Wastewater injected into rock formations can build up significant pressure depending on the volume of wastewater, rate of injection, and the permeability of the rock. This pressure build-up can induce an earthquake if the pressure is relayed to a fault that is already stressed and close to failure. The pressure can reduce the natural friction on the fault enough to cause it to slip and trigger an earthquake.[25] The larger the fault, the larger the magnitude of earthquakes it can host.[26]

As early as the 1960s, scientists began documenting seismic activity from the injection of large volumes of fluids underground.[27] One of the first recorded cases of human-induced earthquakes due to underground fluid injection occurred in 1961, when the U.S. Army began disposing of millions of gallons of liquid hazardous waste 12,000 feet below the surface at the Rocky Mountain Arsenal near Denver, Colorado. This injection spurred more than 1,500 earthquakes over a five-year period in an area not known for active seismicity. It culminated in three earthquakes of magnitudes 5.0 to 5.5 more than a year after injection ceased, the largest of which caused more than $500,000 in damages. Geologists discovered that the Army well had been drilled into an unknown fault. This example, as well as two other well-studied fluid injection projects — at Rangely, Colorado, in the 1970s and Paradox Valley, Colorado, in the 1990s — established that wastewater injection wells could induce earthquakes large enough to cause significant damage.[28]

4. Wastewater injection wells have induced felt and damaging earthquakes of magnitudes 4 and 5 in regions where fracking has proliferated.

In many areas of the U.S. where fracking has proliferated, earthquake activity has increased dramatically. As scientists begin to investigate the causes of these earthquake swarms, a growing number of studies have attributed some of this increased earthquake activity, and some of the largest earthquakes, to the underground injection of oil and gas wastewater in these regions.[29]

Within the Midwestern and Eastern U.S., the number of recorded earthquakes began to increase in 2003, rising dramatically after 2009.[30] In total, an average of 100 earthquakes per year of magnitude[31] 3 (M3) or larger struck between 2010 and 2012, compared with only 21 per year between 1967 and 2000.[32] States experiencing elevated levels of earthquake activity in parallel with booms in unconventional oil and gas development include Oklahoma, Texas, Colorado, New Mexico, Arkansas, Ohio, and West Virginia.[33]

Earthquake activity has increased dramatically in many areas of the U.S. where fracking has proliferated.

Earthquakes of M3 to M5 have been scientifically linked to wastewater injection wells in at least six states: Oklahoma, Texas, Colorado, New Mexico, Arkansas, and Ohio. The largest of these was a M5.7 earthquake near Prague, Oklahoma, outside of Oklahoma City which was the biggest in the state's history. It destroyed 14 homes, damaged infrastructure and numerous buildings, and injured two people.[34]

Other large earthquakes attributed to wastewater injection include a M4.8 in Texas, M5.3 in Colorado, M4.7 in Arkansas, and M3.9 in Ohio, as summarized by state below:

Oklahoma: Oklahoma's earthquake activity has increased dramatically since 2009, with the increase linked to wastewater injection wells.[35] The state has been hit by more than 200 earthquakes of M3 or larger since 2009 — about 40 per year — compared to 1 to 3 a year between 1975 and 2008.[36] According to the U.S. Geological Survey (USGS), the likelihood of an earthquake in central Oklahoma has increased by a factor of 10.[37] These earthquake swarms are striking in populated areas, culminating with the largest earthquake ever recorded in the state — the damaging M5.7 earthquake near Prague outside Oklahoma City in 2011, which scientists have linked to injection wells.[38] In October 2013, the USGS and Oklahoma Geological Survey (OGS) warned that the "earthquake swarm" around Prague and Oklahoma City has increased hazards for city and rural residents, and stated that wastewater injection wells may be a "contributing factor."[39] This warning caused the State Insurance Commissioner to recommend that Oklahoma residents buy earthquake insurance.[40] Recent earthquake swarms have also hit near Marietta in southern Oklahoma and Enid to the north, with these swarms also thought to be linked to wastewater injection wells.[41]

Texas: Several regions of Texas have experienced increased earthquake activity near wastewater injection wells in areas where no previous seismic activity has been recorded. In regions near Dallas-Ft. Worth, Cleburne, and Timpson, scientists have linked increased earthquake activity to wastewater injection wells.[42] Timpson, Texas, has been struck by a series of damaging earthquakes, including the largest ever recorded in eastern Texas — a M4.8 in May 2012 which caused significant structural damage[43] — and M4.1 and M4.3 earthquakes in 2013.[44] In the heavily populated Dallas-Fort Worth region, scientists have attributed a series of small earthquakes in 2009 to wastewater injection.[45] Since 2009, the region has been hit by stronger earthquakes between M3 and M4.[46]

Colorado/New Mexico: Earthquake activity has increased dramatically in the Raton Basin of southern Colorado and northern New Mexico, culminating in a M5.3 earthquake near Trinidad, Colorado, in August 2011, with increased seismicity being attributed to wastewater injection wells.[47] The number of earthquakes of M3 or greater increased from 0.16 per year in the 31-year period before injection, to 9.5 per year after injection began in 2001.

Arkansas: Earthquake activity in central Arkansas increased sharply in 2010 and 2011, when earthquake swarms hit near the towns of Guy and Greenbrier, close to injection wells, culminating in a M4.7 earthquake in February 2011.[48] After the first wastewater disposal well became operational in April 2009, the rate of M≥2.5 earthquakes skyrocketed, with one in 2007, two in 2008, 10 in 2009, 54 in 2010, and 157 in 2011. Scientists have determined that these swarms were likely induced by wastewater injection.[49]

Ohio: The injection of wastewater into a deep well has been linked to a series of earthquakes in a previously earthquake-free region near Youngstown, Ohio.[50] More than 109 earthquakes occurred between January 2011 and February 2012, with a M3.9 earthquake striking on December 31, 2011.

This growing body of research demonstrates that injecting wastewater into underground disposal wells can induce earthquakes. These studies also illustrate what is currently known and unknown about the risks of induced earthquakes from wastewater injection wells, including key uncertainties. Some important facts and uncertainties include:

- While injection wells can operate for years without creating felt earthquakes, some wastewater injection wells have induced earthquakes that can cause structural damage and human injuries, and the number of documented cases is growing.
- While induced seismicity often occurs within months of injection, the onset can be delayed for many years — as much as 20 years in some instances — after the initiation of injection.[51]
- Induced seismicity, including large earthquakes, may continue for months to years after injection is stopped.

- While many induced earthquakes originate near the injection point, they have also occurred up to 7.5 miles (12 kilometers) away, indicating that the potential influence of wastewater injection wells can extend out many miles.[52] Research has not established a maximum distance over which injection wells can induce earthquakes.
- The maximum possible magnitude of an induced earthquake that can be triggered by injection is unknown.

5. Hydraulic fracturing has induced felt earthquakes of magnitudes 2 and 3.

Fracking appears to pose a lower risk of inducing destructive earthquakes than the injection of oil and gas wastewater. Fracking intentionally cracks the shale rock around wells to release oil and gas deposits and routinely produces small earthquakes (M<1) typically not felt at the surface.[53] However, several recent studies have reported that fracking has induced earthquakes of magnitudes 2 and 3 in Oklahoma, British Columbia, and the United Kingdom,[54] including a M3.8 event.

These cases illustrate that fracking can induce larger magnitude earthquakes when the rock formation being fracked intersects a fault:

Oklahoma: In January 2011, a series of 116 earthquakes, ranging from M0.6 to M2.9, occurred near a well being hydraulically fractured in south-central Oklahoma. Multiple earthquakes were felt by a local resident. A study by a scientist at the OGS found that the area was highly faulted, and concluded that "it is likely that hydraulic fracturing triggered the earthquakes observed in this study."[55]

British Columbia: A 2012 study by the British Columbia Oil and Gas Commission determined that seismic events reported in the Horn River Basin between April 2009 and December 2011 were caused when fracking fluids were injected into a fault.[56] A series of 38 earthquakes were recorded between M2.2 and M3.8, with the largest earthquake felt by workers.

United Kingdom: A series of earthquakes culminating in a M2.3 near Blackpool, England, in 2011 has been attributed to fracking.[57]

6. Earthquakes may cause oil and gas leaks and spills, and pose a risk to groundwater near oil and gas infrastructure.

There is ample cause for concern about the potential harm to groundwater associated with earthquakes near oil and gas wells. All wells, including production and wastewater injection wells, rely on the integrity of the well casing to prevent contamination of underground aquifers. Seismic activity that occurs close to wells may increase the likelihood of damaging the well casing or cementing, which can allow contamination of underground sources of drinking and irrigation water from the migration of hydrocarbons, well stimulation and drilling chemicals, or produced water.

Well casing failures are common, but the extent to which they are caused by or exacerbated by seismic movement is unknown. In Pennsylvania, a study using data supplied by industry found failure rates of 6 to 9 percent.[58] A ProPublica review of injection wells nationwide found that from 2007 to 2010, more than 7,000 (3 percent) of 220,000 wells showed signs of leakage, and more than 17,000 (8 percent) had received violations.[59] The same report found that in California over that time period there were 12 cases of groundwater contamination and 63 cases of significant leaks from injection wells.[60]

California lacks key data on well casing failures. DOGGR does not maintain a database of well casing failures, and the agency is unable to identify which wells have failed and the rate at which wells experience integrity failures. The unknown extent of well casing failures and the lack of understanding of the impacts of seismic activity on well casing integrity are especially troubling for California. The state's elevated risk of seismic activity, combined with additional induced seismicity risk from well stimulation and underground injection, could lead to disastrous consequences should an earthquake cause major well casing failures. The rate of well casing failure, along with the effects of seismic activity on well integrity, should be further analyzed to better understand the risk of groundwater contamination from oil and gas wells in California.

Although there is no comprehensive analysis, evidence of well casing failures linked to earthquakes already exists in the state. For example, in Ojai, California, API well #11101020 experienced a failure directly after an earthquake occurred on the nearby San Cayetano fault. According to DOGGR, on March 3, 2006, the Ojai 36 well, located in the Sespe oil field, 1.23 miles from the San Cayetano fault (Figure 2), was plugged and abandoned after a M3.1 earthquake triggered a 5 barrel-per-minute leak of produced water.[61] The well log indicates that there is no record of when the well was initially drilled, but it was deepened in 1918. Like many existing oil and gas wells which were drilled decades ago, there is no record of any assessment of nearby faults and seismic threats to well casings.[62]

In Ojai, California, API well #11101020 experienced a failure directly after an earthquake occurred on the nearby San Cayetano fault.

The example of Ojai 36 demonstrates how seismic events may cause well casing failure and that drilling in seismically active areas may pose increased risk of failures and potential groundwater contamination.

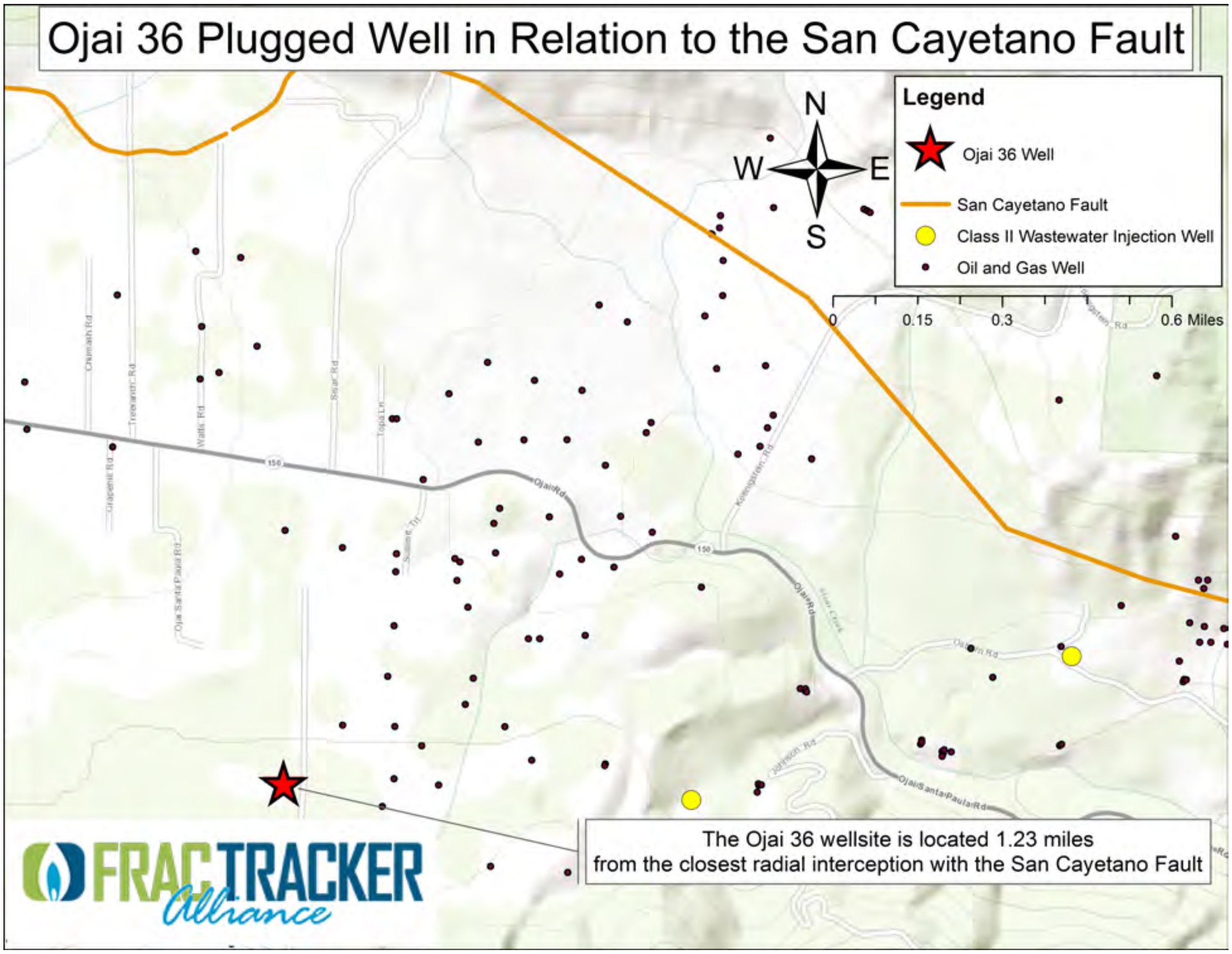

FIGURE 2: Location of Well Failure in Ojai, CA, In Relation to the San Cayetano Fault.

Evaluating Earthquake Risk from Wastewater Injection Wells and Fracking in California

1. California is one of the most seismically active states in the nation, with many active faults and more citizens and infrastructure at risk from earthquakes than any other state.

California lies within the planet's Ring of Fire, a seismically active region surrounding the Pacific Ocean from New Zealand, to Alaska, to Chile. Ninety percent of the world's earthquakes and 81 percent of the largest earthquakes occur along the Ring of Fire.[63] In California, there are thousands of small earthquakes per year that are attributed to the complex system of faults that crisscross the state. The most prominent is the San Andreas fault which cuts across California, forming the boundary between the Pacific and North American tectonic plates.[64] Other active faults are the San Jacinto fault in Southern California and the Mendocino Triple Junction in Northern California, which have historically produced large earthquakes.[65]

Due to its frequent seismic activity and large population centers, California has more citizens and infrastructure at risk from earthquakes than any other U.S. state.[66] In fact, seven of the 10 U.S. metropolitan areas with the highest estimated annualized losses from earthquake damage are in California, with the Los Angeles-Long Beach-Santa Ana area ranking first.[67]

The San Andreas fault and the Hayward-Rodgers Creek fault have the greatest probability of generating a large earthquake.[68] Many earthquakes typically occur within 31 miles (50 kilometers) of the San Andreas fault, including many with M7.0 or above. Examples include the 1906 San Francisco earthquake (M7.9) and the 1989 Loma Prieta earthquake (M7.0). A number of moderate to large earthquakes — M5.5 or above — have occurred in faults away from the San Andreas. These include the 1952 Kern County earthquake (M7.5), the 1971 San Fernando earthquake (M6.7), and the 1994 Northridge earthquake (M6.7).

In California, earthquakes pose added risks from landslides and liquefaction, particularly along the densely populated coast. Liquefaction, a type of ground failure specific to earthquakes, occurs when water-saturated sand and silt behave like a liquid due to the trembling of the earth. The soils can then no longer support structures, may flow down even gentle slopes, and erupt to the surface as sand boils. Liquefaction usually leads to settlement of the surface in uneven patterns that damage infrastructure such as buildings, roads, and pipelines.[69] Areas with high liquefaction hazards include landfills, particularly those in areas once submerged by water, as well as wetlands, river floodplains, and stream channels.[70] Areas of particular concern for liquefaction include the margins of San Francisco Bay[71] and parts of Los Angeles County (Figure 3).

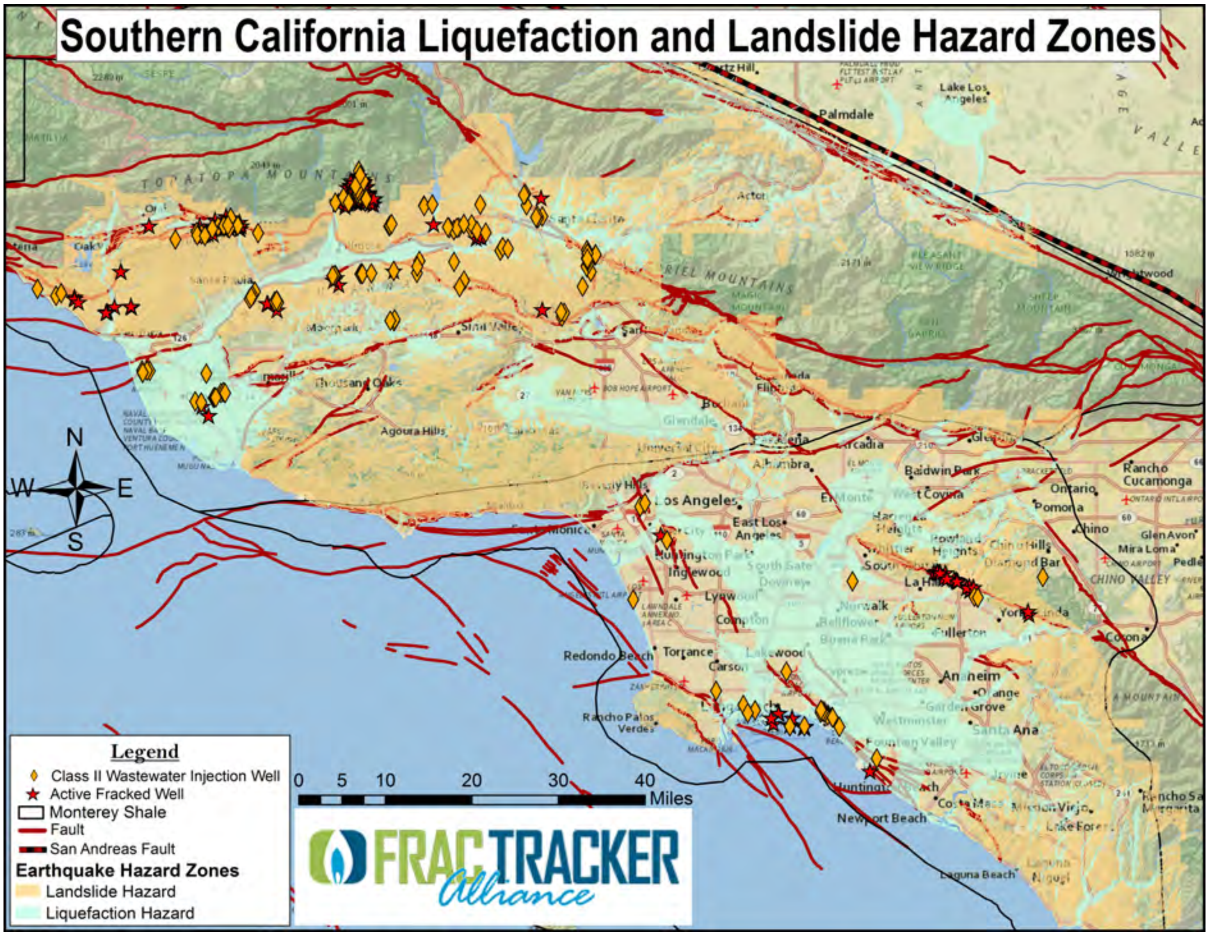

FIGURE 3. Landslide and Liquefaction Zones in Southern CA with Class II Wastewater Injection Wells and Fracked Wells. Areas with high liquefaction hazards include landfills, particularly those in areas once submerged by water, as well as wetlands, river floodplains, and stream channels. Areas of particular concern for liquefaction include the margins of San Francisco Bay and parts of Los Angeles County.

2. More than half of California's 1,553 active wastewater injection wells are within 10 miles of a recently active fault.

Two interactive maps developed by the FracTracker Alliance show the current extent of oil and gas development, seismic activity, and seismic hazards throughout California. The maps depict the state's fault lines, wastewater injection wells, fracked and acidized wells, liquefaction and landslide hazard zones, and the Monterey Shale that is the focus for unconventional development. Users may zoom in and out to determine if their neighborhood is affected by oil and gas development and wastewater injection wells, or lies in a seismic hazard zone. Links are provided here: California Geological Hazards Map, Injection Wells and Hydraulic Fracturing in California's Fault Zones. In the maps, the fault history is categorized into four groups based on the last time that each fault was active: Historic (fault experienced earthquake activity in the last 150 to 200 years), Holocene (activity in the last 11,000 years), Late Quaternary (activity in the last 750,000 years), and Quaternary (activity in the last 1,600,000 years), using the definitions from the USGS and the California Geological Survey (CGS). Detailed descriptions of the maps are provided in Appendix A.

Based on this data, we analyzed the proximity of California's active and new Class II wastewater injection wells to faults in order to assess the risks that injection wells may pose to Californians. We evaluated recently active ("Historic") faults — defined as those with activity in the past 150 to 200 years — and Quaternary faults — defined as those with activity in the past 1.6 million years — using data from the CGS[72] and USGS.[73] We also analyzed a subset of "high-magnitude faults" identified as causing earthquakes greater than M6. New wells are those that have been permitted, may have been drilled, but are not yet actively disposing fluids by injection. A detailed methodology is presented in Appendix A. The distances of both active and inactive wastewater injection wells to faults is presented in Appendix B.

Our analysis shows that more than half of California's 1,553 active and new Class II wastewater injection wells are within 10 miles of a recently active fault that has caused an earthquake in the past 200 years. Specifically, 834 wells (54 percent) are within 10 miles of a recently active fault, 350 wells (23 percent) are within 5 miles, and 87 wells (6 percent) are within 1 mile (Table 1). Of added concern, 42 wells are within 10 miles of a recently active, high-magnitude fault that has caused an earthquake greater than M6 in the past 150 years, 30 wells are within 5 miles, and one well is within 1 mile.

More than half of California's 1,553 active and new wastewater injection wells are within 10 miles of a recently active fault and almost one-quarter are within 5 miles.

When all faults are considered, our analysis found that 1,197 active and new wastewater injection wells (77 percent) are within 10 miles of a Quaternary fault, 808 wells (52 percent) are within 5 miles, and 302 wells (19 percent) are within 1 mile (Table 2). Of these, 529 wells are within 10 miles of a high-magnitude Quaternary fault that has caused an earthquake greater than M6 in the past 1.6 million years, 249 wells are within 5 miles, and 53 wells are within 1 mile.

The close proximity of California's wastewater injection wells to faults raises significant cause for concern over the potential for these wells to induce earthquakes. Earthquakes have been induced at distances up to 7.5 miles (12 kilometers) from an injection well,[74] and many of California's active wastewater injection wells are located much closer to faults. Scientists have recommended using 12.4 miles (20 kilometers) as the distance of concern for evaluating whether an injection well might induce an earthquake,[75] and the vast majority of California's active and new injection wells lie within this distance.

TABLE 1. Number of active and new wastewater injection wells within 1, 5, and 10 miles of recently active faults that have caused earthquakes in the past 200 years

NUMBER OF ACTIVE/NEW WELLS (PERCENT)	DISTANCE TO FAULT
87 wells (6%)	Within 1 mile
350 wells (23%)	Within 5 miles
834 wells (54%)	Within 10 miles

TABLE 2. Number of active and new wastewater injection wells within 1, 5, and 10 miles of Quaternary faults that have caused earthquakes in the past 1.6 million years

NUMBER OF ACTIVE/NEW WELLS (PERCENT)	DISTANCE TO FAULT
302 wells (19%)	Within 1 mile
808 wells (52%)	Within 5 miles
1,197 wells (77%)	Within 10 miles

We also found that some of the state's major population centers, such as Los Angeles and Bakersfield, are in regions where high densities of wastewater injection wells are located near recently active faults (Figure 4). The impacts of induced earthquakes can be particularly costly in these heavily populated regions.

Some of the state's major population centers such as Los Angeles and Bakersfield are in regions where high densities of wastewater injection wells are near recently active faults.

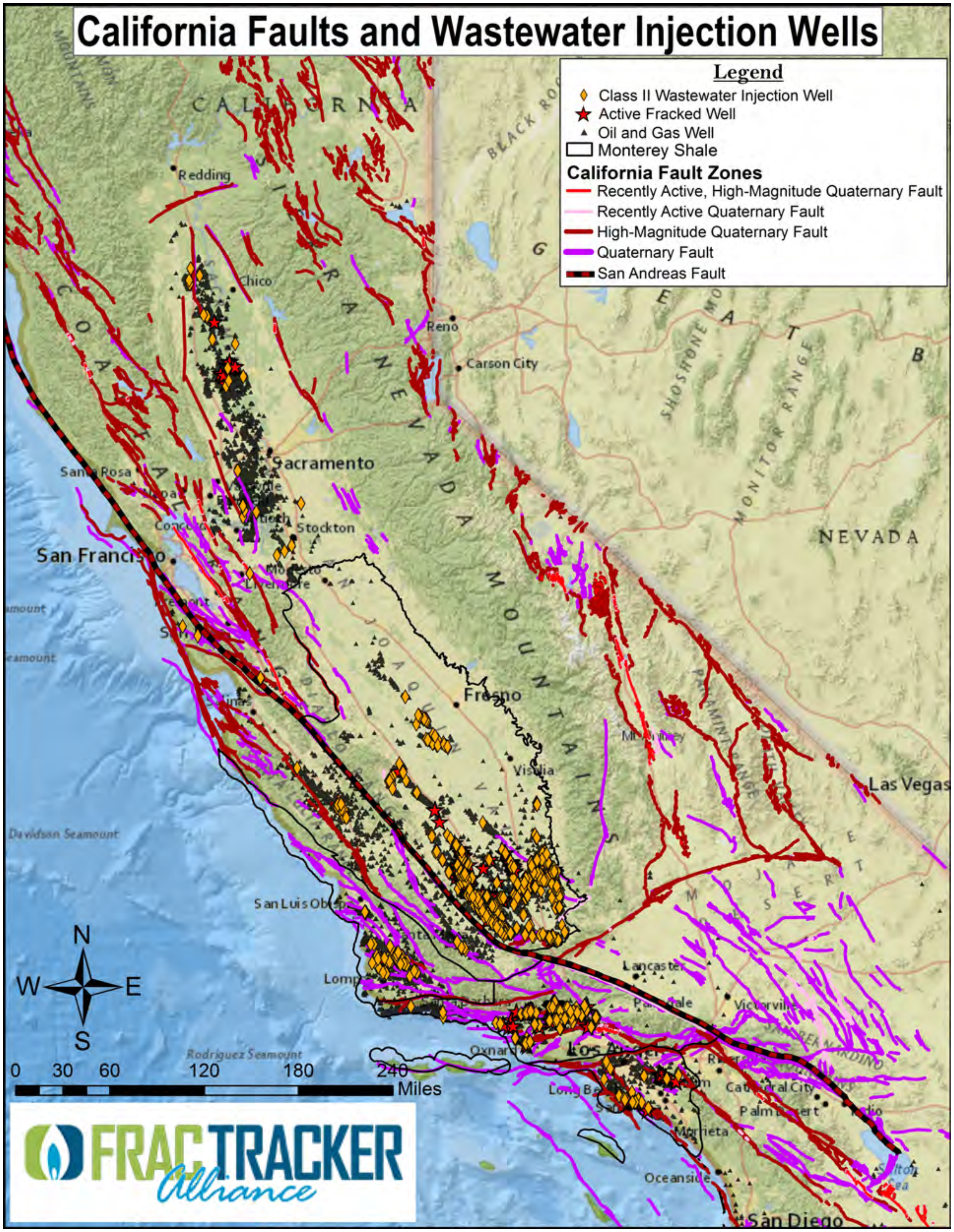

FIGURE 4. California Faults with Class II Wastewater Injection Wells and Fracked Wells. High densities of wastewater injection wells are located near recently active faults.

We highlight three at-risk regions — Kern County, Ventura County, and Los Angeles County:

Kern County: Just to the west of Kern County lies the San Andreas fault — one of the most active faults in the world. Just a few miles from the fault, a large concentration of underground injection wells litters the landscape (Figure 5). There are additional injection wells throughout the county, as well as hundreds of oil wells that are actively fracked and acidized. In 1952, a M7.5 earthquake struck the city of Bakersfield, causing millions of dollars in damage. Kern County produces nearly 80 percent of all oil in California. An earthquake in the area could cause significant environmental damage from well ruptures and spills, as well as injuries, loss of life, and monetary damages.

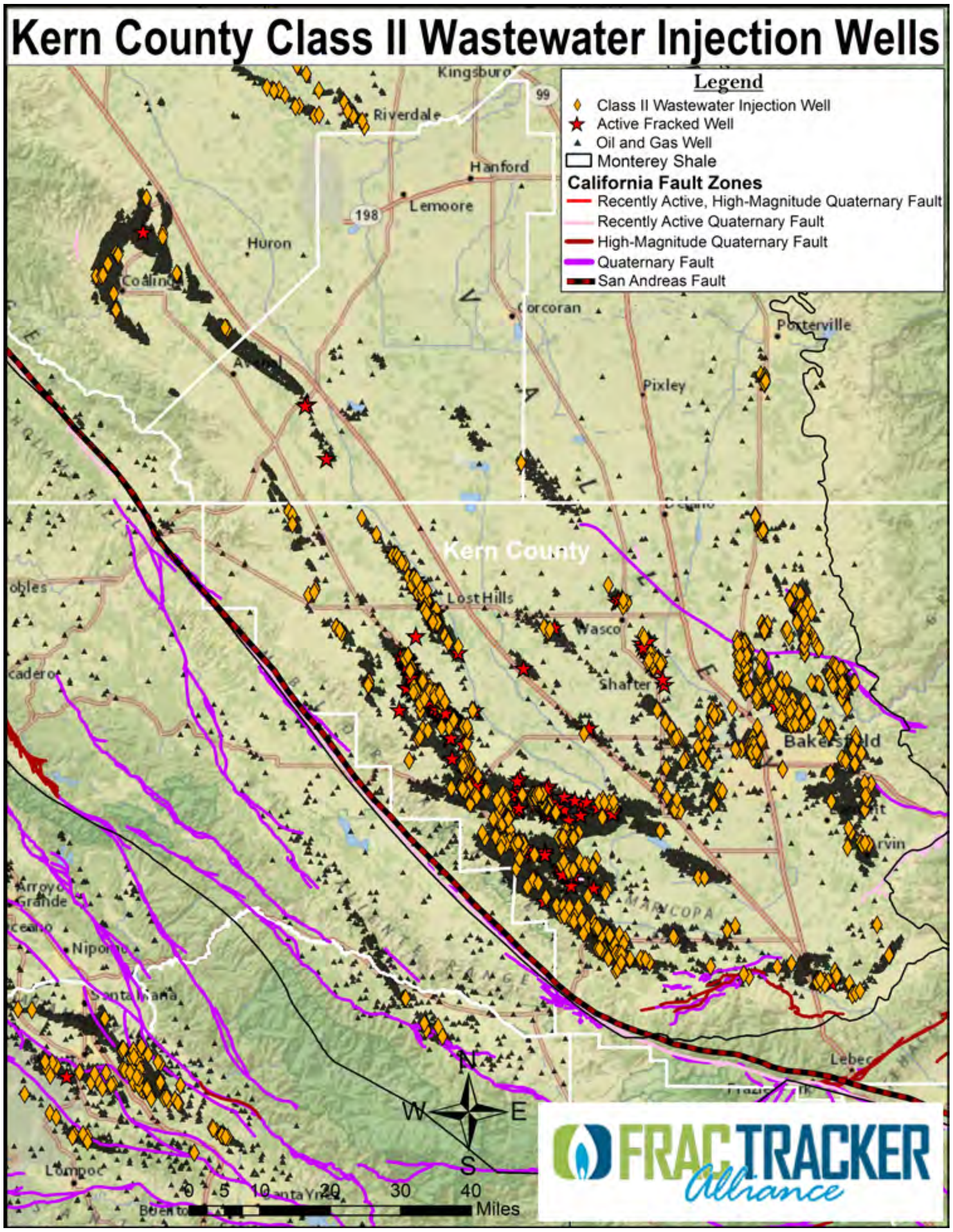

FIGURE 5. Kern County Faults with Class II Wastewater Injection Wells and Fracked Wells

Ventura County: Wastewater injection and oil production, including fracking and acidizing, is occurring near faults in the mountains north of the cities of Ventura and Oxnard (Figure 6). These regions are also high-hazard areas for liquefaction and landslides. Should a significant earthquake occur, it would put hundreds of thousands of residents in danger and could cause billions of dollars in infrastructure damage. The CGS estimated a loss of nearly $82 million in the Ventura-Oxnard area in 2010 due to seismic activity.[76] Ventura County lies in the southern edge of the Monterey Shale, one of the areas of most interest for future oil and gas development in the state.

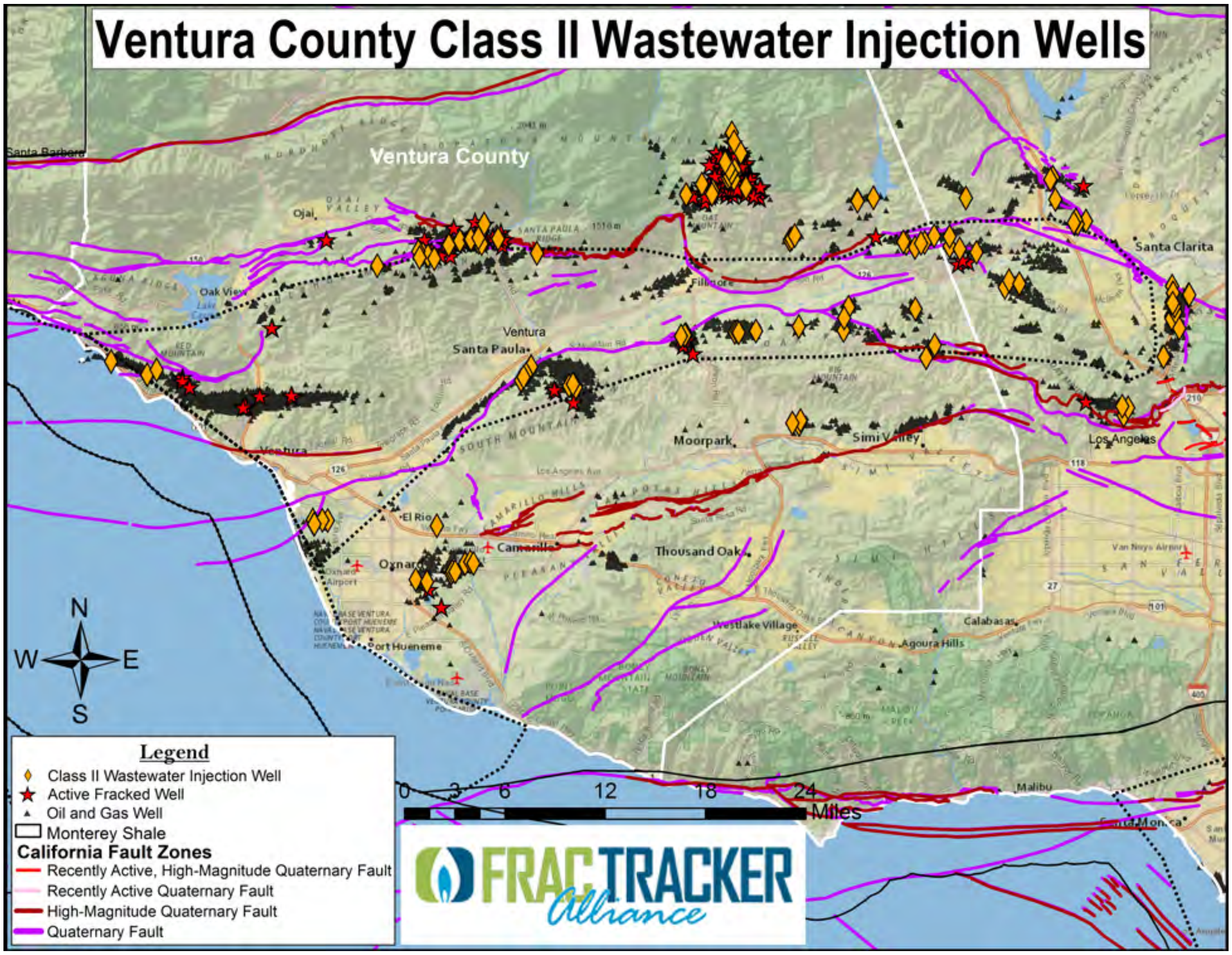

FIGURE **6. Ventura County Faults with Class II Wastewater Injection Wells and Fracked Wells**

Los Angeles County: One of the main areas of concern lies in Los Angeles County where underground injection wells and oil and gas wells subjected to hydraulic fracturing and acidizing are located very near faults that have been shown to be active in the past 150 to 200 years (Figure 7).

The Inglewood oil field, which lies just southwest of downtown Los Angeles and north of the Long Beach area, is littered with disposal wells that receive millions of gallons of wastewater every year. Estimates by the CGS showed a loss of nearly $1.1 billion for the Long Beach/Los Angeles area from seismic activity in 2010 alone.[77]

Were a major earthquake to occur, it could devastate the county. For example, the "ShakeOut Scenario" from the USGS and CGS estimated that a nearby M7.8 earthquake along the San Andreas fault could cause 1,800 fatalities and nearly $213 billion in economic damages.[78] Additionally, much of Los Angeles County lies in high-hazard areas for liquefaction and landslides.

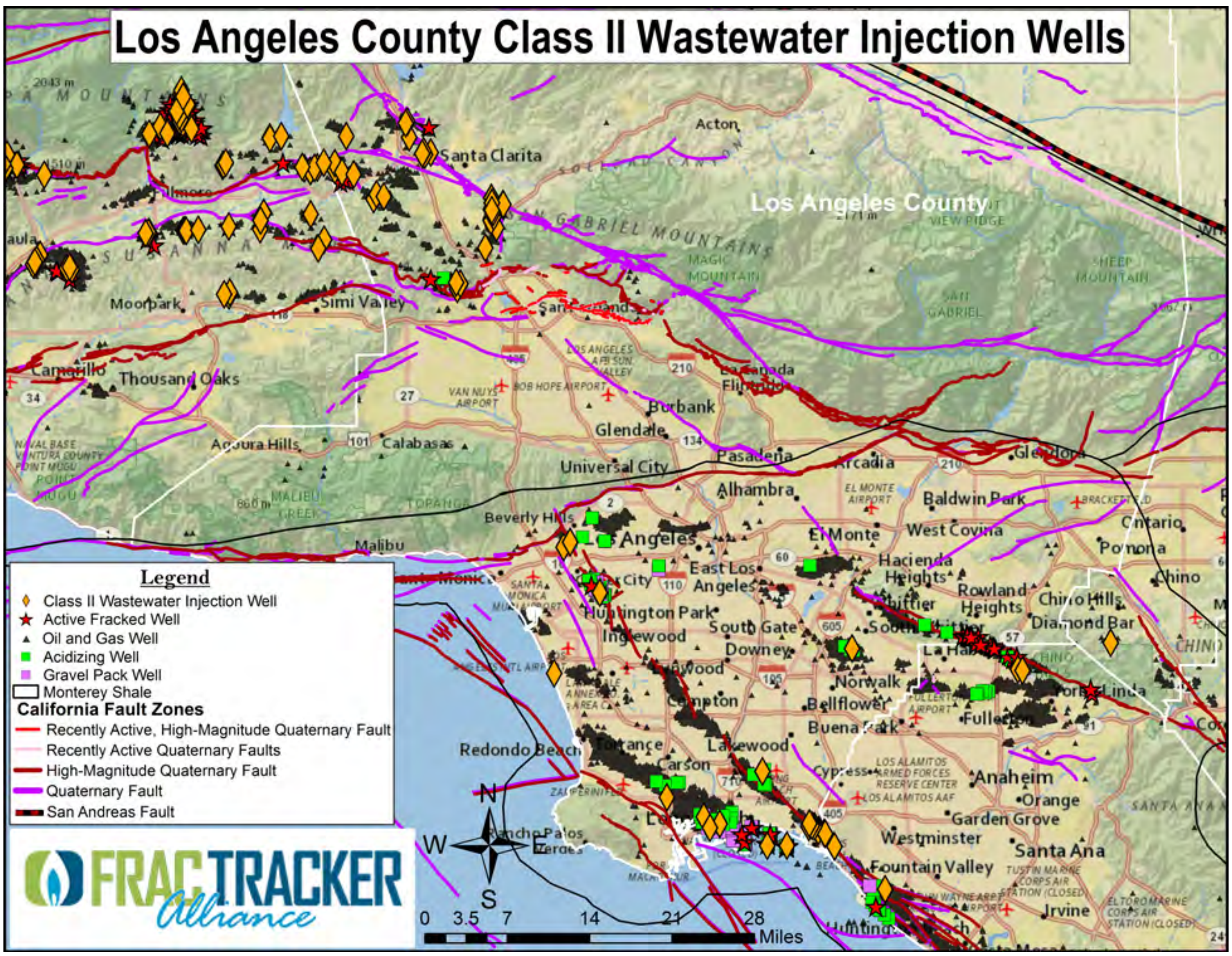

FIGURE 7. LA County Faults with Class II Wastewater Injection Wells and Fracked Wells

3. Critical gaps in monitoring and information prevent the effective detection and risk assessment of human-induced earthquakes.

Despite the advances in research linking wastewater injection wells to induced earthquakes in the Eastern and Midwestern U.S., very little research and monitoring of the earthquake risks from wastewater injection has been conducted in California, despite the state's long history with active faults. At present, no studies have evaluated the potential increase in earthquake risks from the several thousand existing wastewater injection wells, and fracked and acidized wells, in the state. In short, we simply do not know the extent to which existing oil and gas wells and wastewater injection wells in California may have already induced earthquakes.

Other fundamental questions related to the risks of induced seismicity from wastewater injection wells remain unanswered. Several key knowledge gaps exist:

- What is the largest earthquake that could be induced by wastewater injection and fracking activities?
- What is the maximum distance from a fault over which an injection well can induce an earthquake? Examples to date indicate that earthquakes have been induced up to 7.5 miles (12 kilometers) from an injection well.
- What is the time period following the initiation of injection over which earthquakes can be induced, since induced seismicity often occurs within months of initiation but can also occur after many years?
- How quickly can induced seismicity be "turned off" after stopping injection activities, since studies indicate that there may be delays of months or in some cases more than a year?
- How does the density of wells in an area affect the risk of inducing an earthquake? Does a greater density of wells increase this risk?
- What is the risk that wastewater injection wells and oil and gas production wells (including those that have been stimulated), including plugged and abandoned wells, could be damaged by earthquake activity so that they contaminate drinking water sources?
- When and why will a particular injection well induce an earthquake? Why do some injection wells induce earthquakes while others in the same region do not?

Unfortunately, much of the information needed to assess earthquake risks from wastewater injection and oil and gas production wells in California is lacking or incomplete because of (1) the state's failure to require the oil and gas industry to submit critical fluid injection data, (2) gaps in the state's earthquake monitoring networks, and (3) the limitations on collecting comprehensive information on faults and geology.

California regulations have two primary requirements related to fluid injection data from wastewater injection wells: (1) the permit for an injection well must include an injection plan with an estimate of the maximum-anticipated surface injection pressure and daily rate of injection, and an analysis of the injection liquid,[79] and (2) "data shall be maintained to show performance of the project and to establish that no damage to life, health, property, or natural resources is occurring by reason of the project."[80] At present, California only requires industry to submit coarse-scale monthly injection volumes and wellhead pressures,[81] which makes it difficult to determine whether a particular wastewater injection well may have induced an earthquake.

The quantity and distribution of seismic monitoring stations are critical for accurately characterizing the seismicity of a region and determining whether an earthquake is natural or induced. In California, monitoring and reporting of earthquake activity is coordinated under the California Integrated Seismic Network (CISN), a public and private network of monitoring stations.[82]

According to the CISN, the number, type, and distribution of seismic stations are sparse in many parts of the state, and considered inadequate for "producing the best quality of earthquake information from all parts of the state."[83] Collecting data on smaller magnitude earthquakes between magnitudes 1.5 and 2 is particularly important since these smaller earthquakes are much more common than larger ones, can provide warnings that larger magnitude earthquakes are coming, and allow for the statistically robust detection of induced earthquakes.

Critical information on faults and geology is also lacking. California's fault maps are not complete. Some potentially destructive fault types, such as strike-slip faults and blind thrust faults, can be difficult to detect even with traditional seismic imaging technology.[84] Modern 3-D seismic imaging technology that allows for better fault detection is very costly, making it unlikely to be commonly used. There are technological limitations on collecting information on the geological characteristics related to induced seismicity, including pore pressure, permeability, existing stresses, and hydrological connectivity to deeper faults.

4. California regulations do not address the risks of induced earthquakes from wastewater injection wells or fracking.

Underground injection wells for oil and gas wastewater are regulated by the federal Safe Drinking Water Act's Underground Injection Control Program (UIC) and are classified as Class II wells. The EPA granted the State of California primacy to implement the UIC Class II program in California in 1982.[85] The federal UIC Class II regulations and California's UIC Class II program do not adequately address the risks of induced seismicity from wastewater injection wells.

Neither EPA's federal regulations for Class II wells nor California's UIC Class II program contain provisions specific to seismicity, and neither require operators to collect and submit the information needed to assess the risks of induced seismicity. Class II provisions can be compared to the UIC Class I program, which covers hazardous and non-hazardous waste from industrial and municipal sources.[86] Because wastewater from oil and gas production was exempted from hazardous waste regulations under the Resource Conservation and Recovery Act (RCRA), it is not classified as "hazardous" regardless of its composition and is not required to be disposed of under the more stringent requirements of the UIC Class I program.[87]

UIC Class I regulations include requirements for minimizing earthquake risk during well siting, including studies to demonstrate that the injection area has low background seismicity and that the proposed injection will not induce earthquakes.[88] Rules for Class I wells require geologic analysis of a much larger area surrounding each well to demonstrate that hazardous materials will not move out of the injection zone. They also mandate more stringent protocols for construction, operation, testing, and monitoring, as well as monitoring of the well and groundwater after the well is plugged. The weaker regulations for Class II wastewater injection wells may increase the risks of inducing earthquakes and contaminating drinking water.

Current DOGGR regulations for Class II wastewater injection wells are inadequate for protecting against the risks of induced earthquakes. The regulations related to earthquake risks only require that applications for injection projects include a map showing "reservoir characteristics such as… faults,"[89] without providing guidance on how to evaluate faults. Moreover, DOGGR only requires the industry to submit coarse-scale, monthly fluid injection volume and wellhead pressure data,[90] which makes it difficult to determine whether a particular wastewater injection well may have induced an earthquake.[91]

Notably, DOGGR does not require any seismic monitoring at or near wastewater injection wells, nor does it conduct any macro-level analysis — for multiple injection projects or on the field level — of the potential seismic impacts based on the planned or reported injection data.[92] All analysis of these data is on a project only level, which does not address any changes in seismic risk due to high concentrations of disposal well projects within a given field or area, or how neighboring injection projects interact on a cumulative level with surrounding faults.

In sum, although the regulations state that DOGGR should maintain data "to establish that no damage to life, health, property, or natural resources is occurring by reason of the project,"[93] DOGGR does not require the collection and assessment of the geological or fluid injection data needed to adequately evaluate the risks from induced earthquakes, or detect whether induced earthquakes are occurring.

Additionally, in July 2011, Environmental Protection Agency's Region 9 found DOGGR's implementation of its Class II program inadequate in several regards.[94] Specifically, the critique highlights DOGGR's one-size-fits-all Area of Review (AOR) standard that only requires review of a quarter-mile radius around the well, which could result in insufficient analysis of surrounding geologic features such as faults.[95] DOGGR has no systematic process for assessing geologic features outside of the quarter-mile AOR.[96] It appears that this process is ad-hoc and not adequate for identifying important geologic features outside of the quarter-mile radius AOR, and the potential for induced seismic events on faults more than a quarter-mile away from a disposal well. Due to the urgency of the identified deficiencies, the EPA requested that DOGGR provide an "action plan" to address them no later than September 1, 2011.[97] Despite the passage of more than two years, DOGGR has to date failed to bring its program into compliance with federal requirements.

DOGGR's November 2013 proposed regulations for well stimulation touch briefly on earthquake risks associated with well stimulation activities, but do not require any seismic monitoring to detect induced seismicity and mandate no action to respond to or potentially mitigate human-induced earthquakes.[98] The proposed regulations require the following:

- that evaluation prior to well stimulation include a review of all faults within a radius of twice the anticipated well-stimulation treatment length (Section 1784), and
- that the report submitted within 60 days of ending a well stimulation treatment will note if "data from the USGS indicates that, since the commencement of a well stimulation treatment, any earthquake of M2.0 or greater has occurred in the area of the well stimulation treatment radius" (Section 1789).[99]

In 2012, the National Academy of Sciences (NAS) recommended that states and regulators should take steps to prevent human-induced earthquakes.[100] The NAS panel was chaired by Colorado School of Mines professor Murray Hitzman, who cautioned that earthquakes associated with drilling can pose a risk to public health and safety.[101]

California oil and gas regulators have ignored these recommendations. State officials have said they don't need to look at injection wells and earthquakes, stating that the current rules are sufficient. In 2012, DOGGR spokesman Don Drysdale stated: "While seismicity is not specifically mentioned in the California Code of Regulations, DOGGR believes it is adequately addressed. Operators must evaluate oil and gas reservoirs prior to injection, and that evaluation includes faulting."[102] Not only has DOGGR failed to provide guidance or regulation that makes clear to the regulated community how to evaluate "faulting," the agency does not appear to have given much consideration to the risks associated with induced seismicity related to wastewater injection in California, or the risks of well-casing failure in areas that are notable for significant seismic activity.

5. The best way to protect Californians is to halt hydraulic fracturing, acidizing, and other unconventional oil and gas recovery techniques.

Fracking and other unconventional oil and gas extraction techniques are accompanied by numerous risks, including climate disruption, air and water pollution, public health impacts, the use of scarce water resources, and the production of billions of gallons of contaminated wastewater. New and ongoing research has established that much of the increased earthquake activity, and many of the large earthquakes in the Eastern and Midwestern U.S. where fracking-enabled oil and gas production has boomed, can be attributed to the underground injection of wastewater, providing yet more evidence of the negative consequences of fracking, acidizing, and other unconventional extraction techniques.

Our analysis of wastewater injection wells and faults in California found that 87 wastewater injection wells are within 1 mile of a recently active fault, 350 wells are within 5 miles, and 834 wells are within 10 miles. The proximity between many existing wastewater injection wells and recently active faults raises significant cause for concern over the potential for these wells to induce earthquakes.

In California, inadequate monitoring and research, fundamental knowledge gaps, and poor regulation indicate that Californians are not being protected from the earthquake risks posed by wastewater injection wells and fracking. Yet the state may be on the verge of rapid expansion of fracking and other techniques that will dramatically increase the use of wastewater injection wells.

California's current regulations do not adequately address the risks of induced earthquakes from wastewater injection wells and fracking. Additionally, California's proposed well stimulation regulations do almost nothing to reduce the risk of induced seismicity. The proposed DOGGR rules on well stimulation do not mandate the collection and assessment of data to proactively evaluate seismic risk during siting of wells, nor do they require seismic monitoring before, during, or after well operation or actions to respond to and mitigate potential induced-earthquake activity.

Induced earthquakes can impose large safety and economic costs on the public. Earthquakes induced by wastewater injection and fracking can affect a broad area beyond the well, causing damage to homes, workplaces, infrastructure, and potentially cause injury or devastating loss of human life. The public can also pay a high economic price. In response to the earthquake swarms occurring in Oklahoma, the state insurance commissioner recommended that Oklahomans buy earthquake insurance, which comes with prohibitive out-of-pocket costs to repair earthquake damage due to high deductibles,[103] as well as skyrocketing insurance rates near earthquake epicenters.[104]

Through inaction and failure to address the potential risks, the state has in effect transferred to the public many of the potential risks and costs associated with induced seismicity, well-casing failure, and associated leaks that might be caused by earthquakes. Without effective monitoring or regulatory systems in place, those harmed by property damage, water contamination, or other harm will likely face daunting challenges to demonstrating that oil and gas operations caused the harm. By failing to require adequate monitoring and through lack of oversight, California's Department of Conservation fails to comply with its legal mandate to protect public safety and welfare. Furthermore, the state enables companies that profit from oil and gas production to transfer the risks associated with seismicity to the public.

It has been suggested that earthquake risks from wastewater injection wells can be managed if the industry follows a strict series of steps for study and planning prior to injection, performs monitoring in areas where seismicity might be triggered, and establishes protocols for responding, including potential well abandonment if induced seismicity occurs.[105] Existing and proposed California regulations do not require oil and gas operators to take any of these steps. Instituting this system would require far-reaching changes to business-as-usual practices that work in the industry's favor.

Implementing the best-possible system to monitor and manage earthquake risks from wastewater injection wells and fracking could reduce — but not eliminate — the risks to Californians. There are significant technological and cost limitations for locating faults and characterizing geology, as well as large knowledge gaps, which limit the ability to effectively address the risks. Moreover, even the best monitoring and management system would still place safety and economic burdens on the public. Due to these limitations, DOGGR cannot safely regulate induced seismicity.

In light of the known environmental and health risks from unconventional extraction and wastewater disposal, the link between wastewater injection wells and earthquakes in other states, the potential for a huge expansion of drilling and wastewater production in the Monterey Shale, and the gaps in scientific knowledge regarding induced seismicity, the best way to protect Californians is to halt hydraulic fracturing, acidizing, and other unconventional oil and gas recovery techniques. Moreover, no oil and gas wastewater disposal should be allowed that does not account for all risks, including seismic risks.

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Appendix A: Research and Methodology

The data used to generate the "California Geological Hazards" and "Injection Wells and Hydraulic Fracturing in California's Fault Zones" maps on FracMapper come from several sources, including DOGGR, CGS, and USGS. Several map layers were downloaded as shapefiles and imported directly into ArcGIS without amendments, while other datasets were aggregated, queried or significantly edited to produce the map layers.

The well-site locations were downloaded as the full DOGGR dataset, available as "AllWells.zip." The DOGGR database was queried to separate the individual well-types into the various map layers, and differentiate between new, active, idle, plugged, and buried wells. "New" wells have been permitted, but have not yet been drilled. The permit is valid for one year, or up to two years upon request. The database includes an identifier for hydraulically fractured wells; these wells were isolated and then combined with the SkyTruth.org database of hydraulically fractured wells, which they extract from FracFocus.org. The hybrid dataset can be downloaded from FracTracker (CA Hydraulically Fractured Wells). An additional well-site database showing well sites within the South Coast Air Quality Monitoring District is also projected in the maps. The California high-magnitude quaternary faults map layer was generated by clipping the USGS dataset for the entire United States. The dataset of "Named California Faults" also used for the proximity analysis was retrieved from CGS. The Hayward fault shapefile was downloaded from USGS as a package also containing landslide hazard zones. The "Named Faults" dataset that was used for part of the proximity analysis was produced by eliminating all unnamed quaternary fault-lines from the CGS fault database.

The statewide shaking hazards map layers estimate the amplification based on the underlying geology of the soil. A research group consisting of both USGS and CGS geologists developed risk hazards available as shapefiles for both high frequency and low frequency seismic events. High frequency shaking poses a hazard for short building structures, while low frequency shaking is the most hazardous to large multi-story cityscape buildings. For the Bay Area and East Bay, additional shaking hazards analyses have been completed. Liquefaction risks have been estimated by USGS and CGS specifically for the Bay Area, Alameda County and multiple fault-slip scenarios for Santa Clara in separate assessments. All shapefiles are viewable individually in the California Geological Hazards Map.

There are no regional liquefaction risk estimate maps available outside of the Bay Area, although the CGS has identified regions of liquefaction and landslide hazards zones for the metropolitan areas surrounding the Bay Area and Los Angeles. These maps outline the areas where liquefaction and landslides can be expected given a standard set of conservative assumptions. These datasets are only available via individual 7.5-minute quadrangles. To produce the map layers FracTracker aggregated the quadrangles, and combined the data into unified datasets, downloadable here; Landslide and Liquefaction.

For the proximity analysis of Class II wastewater injection wells and faults, we used the most recently updated dataset from DOGGR, posted 9/27/13, which identified 2,583 total Class II water injection wells. Of those, 2,578 entries had latitude/longitude data, with 1,473 wells listed as "active," 80 listed as "new," and 1,031 listed as "plugged." The proximity analysis included the 1,553 wells listed as "active" or "new. "We used the North American Datum 1983 State Plane California IV FIPS 0404 projection because the majority of Class II Water Disposal wells are located in Kern County. The analysis was conducted using ESRI's ArcGIS ArcMap V. 10.1 software. We used two fault databases: (1) the California Geological Survey 2010 Fault Activity Map of California, and (2) the U.S. Geological Survey Quaternary Fault and Fold Database of the U.S. Buffers were created around the Class II Injection Well shapefiles, and the 'intersect' function was used to generate the proximity datasets. Database management was conducted using IBM SPSS Statistics v.20 software.

Appendix B: Analysis of the Distances of All (Active, New, Idle, Plugged, and Buried) Class II Injection Wells to Faults

This Appendix presents analyses similar to those presented for active and new Class II wastewater injection wells, but includes both active and inactive wastewater injection wells, including active, new, idle, plugged, and buried wells, totaling 2,578 wells with location data.

Our analysis shows that 1,177 (46 percent) of California's 2,578 active and inactive wastewater injection wells are within 10 miles of a recently active fault that has caused an earthquake in the past 200 years, 527 wells (20 percent) are within 5 miles, and 112 wells (4 percent) are within 1 mile (Table 1). Of added concern, 115 wells are within 10 miles of a recently active, high-magnitude fault that has caused an earthquake greater than M6 in the past 150 years, 94 wells are within 5 miles, and 3 wells are within 1 mile.

When all faults are considered, our analysis found that 1,936 active and inactive wastewater injection wells (75 percent) are within 10 miles of a Quaternary fault, 1,422 wells (55 percent) are within 5 miles, and 527 wells (20 percent) are within 1 mile (Table 2). Of these, 1,001 wells are within 10 miles of a high-magnitude Quaternary fault that has caused an earthquake greater than M6 in the past 1.6 million years, 606 wells are within 5 miles, and 135 wells are within 1 mile.

TABLE 1. Number of active and inactive wastewater injection wells within 1, 5, and 10 miles of recently active faults that have caused earthquakes in the past 200 years

NUMBER OF WELLS (PERCENT)	**DISTANCE TO FAULT**
112 (4%)	Within 1 mile
527 (20%)	Within 5 miles
1,177 (46%)	Within 10 miles

TABLE 2. Number of active and inactive wastewater injection wells within 1, 5, and 10 miles of Quaternary faults that have caused earthquakes in the past 1.6 million years

NUMBER OF WELLS	**DISTANCE TO FAULT**
527 (20%)	Within 1 mile
1,422 (55%)	Within 5 miles
1,936 (75%)	Within 10 miles

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According to the U.S. EPA website (http://water.epa.gov/type/groundwater/uic/class2/) there are approximately 144,000 Class II wells in operation in the US, injecting over 2 billion gallons of wastewater everyday. Most of these are located in Texas, California, Oklahoma, and Kansas. Three types of Class II wells are associated with the industry: 1) Enhanced recovery wells – flowback fluids, along with other liquids and gases are injected to recover residual oil and gas. This is known as secondary or tertiary recovery. These are the most common type, accounting for nearly 80% of all Class II wells. 2) Disposal wells – flowback fluids are injected into the same, or similar, formations as the well from which it was extracted. Disposal wells account for approximately 20% of all Class II wells. 3) Hydrocarbon storage wells – these serve as underground storage for hydrocarbons, and are found in formations (such as salt caverns). The main use of these wells if for the US Strategic Petroleum Reserve. There are over 100 hydrocarbon storage wells in operation.

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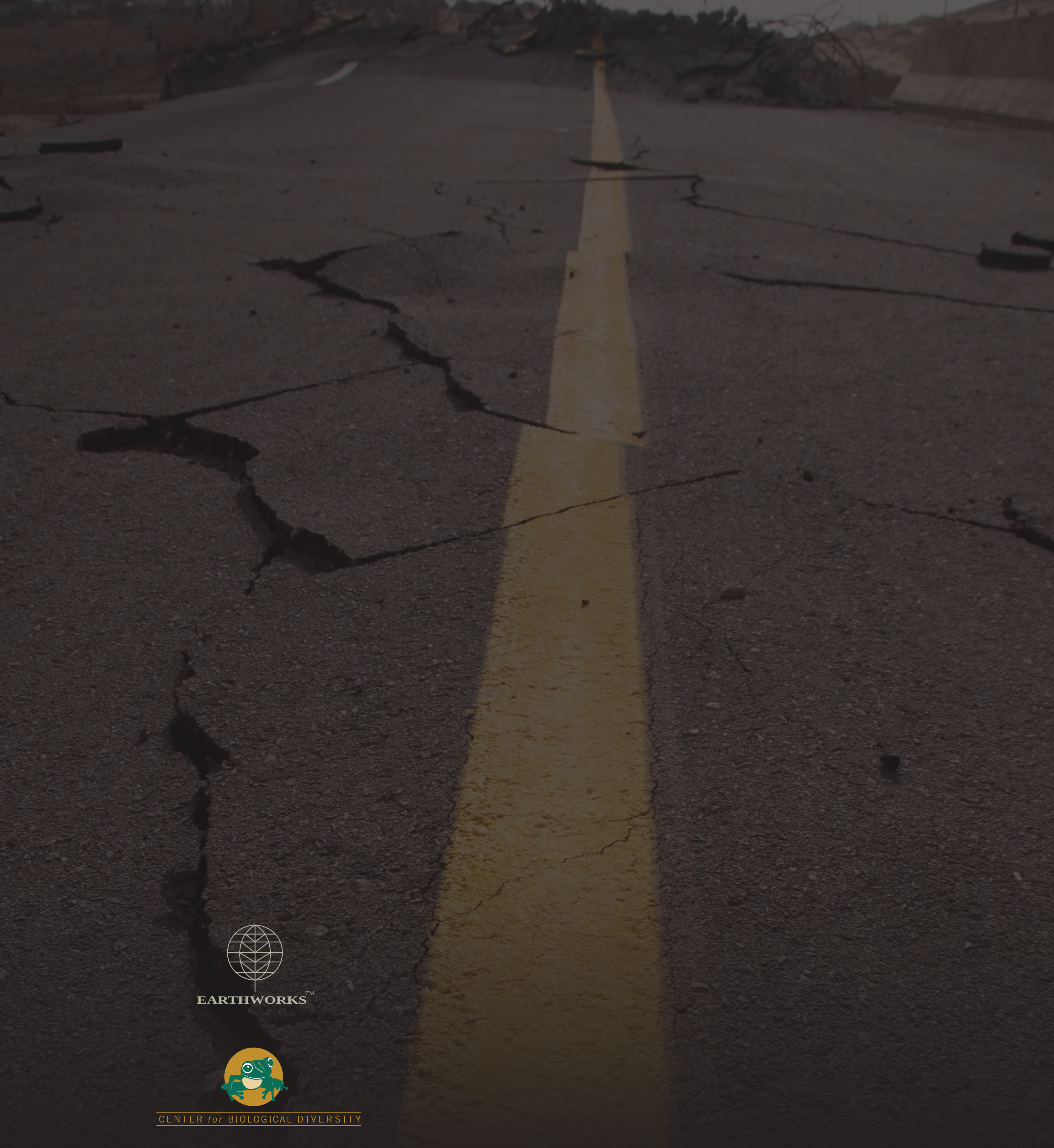

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