pyrene, and triphenylene. The study's analysis supported nearby fracking activities as the possible contamination source. The installation of a water treatment system reducing the PAHs in the PA water to NY levels eliminated the occurrences of dysphagia. Noting that a "similar study of these environmental variables would be nearly impossible to undertake in humans," the researchers state that "domestic large animals such as horses can serve as important sentinels for human health risks" linked to fracking.

- April 27, 2020 – Forest interior songbird numbers declined "at relatively low levels of overall forest loss" associated with shale gas in Marcellus-Utica shale area landscapes within Pennsylvania, West Virginia, and eastern Ohio, a team of forest and wildlife ecologists determined.[1627] Their study consisted of 2,589 bird surveys at 190 sites across this region over two years. They found that some forest interior species "decreased abruptly in abundance and frequency of occurrence above a threshold of 17.0% overall forest loss." Some more sensitive species similar declined at lower thresholds, from 8.7 to 15.9 percent forest loss. Whereas research has shown that some highly adaptive bird species can increase with human disturbance, this study found that species in these other habitat categories did not increase in landscapes with more than 30.5–36.5 percent forest loss from shale gas development. Researchers concluded that their findings of "declines in abundance and richness of forest interior birds in response to anthropogenic forest disturbance at relatively low levels of forest loss" were consistent with previous findings, and warned that the time period is which shale gas development has taken place in the region would not yet allow for science to have observed "the full range of successional impacts to affected forests, or the full response of species to ongoing changes."

- April 10, 2020 – A case study considered the "misalignment of conservation objectives" by analyzing the effects of fracking in the Bakken shale on North Dakota's Theodore Roosevelt National Park (TRNP).[1628] Authors discussed the potential for conflict between federal oversight of shale oil and gas reserves development with the federal obligation "to preserve designated areas of 'wilderness,' as well as protect social and cultural significance, ecosystem services, recreational benefits, and inherent beauty," with particular attention to the Trump administration's executive orders weakening and repealing pertinent protections. Twelve national parks contain active oil and gas wells within their boundaries, while others, including TRNP, do not, but effects of surrounding oil and gas development have included air pollution, noise pollution, and land fragmentation. Documented "evidence of encroachment" included "noticeable changes to viewscape and soundscape." The authors posit that the Trump administration's steps toward weakening protections and prioritizing oil and gas development over conservation "conflicts with the original intent to set aside TRNP and other federal parklands for current and future generations." They ask, "In regulating fracking and conservation, can the federal government be both the gamekeeper and the poacher?"

[1627] Laura S. Farwell et al., "Threshold Responses of Songbirds to Forest Loss and Fragmentation across the Marcellus-Utica Shale Gas Region of Central Appalachia, USA," *Landscape Ecology* 35, no. 6 (2020): 1353–70, https://doi.org/10.1007/s10980-020-01019-3.
[1628] Miriam R. Aczel and Karen E. Makuch, "Shale Resources, Parks Conservation, and Contested Public Lands in North Dakota's Theodore Roosevelt National Park: Is Fracking Booming?," *Case Studies in the Environment* 4, no. 1 (2020): 1–13, https://doi.org/10.1525/cse.2019.002121.

- March 27, 2020 – West Virginia wildlife researchers found sex-specific genetic changes in Louisiana waterthrush linked to shale gas development, concluding these changes "may affect long-term population survival and fitness" of the species.[1629] This was the first study relating shale gas development to a molecular-level, epigenetic response in a wildlife population. This species is known to be sensitive to changes in ecological conditions and is of conservation concern. It has a specialized habitat and its core breeding range overlaps the Marcellus-Shale region. The researchers' previous six-year study determined that shale gas development negatively impacted the Louisiana waterthrush population. Here, the researchers studied the epigenetic response—DNA changes, or, methylation variation, in response to environmental exposures that may be inherited by future generations—of this species, comparing those in shale gas development regions to those without disturbance from shale gas development. Researchers wrote that their study "adds to existing evidence that methylation varies with pollutant concentrations," and was the first to show a differing pattern of methylation between males and females in a wildlife population. Females had more "methylated restriction sites" than males, which authors proposed may be due to their different use and movement patterns within their territories. Researchers also correlated methylation to the accumulation in feathers of barium and strontium, two heavy metals linked to fracking and already documented to be higher in waterthrush feathers in fracking areas.

- March 14, 2020 – Researchers found degraded soil health, lower wheat yields, and loss of microbial diversity in a greenhouse experiment that involved treating wheat with various dilutions of wastewater from oil and gas production in an effort to determine if it can safely be used as a viable water source for agricultural irrigation. Using a soil health index that reflected chemical, biological, physical, and nutrient properties, the team found irrigation with wastewater from oil and gas production significantly reduced soil health as compared to the soil receiving the control irrigation water. Both dilutions led to lower wheat yields. Further, the microbial community within the soil was significantly different between irrigation treatments in ways that may affect biochemical cycling.[1630]

- November 19, 2019 – Expanding oil and gas well pads and infrastructure covered 2.5 percent and nearly eleven percent of two priority greater sage-grouse population habitat management area zones within the Parachute-Piceance-Roan, according to study by Colorado Parks and Wildlife researchers.[1631] Oil and gas infrastructure developed during the 2005-2015 study period included 195 new well pads, 930 hectares of new pipelines, and 230 kilometers of new roads. The total oil and gas "footprint" within the greater sage-grouse range in this location more than doubled in the study period, with the rate of new energy development slowing from 2009 to 2015. The researchers predicted,

[1629] Mack W. Frantz et al., "Epigenetic Response of Louisiana Waterthrush *Parkesia Motacilla* to Shale Gas Development," *Ibis* 162, no. 4 (2020): 1211–24, https://doi.org/10.1111/ibi.12833.
[1630] Hannah Miller et al., "Reusing Oil and Gas Produced Water for Agricultural Irrigation: Effects on Soil Health and the Soil Microbiome," *Science of the Total Environment* 722 (2020), https://doi.org/10.1016/j.scitotenv.2020.137888.
[1631] Brett L. Walker et al., "Quantifying Habitat Loss and Modification from Recent Expansion of Energy Infrastructure in an Isolated, Peripheral Greater Sage-Grouse Population," *Journal of Environmental Management* 255 (2020): 109819, https://doi.org/10.1016/j.jenvman.2019.109819.

however, that oil and gas will continue to be the main source of greater sage-grouse habitat loss and change in this area over the next few decades. The greater sage-grouse is a "species of concern," that "has experienced historical population declines, especially in peripheral populations" such as the Parachute-Piceance-Roan, and energy development has been widely cited, including by the U.S. Fish and Wildlife Service, as one of the main concerns. This study sought to remedy the "lack the comprehensive, accurate, time-stamped spatial data layers needed to rigorously quantify effects of energy infrastructure" in a greater sage-grouse population. Researchers chose Parachute-Piceance-Roan, which overlays large shale reserves, for its increasing oil and gas development and concern about long-term population viability. Within the study area researchers found that the same topographic constraints that lead to oil and gas development in gentler topography, hold true for the greater sage-grouse habitat preference.

- September 23, 2019 – Farmers in the path of the Spire Inc. STL gas pipeline in Illinois said access to their fields has been blocked, their topsoil damaged, and fields flooded by the construction.[1632] The farmers' claims were backed up by an 80-page inspection report by the Illinois Environmental Protection Agency, linked in the *E&E News* piece, and a consulting firm working on behalf of some of the farmers filed at least 25 complaints with the Federal Energy Regulatory Commission (FERC) on their behalf. Fifty farmers in the pipeline's path had denied easements; the company subsequently employed a legal process called "quick take" to gain access to the properties.

- August 7, 2019 – Between 1975 and 2017, four British Columbian shale gas plays together lost over one percent of their forest cover, due to the construction of well pads, access roads, and pipelines.[1633] The Canadian and U.S. research team combined a geospatial approach with metrics from landscape ecology. Authors suggested that forest cover loss was held to the degree found due to the International Boreal Conservation Science Panel recommendation that "at least fifty percent of the intact boreal forest of Canada should be conserved," but that increased understanding is needed of "specific forest conservation or land management context of each of these shale gas plays."

- June 11, 2019 – Drilling and fracking activities decreased the abundance of forest interior-dependent songbird populations in central Appalachia, according to a study of the relationship between 27 bird species and their distance from shale gas construction in northern West Virginia from 2008 to 2017.[1634] Ovenbird species populations declined 35 percent and cerulean warblers by 34 percent. Over the study period the footprint of shale gas increased tenfold, with a larger increase in new "forest edges." Though other, highly adaptable species may benefit from forest disturbance, the researchers noted that species negatively affected include those of "conservation concern." The researchers stated that

[1632] Mike Soraghan, "'A Muddy Mess.' Ill. Landowners Fight FERC over Pipeline," *E&E News*, September 23, 2019, https://web.archive.org/web/20191226021302/https://www.eenews.net/energywire/stories/1061140891.
[1633] J. Oduro Appiah, C. Opio, and S. Donnelly, "Quantifying, Comparing, and Contrasting Forest Change Pattern from Shale Gas Infrastructure Development in the British Columbia's Shale Gas Plays," *International Journal of Sustainable Development & World Ecology* 27, no. 2 (2020): 114–28, https://doi.org/10.1080/13504509.2019.1649313.
[1634] Farwell et al., "Proximity to Unconventional Shale Gas Infrastructure Alters Breeding Bird Abundance and Distribution."

their findings of losses to populations of edge-avoiding, forest interior bird declines near shale gas development is consistent with other studies of energy development impacts on birds.

- April 9, 2019 – Shale gas development impacted "site fidelity," or breeding site return rates, of the Louisiana waterthrush, according to a six-year study by West Virginia wildlife researchers.[1635] This species is of "conservation concern" because of its specialized habitat, and because most of its core breeding range is within the Marcellus-Utica shale region. Previous research by the team showed diminished waterthrush habitat quality, nest survival, and productivity, and this study turned its focus to site fidelity, typically high among Louisiana waterthrush. This is important, as researchers explained, because "site fidelity can directly influence fecundity and survival of individuals." Specifically, the study analyzed waterthrush annual site fidelity, factors that might affect annual site fidelity, and apparent annual survival across 14 headwater streams with varying amounts of shale gas disturbance in the Lewis Wetzel Wildlife Management Area in West Virginia. Shale gas disturbance on streams varied greatly within each year of the study, but on average streams had more than one-fifth of their length disturbed by fracking development, and there were no undisturbed streams. Results showed that the males had very high site fidelity initially, returning to areas despite lowered habitat quality, but females were less likely to return, had a higher number of breeding attempts, and lowered productivity. The disruptions to the birds' normal behaviors, such as maintaining pair bonds from one year to the next, "may affect the population's long-term persistence," according to the researchers, and their study "adds to previous evidence that shale gas disturbed areas may serve as sink habitats." In sink habitats, death rates exceed birth rates.

- 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,

[1635] Mack W. Frantz et al., "Louisiana Waterthrush (Parkesia Motacilla) Survival and Site Fidelity in an Area Undergoing Shale Gas Development," *The Wilson Journal of Ornithology* 131, no. 1 (2019): 84, https://doi.org/10.1676/18-6.

Bradford, Wyoming, and Susquehanna. Although timber operations removed more canopy overall, that loss was concentrated in a smaller area.[1636]

- 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 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."[1637]

- 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.[1638]

- 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."[1639] 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."

[1636] John Young et al., "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 (2018): 66–75, https://doi.org/10.1016/j.jenvman.2018.05.041.
[1637] Reid Frazier, "Bringing the Forest Back after Shale Gas," *State Impact Pennsylvania*, September 7, 2018, https://stateimpact.npr.org/pennsylvania/2018/09/07/bringing-the-forest-back-after-shale-gas/.
[1638] Eric K. Waller et al., "Landsat Time Series Analysis of Fractional Plant Cover Changes on Abandoned Energy Development Sites," *International Journal of Applied Earth Observation and Geoinformation* 73 (2018): 407–19, https://doi.org/10.1016/j.jag.2018.07.008.
[1639] Karl Oetjen et al., "Simulation of a Hydraulic Fracturing Wastewater Surface Spill on Agricultural Soil," *Science of The Total Environment* 645 (2018): 229–34, https://doi.org/10.1016/j.scitotenv.2018.07.043.

- 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 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."[1640]

- 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."[1641] "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."[1642]

- 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

[1640] Brad D. Wolaver et al., "An Improved Approach for Forecasting Ecological Impacts from Future Drilling in Unconventional Shale Oil and Gas Plays," *Environmental Management* 62, no. 2 (2018): 323–33, https://doi.org/10.1007/s00267-018-1042-5.
[1641] Kathryn M. Barlow et al., "Unconventional Gas Development Facilitates Plant Invasions," *Journal of Environmental Management* 202 (2017): 208–16, https://doi.org/10.1016/j.jenvman.2017.07.005.
[1642] Jeff Mulhollem, "Shale Gas Development Spurring Spread of Invasive Plants in Pa. Forests | Penn State University," *Penn State News*, July 20, 2017, https://news.psu.edu/story/475225/2017/07/20/research/shale-gas-development-spurring-spread-invasive-plants-pa-forests.

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."[1643]

- 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."[1644]

- 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. Arsenic, 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."[1645]

- 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

[1643] Matthew D Moran et al., "Land-Use and Ecosystem Services Costs of Unconventional US Oil and Gas Development," *Frontiers in Ecology and the Environment* 15, no. 5 (2017): 237–42, https://doi.org/10.1002/fee.1492.
[1644] Lillie A. Langlois, Patrick J. Drohan, and Margaret C. Brittingham, "Linear Infrastructure Drives Habitat Conversion and Forest Fragmentation Associated with Marcellus Shale Gas Development in a Forested Landscape," *Journal of Environmental Management* 197 (2017): 167–76, https://doi.org/10.1016/j.jenvman.2017.03.045.
[1645] Season S. Chen et al., "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 (2017): 1419–26, https://doi.org/10.1016/j.scitotenv.2016.11.141.

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."[1646]

- 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.[1647]

- 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."[1648]

- November 23, 2015 – Gas-related impacts on Pennsylvania farmers may include pipelines crisscrossing 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-

[1646] Seth B. C. Shonkoff, William T. Stringfellow, and Jeremy K. Domen, "Hazard Assessment of Chemical Additives Used in Oil Fields That Reuse Produced Water for Agricultural Irrigation, Livestock Watering, and Groundwater Recharge in The San Joaquin Valley of California: Preliminary Results," Technical Report (PSE Healthy Energy, September 2016), https://www.psehealthyenergy.org/wp-content/uploads/2017/04/Preliminary_Results_13267_Disclosures_FINAL-1.pdf.
[1647] Molly C. McLaughlin, Thomas Borch, and Jens Blotevogel, "Spills of Hydraulic Fracturing Chemicals on Agricultural Topsoil: Biodegradation, Sorption, and Co-Contaminant Interactions," *Environmental Science & Technology* 50, no. 11 (2016): 6071–78, https://doi.org/10.1021/acs.est.6b00240.
[1648] John Parnell et al., "Selenium Enrichment in Carboniferous Shales, Britain and Ireland: Problem or Opportunity for Shale Gas Extraction?," *Applied Geochemistry* 66 (2016): 82–87, https://doi.org/10.1016/j.apgeochem.2015.12.008.

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."[1649]

- October 25, 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 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.[1650]

- 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.[1651] 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.[1652]) Broader testing requirements involving chemicals covered under California's new fracking disclosure regulations went into effect June 15, 2015.[1653]

- 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

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[1649] Potter County Today, "Shale Gas Impact on Agriculture 'Profound,'" November 23, 2015, https://web.archive.org/web/20151206011350/http://today.pottercountypa.net/shale-gas-impact-on-agriculture-profound/.
[1650] J. Flesher, "Fatal Flow: Brine from Oil, Gas Drilling Fouls Land, Kills Wildlife at Alarming Rate," *The Dallas Morning News*, October 25, 2015, sec. News, https://www.dallasnews.com/news/2015/10/25/fatal-flow-brine-from-oil-gas-drilling-fouls-land-kills-wildlife-at-alarming-rate/.
[1651] Julie Cart, "Central Valley's Growing Concern: Crops Raised with Oil Field Water," *Los Angeles Times*, May 2, 2015, sec. California, https://www.latimes.com/local/california/la-me-drought-oil-water-20150503-story.html.
[1652] Amec Foster Wheeler Environment & Infrastructure, Inc., "Reclaimed Water Impoundments Sampling, Cawelo Water District Ponds, Kern River Oil Field, Kern County, California, Prepared for Chevron U.S.A. Inc.," Technical Report, June 15, 2015.
[1653] Daniel Ross, "Has Our Food Been Contaminated by Chevron's Wastewater?," *Truthout*, June 19, 2015, sec. Environment, https://truthout.org/articles/has-our-food-been-contaminated-by-chevron-s-wastewater/.

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."[1654]

- 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.[1655]

- 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.[1656]

- 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.[1657]

- 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.[1658]

[1654] B. W. Allred et al., "Ecosystem Services Lost to Oil and Gas in North America," *Science* 348, no. 6233 (2015): 401–2, https://doi.org/10.1126/science.aaa4785.
[1655] Tamera J. Minnick and Richard D. Alward, "Plant–Soil Feedbacks and the Partial Recovery of Soil Spatial Patterns on Abandoned Well Pads in a Sagebrush Shrubland," *Ecological Applications* 25, no. 1 (2015): 3–10, https://doi.org/10.1890/13-1698.1.
[1656] Sandy Dechert, "Fracking Wastewater Spoils California Drinking, Farm Supplies," CleanTechnica, October 14, 2014, https://cleantechnica.com/2014/10/14/fracking-wastewater-spoils-california-drinking-farm-supplies/.
[1657] Laura Gottesdiener, "In Shadow of Oil Boom, North Dakota Farmers Fight Contamination," *Al Jazeera America*, September 6, 2014, http://america.aljazeera.com/articles/2014/9/6/north-dakota-wastewaterlegacy.html.
[1658] Don Hopey, "State: Fracking Waste Tainted Groundwater, Soil at Three Washington County Sites," *Pittsburgh Post-Gazette*, August 6, 2014, https://www.post-gazette.com/local/washington/2014/08/06/Pa-finds-tainted-water-soil-at-three-Washington-County-shale-sites/stories/201408050198.

- 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 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.[1659]

- 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.[1660]

- May 3, 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."[1661]

- 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.[1662]

- 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.[1663] 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

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[1659] Michelle Bamberger and Robert Oswald, *The Real Cost Of Fracking: How America's Shale Gas Boom Is Threatening Our Families, Pets, and Food* (Beacon Press, 2015).
[1660] Kim Passoth, "Major Oil Field Spill in Kingfisher Co.," *KOCO News 5 ABC*, August 2, 2014, sec. News, https://www.koco.com/article/major-oil-field-spill-in-kingfisher-co/4299547.
[1661] Bruce Finley, "Colorado Faces Oil Boom 'Death Sentence' for Soil, Eyes Microbe Fix," *The Denver Post*, May 3, 2014, https://www.denverpost.com/2014/05/03/colorado-faces-oil-boom-death-sentence-for-soil-eyes-microbe-fix/.
[1662] Elizabeth Royte, "Fracking Our Food Supply," *The Nation*, November 28, 2012, https://www.thenation.com/article/archive/fracking-our-food-supply/.
[1663] Michelle Bamberger and Robert E. Oswald, "Impacts of Gas Drilling on Human and Animal Health," *New Solutions: A Journal of Environmental and Occupational Health Policy* 22, no. 1 (2012): 51–77, https://doi.org/10.2190/NS.22.1.e.

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.[1664]

- 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.[1665]

- 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."[1666]

- 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.[1667]

[1664] Krishna Ramanujan, "Study Suggests Hydrofracking Is Killing Farm Animals, Pets," *Cornell Chronicle*, March 7, 2012, https://news.cornell.edu/stories/2012/03/reproductive-problems-death-animals-exposed-fracking.
[1665] Mary Beth Adams et al., "Effects of Development of a Natural Gas Well and Associated Pipeline on the Natural and Scientific Resources of the Fernow Experimental Forest," General Technical (U.S. Department of Agriculture, January 2011), https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf.
[1666] Susan Phillips, "Burning Questions: Quarantined Cows Give Birth to Dead Calves," *State Impact Pennsylvania*, September 27, 2011, https://stateimpact.npr.org/pennsylvania/2011/09/27/burning-questions-quarantined-cows-give-birth-to-dead-calves/.
[1667] Penn State Extension, "Pennsylvania Dairy Farms and Marcellus Shale, 2007-2010," *Penn State Extension*, March 2010, https://extension.psu.edu/pennsylvania-dairy-farms-and-marcellus-shale-2007-2010.

- 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 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*.[1668, 1669]

- 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.[1670]

[1668] KSLA, "Cows in Caddo Parish Fall Dead near Gas Well," *KSLA News*, April 29, 2009, https://www.ksla.com/story/10268585/cows-in-caddo-parish-fall-dead-near-gas-well/.
[1669] Mark Schleifstein, "Haynesville Natural Gas Field Is the Most Productive in the U.S.," *The New Orleans Advocate*, March 27, 2011, https://www.nola.com/news/politics/article_fbdcb467-382d-52a8-90e7-7dc667edecb4.html.
[1670] Spencer H. Davis Jr., "The Effect of Natural Gas on Trees and Other Vegetation," *Journal of Arboriculture* 3, no. 8 (1977): 153–54.

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 are omnipresent, much higher than previously supposed, and a main driver of rising methane emissions in the United States. The science is settled on these facts.

A significant proportion of fracking-related methane 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. Storage tanks, compressor stations, and unlit flare stacks are emerging as significant sources of methane emissions, according to studies published in both Canada and the United States. The problem of methane leakage appears to be getting worse rather than better with newer fracking sites in the Permian Basin leaking more methane than older sites. A 2018 analysis of methane emissions from the U.S. oil and gas supply chain found leakage rates 60 percent higher than reported by the U.S. Environmental Protection Agency (EPA). A 2023 analysis using both satellite and surface observations found leakage rates 70 percent higher than EPA estimates. 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, which underwent its own surge in activity during the same time period.

Several lines of evidence point to the important role of drilling and fracking operations 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. shale gas and oil boom; and documentation of large pulses of methane released from storage facilities and other "super-emitting" sites. Reducing atmospheric methane is key to reducing the rate of global warming and limiting temperature rise to 1.5 º C according to a 2021 assessment from the United Nations, which identified the fossil fuel industry as the sector with the greatest potential to cut methane emissions rapidly.

The widely touted claim that the U.S. shale gas and oil boom has contributed to recent declines in carbon dioxide emissions in the United States has been invalidated by research showing that

almost all 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, which enables the extraction of oil and gas from shale, is a major driver of rising methane emissions, is incompatible with climate stability, and stands as an obstacle to rapid decarbonization that the goal of climate stability requires.

- May 19, 2023 – The Paris Agreement has set 1.5ºC as the limit for global warming. This goal cannot be reached without slashing methane emissions by at least 40-45 percent by 2030 when compared with 2020 levels. Currently, methane emissions are underregulated, but also the effectiveness of the regulatory practices in place are not well understood. A first-ever global review of the 281 existing methane mitigation measures across energy, waste, and agricultural sectors around the world found that only 13 percent of methane emissions are covered by existing policies and that these are not uniformly distributed across all sources. For example, of the 110 methane mitigation policies covering methane emissions from fossil fuels that were identified in this review, only six targeted downstream and end-use emission with the vast majority focused on extraction, gathering, and distribution. Only three policies aimed to reduce methane emissions from abandoned and inactive wells via identifying and repairing failing plugs. The researchers also found that fossil fuel policies, which rely more on financial incentives, are less stringent than those governing methane emissions from livestock and waste. "Methane reduction is still perceived as a choice rather than a necessity complementing the ongoing decarbonization efforts focused largely on CO2." Further, because most methane reduction policies are based on estimates rather than direct measures of methane, their effectiveness is unclear.[1671]

- April 17, 2023 – The United States is the leading methane emitter in the world, contributing 15 percent of the world's gas- and oil-derived methane emissions. An international team of researchers using satellite observations and surface observations to quantify temporal trends in U.S. emissions from the oil and gas industry found a significant underestimation in the national inventory of oil and gas methane emissions. In the United States, emissions from 2010-2019 were 70 percent higher than the estimates reported by the U.S. Environmental Protection Agency. In general, methane emissions rose and fell during this decade in ways that tracked production rates, active well counts, and new wells drilled in three major U.S. shale regions, demonstrating that drilling and fracking activities are a main driver of methane emissions in the United States. U.S. methane emissions rose between 2010-2014, decreased from 2014-2017, and then rose again after 2017. The 2014-2017 decline corresponds to a reduction in new wells drilled during that period and new regulations requiring the capture of gas from the completion-

[1671] Maria Olczak, Andris Piebalgs, and Paul Balcombe, "A Global Review of Methane Policies Reveals That Only 13% of Emissions Are Covered with Unclear Effectiveness," *One Earth* 6, no. 5 (May 2023): 519–35, https://doi.org/10.1016/j.oneear.2023.04.009.

venting step of hydraulic fracturing. The 2017-2019 surge was accompanied by an upswing in oil and gas extraction activities during that period.[1672]

- January 31, 2023 – Using aerial remote sensing data from four surveys plus activity data on oil and gas production, a research team quantified methane emission intensity from oil and gas operators in the Permian basin and made comparisons among them. The results showed a wide range of emission intensities during several periods of time. Half of all operators showed improvements over time with a 50 percent reduction in super-emitter intensity between 2019 and 2021. The authors note that they did not consider the significant emissions from the midstream sector (for example, pipelines and compressor stations).[1673]

- December 22, 2022 – The U.K.'s National Atmospheric Emissions Inventory (NAEI) reports greenhouse gas emissions from the United Kingdom to the United Nations. A critical evaluation of the methods used to collect data for this inventory demonstrated that it significantly underestimates methane from the extraction and transport of oil and natural gas. The U.K. inventory relies on direct, surface-level measurements of leaks. A reassessment using an integrated approach that combines direct measurements with airborne monitoring and published data estimates the U.K.'s 2019 methane emissions at five times the NAEI estimate. The authors call for funding of efforts to improve the detection of methane leakage via remote sensing.[1674]

- November 5, 2022 – A study using optical gas imaging cameras to measure fugitive and vented methane leaks at fifteen shale gas well pads in West Virginia found that pneumatic devices and liquid storage tanks had the highest leak rates, with twelve of the fifteen sites showing tank-related leaks. While reporting data and permits assume 100 percent capture efficiency for storage tanks, the researchers estimated that their real-life capture efficiencies ranged from 63 - 92 percent.[1675]

- September 30, 2022 – A commentary on recent findings on gas flaring [see entry below] noted that most oil and gas extraction operations provide no direct tracking of their methane removal efficiency of their flares—nor even report their operational status. Further, flares are often used for a variety of reasons unrelated to emergencies and safety precautions, which are their intended purpose. The authors called for improved monitoring and better models to guide improvements in flare design and operation. "Together, satellites, surface sensors, and models can provide more accurate assessments

[1672] Xiao Lu et al., "Observation-Derived 2010-2019 Trends in Methane Emissions and Intensities from US Oil and Gas Fields Tied to Activity Metrics," *Proceedings of the National Academy of Sciences* 120, no. 17 (April 25, 2023): e2217900120, https://doi.org/10.1073/pnas.2217900120.
[1673] Benjamin Hmiel et al., "Empirical Quantification of Methane Emission Intensity from Oil and Gas Producers in the Permian Basin," *Environmental Research Letters* 18, no. 2 (February 1, 2023): 024029, https://doi.org/10.1088/1748-9326/acb27e.
[1674] Stuart N. Riddick and Denise L. Mauzerall, "Likely Substantial Underestimation of Reported Methane Emissions from United Kingdom Upstream Oil and Gas Activities," *Energy & Environmental Science*, 2023, 10.1039.D2EE03072A, https://doi.org/10.1039/D2EE03072A.
[1675] Derek Johnson et al., "Methane Emissions from Oil and Gas Production Sites and Their Storage Tanks in West Virginia," *Atmospheric Environment: X* 16 (December 2022): 100193, https://doi.org/10.1016/j.aeaoa.2022.100193.

of the role that improved flaring efficiency plays in overall oil and gas emissions and future mitigation efforts…. As the global climate crisis continues to worsen, resolving the flaring problem in this decisive decade is among the easiest routes to help mitigate the problem."[1676]

- September 29, 2022 – Unlit flares and inefficient gas flaring are responsible for a fivefold increase in methane emissions above present assumptions and, taken together, constitute 4 to 10 percent of total U.S. oil and gas methane emissions, according to an observational study that used airborne sampling of 300 different flares to calculate flare efficiency in the Permian, Bakken, and Eagle Ford shale basins. The findings of this study showed that flaring by U.S. oil and gas operations destroyed, on average, only 87-94 percent of the methane that it attempted to combust. The widely presumed efficiency of flaring is 98 percent. At the same time, unlit flares—most often the result of flames extinguishing or never igniting in the first place—directly release plumes of unburned gas to the atmosphere and erode efficiency further. By both pathways, inefficient and unlit natural gas flares are responsible for releasing into the atmosphere a quantity of methane that is five times higher than amounts previously assumed in the EPA greenhouse gas inventory. Addressing unlit flares presents a simple and cost-effective methane mitigation opportunity.[1677]

- September 13, 2022 – A study using a tiered observing system of airborne imaging spectrometers identified point sources of methane emissions in five intensely fracked regions the United States: the San Joaquin Valley in California; the Uinta Basin in Utah; the Denver-Julesburg and Permian Basins in Texas and New Mexico; and the Marcellus Basin in Appalachia. By measuring the fluctuations in emissions across time and comparing these point source emissions to the fluxes in methane emissions across the entire basins, the researchers determined that point sources make up, on average, 40 percent of the regional flux. In other words, a proportionally few methane super-emitters contribute a disproportionate fraction of total emissions across multiple shale basins in the United States. "These results show that a significant climate benefit can be realized by specific isolation and remediation of relatively few sources."[1678]

- March 23, 2022 – A Stanford University study that combined aerial data with surface-level measurements calculated methane emissions at 9.4 percent of gas production in New Mexico's portion of the intensely fracked Permian Basin, one of the most active oil producing regions in the world. This leakage rate is 6.7 times higher than the EPA's estimate of 1.4 percent. "The clear impact of large emissions found by this study suggests

[1676] Riley Duren and Deborah Gordon, "Tackling Unlit and Inefficient Gas Flaring," *Science* 377, no. 6614 (September 30, 2022): 1486–87, https://doi.org/10.1126/science.ade2315.
[1677] Genevieve Plant et al., "Inefficient and Unlit Natural Gas Flares Both Emit Large Quantities of Methane," *Science* 377, no. 6614 (September 30, 2022): 1566–71, https://doi.org/10.1126/science.abq0385.
[1678] Daniel H. Cusworth et al., "Strong Methane Point Sources Contribute a Disproportionate Fraction of Total Emissions across Multiple Basins in the United States," *Proceedings of the National Academy of Sciences* 119, no. 38 (September 20, 2022): e2202338119, https://doi.org/10.1073/pnas.2202338119.

that estimates from ground-based methane surveys may be underestimating total emissions by missing low-frequency, high-impact large emissions."[1679]

- February 1, 2022 – The west coast of Turkmenistan on the shore of the Caspian Sea is one of the world's largest methane hotspots. A research team combined three sets of satellite data to evaluate individual methane emission sources in this area. Between January 2017 and November 2020, the team identified 29 super-emitters. All 29 of them were point sources linked to oil extraction activities, with 24 of 29 representing unlit flares venting unburned methane. Two other sources represent pipeline leaks. The three other remaining emission points are from unknown sources. Identifying and remediating high-emitting sources are fundamental in short-term mitigation.[1680]

- November 16, 2021 – Using multi-year observations and atmospheric modeling, a study of the intensely drilled and fracked Uinta Basin in northern Utah found that 6 to 8 percent of the total gas extracted escaped as atmospheric emissions. This leakage rate, among the highest in the United States, remained constant between 2015 and 2020, even as gas production in the region declined over the same period.[1681]

- August 5, 2021 – A study using a new bottom-up emissions estimation tool that is on a comprehensive database of leakage from different oil and gas production components found that liquid storage tanks are much larger emitters of methane than previous appreciated. These results help explain the disparity between field measurements of methane emissions and official greenhouse gas inventory estimates generated by the EPA.[1682]

- July 12, 2021 – Combining two different methods of measurement, Canadian researchers found that methane emissions from oil and gas extraction operations in British Columbia are 1.6 to 2.2 times higher than estimated by Canada's current federal inventory. Their results showed that more than half of emissions could be attributed to three main sources: tanks (24 percent); compressors (15 percent); and unlit flares (13 percent). The researchers wrote, "In particular, tank emissions appear much more important than current inventories suggest and unlit flares are a second important gap, bolstering observations from recent helicopter measurements in the Permian basin." This new combined-measurement approach, which matched optical gas imaging (OGI) cameras on the ground with aerial surveys, greatly improved accuracies in sites where OGI surveys alone are unreliable. Total emissions measured by the aerial survey were 18 times higher

[1679] Yuanlei Chen et al., "Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey," *Environmental Science & Technology*, March 23, 2022, acs.est.1c06458, https://doi.org/10.1021/acs.est.1c06458.
[1680] Itziar Irakulis-Loitxate et al., "Satellites Detect Abatable Super-Emissions in One of the World's Largest Methane Hotspot Regions," *Environmental Science & Technology* 56, no. 4 (February 15, 2022): 2143–52, https://doi.org/10.1021/acs.est.1c04873.
[1681] John C. Lin et al., "Declining Methane Emissions and Steady, High Leakage Rates Observed over Multiple Years in a Western US Oil/Gas Production Basin," *Nature Scientific Reports* 11, no. 1 (2021): 22291, https://doi.org/10.1038/s41598-021-01721-5.
[1682] Jeffrey S. Rutherford et al., "Closing the Methane Gap in US Oil and Natural Gas Production Emissions Inventories," *Nature Communications* 12, no. 1 (2021): 4715, https://doi.org/10.1038/s41467-021-25017-4.

than those recorded by the OGI cameras. In the case of leaking tanks, for example, disparities between ground and aerial measurements of methane emission rates differ by a factor of more than 40: whereas the ground survey mean rate, as estimated by OGI, was 1.3 kg/h, the rate estimated by aerial surveys was 48.3 kg/h. Further, methane emissions from unlit flairs are inherently difficult to capture by OGI camera, and this study's aerial measurements showed that they were a significant contributor to methane emissions. Similarly, the study found that "unburned methane entrained in natural gas engine-driven compressor exhaust," also not easily measurable with OGI, is responsible for much of the total emissions at compressor stations. Conversely, the aerial survey identified 10-fold fewer total sources of emissions than did OGI, suggesting that the two methodologies are prone to different types of inaccuracies in data collection. The research team concluded that "policy and regulations that rely on OGI surveys alone risk missing a significant portion of total emissions."[1683]

- June 30, 2021 – The Permian Basin is now the largest oil and gas-producing basin in the United States. Using high-resolution satellite measurements collected over several days, an international team of researchers identified 37 different "extreme" methane plumes (that is, those emitting more than 500 kg of methane per hour) and attributed them to specific types of infrastructure. The results showed that newer facilities—those starting production in 2018 or later—contributed more extreme emissions than older facilities. Specifically, extreme emissions occurred 2.6 times more frequently for new facilities than old, and the amount of methane emitted by new facilities is twice that of older facilities. "This result supports the speculation that recently developed wells and infrastructure associated with these wells are the major methane emitters in the Permian basin, which is likely due to a faster development of gas extraction methods than of storage and processing capabilities." The results showed that fully half of all methane emissions originated from compressor stations, 24 percent from tank batteries, 21 percent from flaring, and 6 percent from wells themselves. The high proportion of emissions (21 percent in terms of both number of plumes and amount of methane emitted) that come from flare stacks was a surprising discovery. "Such high emission rates can only be explained by inefficient or malfunctioning flaring operations…. Our results suggest that the rapid installation of new O&G production facilities in the Permian basin might not be counterbalanced by sufficient parallel development of gas gathering and processing infrastructure, which would lead to a high concentration of extreme emissions in the region due to issues such as unlit associated gas flares."[1684]

- June 24, 2021 – At least 123 oil and gas sites in Austria, Czech Republic, Germany, Hungary, Italy, Poland and Romania emit methane, according to data released by the international nonprofit organization Clean Air Task Force (CATF) and reported by Reuters. At the time of reporting, the European Union did not regulate methane leaks and vents to the atmosphere and reporting requirements were limited to only some of the

[1683] David R. Tyner and Matthew R. Johnson, "Where the Methane Is: Insights from Novel Airborne LiDAR Measurements Combined with Ground Survey Data," *Environmental Science & Technology* 55 (2021): 9773–83, https://doi.org/10.1021/acs.est.1c01572.
[1684] Itziar Irakulis-Loitxate et al., "Satellite-Based Survey of Extreme Methane Emissions in the Permian Basin," *Science Advances* 7, no. 27 (2021): eabf4507, https://doi.org/10.1126/sciadv.abf4507.

individual nation states. Hence, no laws were broken by companies responsible for these emissions. According to James Turitto, who filmed the emissions for CATF, 90 percent of the sites visited in the Czech Republic, Hungary, Italy, Poland, and Romania were emitting methane, while the frequency of leaking sites in Germany and Austria was lower. Using independent experts to review a selection of the CATF infrared thermography, Reuters reported that a significant proportion of these emissions was avoidable with commercially available measurement and abatement technology. While the omnipresence of leaks in Europe's gas system currently resembles that of the United States, said Reuters, proposed EU restrictions on venting and flaring methane have put energy companies on notice. These rules will not go into force until 2023 or thereafter.[1685]

- June 15, 2021 – Newly launched and soon to be deployed satellites will continue to sharpen identification of methane leaks from oil and gas operations, filling gaps left by ground-based sensors and aerial surveys, according to an analysis by *Yale Environment 360*. While earlier generations of satellites were consistently unable to link specific sources with emissions data, newer satellites have been able, despite the pandemic, to match recent rises in methane releases to their origins in Russia, Turkmenistan, and Canada.[1686]

- June 2, 2021 – A report funded by Bank of America and developed by the energy consultancy M.J. Bradley & Associates—in collaboration with the non-profit organizations Ceres and the Clean Air Task Force—looked at the relationship between methane emissions and oil and gas extraction volumes. An analysis of 295 oil and gas producers that report data to the EPA under its Greenhouse Gas Reporting Program showed that the magnitude of methane emissions was not a function of a company's production levels.[1687] Indeed, the largest methane emitter in the United States, Hilcorp Energy, emitted 50 percent more methane from its operations than did Exxon Mobil, even though Hilcorp pumps far less oil and gas. Four other relatively unknown companies—Terra Energy Partners, Flywheel Energy, Blackbeard Operating and Scout Energy—each self-reported more methane emissions than many top producers. As further described in reporting by the *New York Times* small, privately held drilling companies that are buying up high-polluting assets from larger companies are rapidly becoming the nation's highest emitters of methane and other greenhouse gases. In this way, oil and gas majors are able to remove highly leaky facilities from their books. "Hilcorp's methane

[1685] Kate Abnett and Shadia Nasralla, "EXCLUSIVE: Gas Infrastructure Across Europe Leaking Planet-Alarming Methane," Reuters, June 24, 2021, https://www.reuters.com/business/environment/exclusive-gas-infrastructure-across-europe-leaking-planet-warming-methane-video-2021-06-24/.
[1686] Cheryl Katz, "In Push to Find Methane Leaks, Satellites Gear Up for the Hunt," Yale Environment 360, June 15, 2021, https://e360.yale.edu/features/in-push-to-find-methane-leaks-satellites-gear-up-for-the-hunt.
[1687] Robert LaCount et al., "Benchmarking Methane and Other GHG Emissions of Oil & Natural Gas Production in the United States" (M.J. Bradley & Associates, June 2021), https://www.mjbradley.com/sites/default/files/OilandGas_BenchmarkingReport_2021.pdf.

emissions intensity, or leak rate, was almost six times higher than the average of the top 30 producers, largely caused by high emissions from its aging San Juan operations."[1688]

- June 1, 2021 – After a brief pandemic-related drop, fracking activities in the Permian Basin in West Texas once again rebounded and now represent the number one source of methane emissions in the United States. Continued expansion of these operations threatens "any credible US response to the climate crisis," according to investigative reporter Rebecca Leber, who described several formidable obstacles to reining in this "ticking time bomb." Sited on land entirely state-owned or privately held, Permian Basin fracking operations are not governed by future regulations that might restrict new federal leasing. Further, economic incentives do not constrain methane emissions. Permian producers, for whom oil brings a bigger profit, largely consider natural gas a waste product and, hence, intentionally release methane via unlit or burning flares in the absence of any state-based regulation. Leber notes that the EPA could be authorized to intervene but has limited resources for doing so. Another strategy, which goes beyond limiting emissions to addressing production, seeks to interrupt industry's export plans, on which the industry is relying in light of US market "saturation." Declaring a climate emergency, Leber wrote, may be the federal administration's only option to "cut off producers from their global customers" if Congress does not enact appropriate climate measures. "There is a narrow pathway to do this. In 2015, Congress lifted a crude-oil export ban but kept a 'get-out' clause. It allows a president to suspend these exports by declaring a national emergency. Other kinds of exports, like liquefied natural gas, would require permitting from FERC, an independent energy regulatory agency, and the Department of Energy."[1689]

- May 27, 2021 – Episodic releases of methane from various types of fracking infrastructure create monitoring challenges. Researchers investigated the potential impact of variations over time in emissions from known "super-emitter" sites by performing 17 methane audits at one such natural gas extraction site over a four-year time period, from 2016 to 2020. Results revealed high temporal variability, with minimum and maximum levels varying by a factor of 560. These results suggest that substantial methane emissions may go undetected by infrequent audits. "These data highlight that single snapshots in time from direct methane quantification audits could significantly overpredict or underpredict methane emissions on an annual basis." The results also highlighted the importance of storage tanks as a potential source of methane emissions. At this super-emitting facility, tank emissions represented the majority of emissions for eight audits (54.7−99.7 percent by mass) and overall represented 91 percent of all measured methane emissions.[1690]

[1688] Hiroko Tabuchi, "Here Are America's Top Methane Emitters. Some Will Surprise You," *The New York Times*, June 2, 2021, https://www.nytimes.com/2021/06/02/climate/biggest-methane-emitters.html?referringSource=articleShare.
[1689] Rebecca Leber, "There's a Ticking Climate Time Bomb in West Texas," *Vox*, June 1, 2021, https://www.vox.com/22407581/gas-texas-biden-climate-change-methane-permian-basin.
[1690] Derek Johnson and Robert Heltzel, "On the Long-Term Temporal Variations in Methane Emissions from an Unconventional Natural Gas Well Site," *ACS Omega* 6, no. 22 (2021): 14200–207, https://doi.org/10.1021/acsomega.1c00874.

- May 6, 2021 – Reducing atmospheric methane is key to reducing the rate of global warming and limiting temperature rise to 1.5º C, and the fossil fuel industry has the greatest potential to cut methane emissions rapidly, according to the latest United Nations assessment report. The assessment found the fossil fuel industry is responsible for 35 percent of human-caused emissions and identified "readily available targeted measures" that could reduce emissions 30 percent by 2030. The industry could implement up to 80 percent of these measures at negative or low cost. The report states that methane mitigation must take place even alongside decarbonization strategies, and that "expansion of natural gas infrastructure and usage is incompatible with keeping warming to 1.5° C." In addition to the climate-related urgency of reducing this powerful, short-lived climate pollutant, the report points to other reasons for global action on methane, including its contribution to the formation of ground-level ozone. The assessment "found that every million tonnes (Mt) of methane reduced prevents approximately 1,430 annual premature deaths due to ozone globally."[1691]

- May 4, 2021 – A U.S. team of researchers analyzed the climate benefits of rapidly reducing methane emissions across all known sectors, which would improve the ability to limit climate damages in the near term. Using a validated model for assessing greenhouse gas-induced climate change, they found that pursuing all known mitigation measures now could slow the global-mean rate of near-term warming by around 30 percent within the decade and so avoid a quarter of a degree centigrade of additional warming by midcentury. Such an approach would create a path that could prevent a rise in mean global temperatures that would exceed more than half a degree centigrade by end of this century. Conversely, a slow implementation of measures to limit methane may well result in an additional tenth of a degree of warming by midcentury and a five percent faster warming rate when compared to rapid action. Waiting to pursue these measures until midcentury may result in an additional two tenths of a degree centigrade by midcentury and 15 percent faster warming rate. The researchers also note that existing mitigation measures across all sectors (rice, livestock, oil and gas, coal mining, landfills, wastewater), if deployed now, could cut expected 2030 methane emissions in half, with a quarter of these at no net cost. "We find that full deployment of these available mitigation measures by 2030 can slow the rate of global-mean warming over the next few decades by more than 25 percent."[1692]

- April 30, 2021 – In response to announced plans by the Mexican government to reduce oil and gas related methane emissions in the country by 40-45 percent by year 2025 (relative to 2012 levels), a research team used satellite imagery of areas overlying onshore and offshore oil and gas facilities in eastern Mexico to quantify the current magnitude of emissions and better understand the location of their key sources. Data

[1691] United Nations Environment Programme and Climate and Clean Air Coalition, "Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions" (United Nations Environment Programme, May 2021), https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions.
[1692] Ilissa B. Ocko et al., "Acting Rapidly to Deploy Readily Available Methane Mitigation Measures by Sector Can Immediately Slow Global Warming," *Environmental Research Letters* 16, no. 5 (2021): 054042, https://doi.org/10.1088/1748-9326/abf9c8.

showed substantial methane concentrations along the eastern coastal areas and in Mexico City, with enhanced concentrations of nitrous oxide, attributable to gas flaring, also observed over both onshore and offshore production areas. Estimates of methane emissions from satellite data were nearly double those estimated by ground-based, facilities-level emission inventories. The research team calculated an overall methane loss rate of 4.7 percent for oil and gas extraction operations in eastern Mexico (as compared to a 3.7 percent loss rate in the Texas Permian basin gas and oil fields). High loss rates reveal that Mexico's oil and gas basins have "strong mitigation potential," especially at production sites and processing plants.[1693]

- April 24, 2021 – Reducing methane emissions is required to ward off the worst effects of climate change, according to a *New York Times* review of a forthcoming UN report (see May 6, 2021 entry above). According to the summary obtained by the *Times* in advance, the report will single out the fossil fuel industry as the sector which can make the easiest cuts to methane emissions, at little or no cost. The report will also state that expanding the use of natural gas is very likely incompatible with keeping global warming to 1.5° C.[1694]

- March 22, 2021 – Using satellite observations of atmospheric methane across the entire United States and Mexico, an international team discovered that anthropogenic (human-caused) emissions increased between 2010-2015, rather than decreased, as had been estimated by the EPA. For the oil and gas sector, measured methane emissions were almost twice the level estimated by the EPA's greenhouse gas inventory, with the increase largely driven by the rapid growth of fracking operations in the eastern United States. Emissions from oil and gas production facilities in Mexico were also higher than in the nationally reported inventory. The discrepancies between satellite-generated estimates in this study and the national inventories are likely due to an undercount of all potential sources of emissions and high variability of leakage rates within those sources.[1695] The EPA calculates total emissions by estimating methane leaks from specific types of processes and equipment and then extrapolating, based on the numbers of pieces of that kind of equipment operating across the country. This method, noted lead author Joannes Maasakkers, "makes it really hard to get estimates for individual facilities because it is hard to take into account every possible source of emission." Maasakkers also emphasized that "we shouldn't wait until we fully understand these emissions to start trying to reduce them."[1696]

- January 26, 2021 – Combining satellite data with estimates of methane emissions as determined by aircraft-based measurements above onshore and offshore facilities in

[1693] Lu Shen et al., "Unravelling a Large Methane Emission Discrepancy in Mexico Using Satellite Observations," *Remote Sensing of the Environment* 260 (2021), https://doi.org/10.1016/j.rse.2021.112461.
[1694] Hiroko Tabuchi, "Halting the Vast Release of Methane Is Critical for Climate, U.N. Says," *New York Times*, April 24, 2021, https://www.nytimes.com/2021/04/24/climate/methane-leaks-united-nations.html.
[1695] Joannes D. Maasakkers et al., "2010–2015 North American Methane Emissions, Sectoral Contributions, and Trends: A High-Resolution Inversion of GOSAT Observations of Atmospheric Methane," *Atmospheric Chemistry and Physics* 21 (2021): 4339–56.
[1696] Leah Burrows, "Oil and Natural Gas Production Emit More Methane than Previously Thought," Phys.org, March 26, 2021, https://phys.org/news/2021-03-oil-natural-gas-production-emit.html.

Mexico, an international research team calculated methane leakage rates and compared these findings with estimates from Mexico's national greenhouse gas inventory. Estimates of offshore emissions were an order of magnitude lower than the official inventory estimate, but onshore emission estimates were more than an order of magnitude higher. The results showed that a large proportion of emissions is attributable to flaring. One single facility—an onshore gas-processing complex that receives offshore gas—was responsible for greater emissions than the entirety of the largest offshore production region, "suggesting that offshore-produced associated gas is being transported onshore where it is burned and in the process some released to the atmosphere." The majority of those emissions are from flaring and represents "a substantial waste of gas, enough to cover half the natural gas consumption for the national residential section during 2018." The low combustion efficiency of gas flaring operations also makes them a locally important source of unhealthful air pollutants, including volatile organic compounds, polycyclic aromatic hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides, and soot. The researchers urge a greater reliance on empirically estimated methane emissions, along with more effective mitigation policies, especially when communities live in proximity to oil and gas production regions.[1697]

- December 15, 2020 – The U.S. natural gas supply chain is leaking substantially more methane than previously presumed, according to the nonprofit organization Global Energy Monitor's "Gas Index." Compiling data from dozens of studies that have measured methane emissions from all components of the U.S. natural gas system—from oil and gas extraction wells to urban distribution pipelines and within homes and businesses—this analysis calculated full life-cycle methane leakage for 71 U.S. cities. The results showed that, in all cases, methane leakage is more extensive across the system than in many earlier estimates, including the EPA's Greenhouse Gas Inventory, with some cities showing leakage rates over four times higher than EPA estimates. City-by-city results highlight where efforts to fix the gas system can be most effective and how cities can achieve large reductions in emissions by switching homes and other buildings from natural gas to electricity, especially for heating systems. "Electrifying building heating would lead to emissions reductions in many cases… replacing gas heaters with efficient electric heat pumps would lead to emissions cuts in every city evaluated." The ten cities with the leakiest gas supplies are Indianapolis, Los Angeles, Phoenix, Miami, Oklahoma City, Orlando, Boston, Little Rock, Reno, and Tampa.[1698]

- November 5, 2020 – Satellite maps compiled in 2014 revealed an anomalous methane hot spot over the intensely drilled and fracked San Juan Basin that straddles the Colorado and New Mexico border. As part of a follow-up study led by the University of Colorado and the National Oceanographic and Atmospheric Administration's Earth System Research Laboratory in Boulder, a research team investigated daily wind patterns in the region and collected both ground-based and airborne atmospheric data on levels of methane, ethane, and other light-chain carbon concentrations to identify and characterized the sources of the emissions. The results revealed that fossil fuel sources are collectively responsible for

[1697] Daniel Zavala-Araiza et al., "A Tale of Two Regions: Methane Emissions from Oil and Gas Production in Offshore/Onshore Mexico," *Environmental Research Letters* 16 (2021), https://doi.org/10.1088/1748-9326/abceeb.
[1698] Mason Inman, "The Gas Index" (Global Energy Monitor, December 15, 2020), https://thegasindex.org/.

the vast majority (72-85 percent) of the observed methane and ethane over the San Juan Basin, with emissions from coalbed methane and natural gas operations alone contributing 66-75 percent of the methane in the hot spot and with 75 percent of the detected methane originating from operations in New Mexico. Moreover, ground-based measurements and meteorological data illustrate that local methane sources are especially influencing surface air composition at night and in the early morning "when limited air circulation leads to the pooling of emissions near sources, especially in low elevation portions of the basin." While mean leakage rates appear to be comparable to other basins in the United States, emissions in some parts of the San Juan Basin are essentially trapped due to topography. Noting that the background air quality in and near Durango, Colorado is likely being harmed by emissions from oil and gas operations in the San Juan Basin, these researchers cite the need for "rapid and deep" mitigation, with "much bolder emission cuts necessitating substantial and industry transformations" in order to meet global climate goals.[1699]

- October 15, 2020 – A team led by University of Wyoming researchers determined that methane emissions from oil and gas well pads in the western Permian Basin are 5.5-9.0 times greater the EPA has estimated. Using a mobile laboratory that collects ground-level data, researchers obtained measurements of methane 40-200 meters downwind of 71 oil and gas facilities in the Permian Basin of western Texas and southeastern New Mexico. Methane emissions in the Permian Basin had not previously been studied in ground-based fashion, and most of the basin is difficult to study with aerial approaches. Detailed analysis of the data revealed differences between "simple" sites, with no or minimal processing equipment and storage of liquids on-site, and "complex" sites that stored and processed liquids at or near the well pad. The emission profile of the simple sites was distinct, with far more simple sites registering methane levels below detection thresholds. Disaggregating these two types of sites in the data analysis can lead to greater accuracy in evaluating the high end of the emission distribution where complex sites account for 91 percent of total emissions and also allows for more meaningful statistical analysis, with better fit of data in commonly used probability plots. Total estimated emission rates for the New Mexico portion of the Permian Basin, as calculated by these methods, ranged from approximately 520,000 to 610,000 tons per year.[1700]

- September 19, 2020 – Researchers at the California Air Resources Board developed and deployed a novel measurement system for mobile sampling of methane emissions with the intent of identifying and fixing unexpected fugitive leaks. Measurements from a highly instrumented sport utility vehicle (the Mobile Measurement Platform) correlated with and extended inventory-based estimates when used for monitoring emissions at 86 natural gas well pads, including 20 idle well pads. Within approximately 100 meters downwind of emission sources, the system was able to detect low-level emissions, making the system potentially much easier to use than Optical Gas Imaging cameras, which require close proximity to a source (approximately 3-10 meters) for detection of

[1699] Gabrielle Pétron et al., "Investigating Large Methane Enhancements in the U.S. San Juan Basin," *Elementa Science of the Anthropocene* 8 (2020), https://doi.org/10.1525/elementa.038.
[1700] Anna M. Robertson et al., "New Mexico Permian Basin Measured Well Pad Methane Emissions Are a Factor of 5−9 Times Higher Than U.S. EPA Estimates," *Environmental Science & Technology* 54 (2020): 13926–34.

methane at similar and lower levels. The mobile system documented a highly skewed distribution. For active well pads, the top 10 percent of leaking wells were responsible for 80 percent of total emissions, and the top 20 percent were responsible for roughly 90 percent of total emissions. Findings for the idle well pads showed a similar distribution pattern but at much smaller magnitudes. These results demonstrate that using a mobile measuring system as a screening tool may lead to real-time detections of previously overlooked sources of large, potentially avoidable emissions of methane and "suggest that controlling a small number of large emitters can significantly reduce methane emissions."[1701]

- July 21, 2020 – A lawsuit brought by 15 states, spearheaded by Massachusetts and New York, led to the release of email messages that documents a successful, coordinated effort by oil and gas industry leaders to compel the White House to cancel nationwide methane reporting requirements. The suit alleges that the EPA engineered the repeal of the requirements without any internal analysis, illegally delaying the development of additional regulations to reduce methane emissions.[1702]

- July 15, 2020 – Continuing a "living review" of global methane emissions, an interdisciplinary consortium of scientists working under the rubric of the Global Carbon Project conducted a three-year update of their meta-analysis of data relevant to the global methane cycle. These data were gleaned from hundreds of individual studies. Incorporating regional atmospheric measurements, they calculated global methane emissions at 576 teragrams per year (range of 550-594), with 60 percent of global methane emissions coming from anthropogenic sources of all kinds. According to their analysis, mean annual emissions continue to rise with oil and gas production accounting for approximately 35 percent (range 30-42 percent) of total global anthropogenic emissions.[1703]

- July 14, 2020 − Stanford-led researchers estimated methane emissions by combining "top down" measurements of atmospheric methane emissions with a "bottom up" analysis of comprehensive global inventories to attribute emissions by sector. ("Top down" methods involve using aircraft to measure methane levels over an entire region. "Bottom up" approaches measure methane emissions on the ground from a representative sample of equipment.) They concluded that methane emissions reached a record high in 2017, the last year for which complete data are available.[1704] "Throughout the study period, agriculture [primarily cattle and sheep ranching] accounted for roughly two-thirds of all methane emissions related to human activities; fossil fuels contributed most of the

[1701] Xiaochi Zhou et al., "Mobile Sampling of Methane Emissions from Natural Gas Well Pads in California," *Atmospheric Environment* 244 (2021), https://doi.org/10.1016/j.atmosenv.2020.117930.
[1702] Lisa Friedman, "New Emails Show How Energy Industry Moved Fast to Undo Curbs," *The New York Times*, July 21, 2020, https://www.nytimes.com/2020/07/21/climate/trump-methane-climate-change.html?smid=tw-share.
[1703] Marielle Saunois et al., "The Global Methane Budget 2000–2017," *Earth System Science Data* 12, no. 3 (2020): 1561–1623, https://doi.org/10.5194/essd-12-1561-2020.
[1704] R. B. Jackson et al., "Increasing Anthropogenic Methane Emissions Arise Equally From Agricultural and Fossil Fuel Sources," *Environmental Research Letters* 15, no. 7 (2020), https://doi.org/10.1088/1748-9326/ab9ed2.

remaining third. However, those two sources have contributed in roughly equal measure to the increases seen since the early 2000s."[1705]

- July 12, 2020 – An investigation by Hiroko Tabuchi of the *New York Times* revealed that many oil and gas companies were hurtling toward bankruptcy, potentially leaving wells untended and leaking planet-warming methane, with the costs of clean up left to local communities. Rystad Energy, an analytics company, noted that almost 250 oil and gas companies could file for bankruptcy protection by the end of next year, more than the previous five years combined. As these businesses collapse, millions of dollars often flow to executive compensation.[1706]

- June 9, 2020 – Methane leaking from its natural gas infrastructure is increasing Israel's overall greenhouse gas emissions by eight percent and is threatening its international climate change commitments. The estimation of methane leakage addressed "the entire chain of production and distribution of Israel's Tamar and Leviathan gas wells, up to its arrival at gas-fired power stations." The more comprehensive national estimate reflects emissions that are routinely neither measured nor reported. Israel reported 7,000 tons of methane to the UN Framework Convention on Climate Change in 2018, but the report calculated that the Tamar and Leviathan wells 372,672.2 tons.[1707]

- May 13, 2020 – Pennsylvania gas drillers released more than 1.1 million tons of methane into 2017, 16 times the amount they reported to the state, according to an online report building on an earlier, peer-reviewed study. (See June 21, 2018 entry.) The updated data showed that fugitive emissions from fracked wells alone totaled 543,000 tons for 2017, not the 70,150 tons reported to the state Department of Environmental Protection (DEP). A similar amount was calculated from older, conventionally drilled wells, data that is not collected by the state. The total is more than 15 times higher than what oil and gas companies reported.[1708]

- May 1, 2020 – A helicopter survey of the Permian Basin employing infrared cameras found that 1 in 10 flares burning at oil and gas sites was unlit or malfunctioning and

[1705] Stanford's School of Earth, Energy & Environmental Sciences, "Global Methane Emissions Soar to Record High, Even As Pandemic Has Reduced Carbon Emissions," *Sci Tech Daily*, July 14, 2020, https://scitechdaily.com/global-methane-emissions-soar-to-record-high-even-as-pandemic-has-reduced-carbon-emissions/.

[1706] Hiroko Tabuchi, "Fracking Firms Fail, Rewarding Executives and Raising Climate Fears," *The New York Times*, July 12, 2020, https://www.nytimes.com/2020/07/12/climate/oil-fracking-bankruptcy-methane-executive-pay.html#:~:text=Fracking%20Firms%20Fail%2C%20Rewarding%20Executives%20and%20Raising%20Climate, methane%20%28which%20is%20invisible%20to%20the%20naked%20eye%29.

[1707] Sue Surkes, "Methane From Natural Gas Boosts Annual Global Warming Gases by 8% – Study," *The Times of Israel*, June 9, 2020, https://www.timesofisrael.com/methane-from-natural-gas-boosts-annual-global-warming-gases-by-8-study/.

[1708] Don Hopey, "Methane Leaks Much Worse than Previously Thought, Study Says," *Pittsburgh Post-Gazette*, May 13, 2020, https://www.post-gazette.com/news/environment/2020/05/13/Methane-leaks-much-worse-than-previously-thought/stories/202005120163.

venting methane gas straight into the atmosphere. These unlit flares may be responsible for more than 10 percent of the Permian's overall methane emissions.[1709]

- April 22, 2020 – Satellite analysis from a Harvard-led study using high-resolution instrumentation showed that methane is leaking from Permian Basin wells into the atmosphere at a rate of 3.7 percent.[1710, 1711] This leakage rate is approximately 60 percent higher than the national leakage rate of 2.3 ± 0.3 percent, a discrepancy that the authors attribute to the practice of extensive venting and flaring in the Permian oil fields. The Delaware sub-basin, part of the larger Permian, demonstrated an even higher rate than the average for the Basin, at 4.1 percent. Authors wrote, "with the rescinding of U.S. federal requirements on gas capture and fugitive emissions in 2018, current regulations on O/G methane emissions in the Permian Basin are less stringent at both federal and state levels… All these factors may increase the incentive for operators to vent and flare their product."

- April 17, 2020 – In 2020, the U.S. EPA began collecting emissions estimates from individual pieces of equipment, walking back an Obama-era method of estimating emissions drawn from "gathering stations," facilities that transport and control the flow of natural gas to processing plants and transmission pipelines. The new method can omit very large intermittent emissions and emissions from super-emitting sites. Environmental analysts contend that the new method may under-report methane emissions by as much as 40 percent. The old method reported 2.2 million metric tons of methane emissions in 2017, whereas the new method measured only 1.3 million metric tons of leaking methane even though production had increased.[1712]

- April 13, 2020 – Using technology previously used to detect methane emissions from land-based fossil fuel development, researchers found an "effective loss rate" of 2.9 percent over offshore oil and gas platforms in the Gulf of Mexico.[1713] Authors wrote that onshore methane emissions are large and often underestimated, while offshore methane emissions have not been closely examined. Gulf of Mexico drilling represented three percent of U.S. gas production in 2017. The study findings suggest the federal government's calculations of such emissions are too low, and "analogous to the highest emitting onshore basins." Large shallow-water central hub facilities are particularly likely to be related to "disproportionately high emission events."

[1709] Rachel Adams-Heard and Akshat Rathi, "When Flames Go Out, the Permian's Methane Problem Worsens," *Houston Chronicle*, May 1, 2020, https://www.houstonchronicle.com/business/energy/article/When-the-Flames-Go-Out-the-Permian-s-Methane-15239528.php.

[1710] Yuzhong Zhang et al., "Quantifying Methane Emissions From the Largest Oil-Producing Basin in the United States From Space," *Science Advances* 6, no. 17 (2020): eaaz5120, https://doi.org/10.1126/sciadv.aaz5120.

[1711] Adam Vaughan, "Fracking Wells In the US Are Leaking Loads of Planet-Warming Methane," *New Scientist*, April 22, 2020, sec. Environment, https://www.newscientist.com/article/2241347-fracking-wells-in-the-us-are-leaking-loads-of-planet-warming-methane/.

[1712] Stephen Lee, "EPA Estimate Undercounts Methane Emissions: Environmentalists," *Bloomberg Law*, April 17, 2020, https://news.bloomberglaw.com/environment-and-energy/epa-approach-undercounts-methane-emissions-environmentalists.

[1713] Alan M. Gorchov Negron et al., "Airborne Assessment of Methane Emissions from Offshore Platforms in the U.S. Gulf of Mexico," *Environmental Science & Technology* 54 (2020): 5112–20, https://doi.org/10.1021/acs.est.0c00179.

- April 9, 2020 – Using Pennsylvania's unique quarterly mechanical inspection reports, researchers determined that methane emissions from abandoned and active wells were at least 15 percent higher than previously thought.[1714] The researchers used 589,175 operator reports on methane leaks from both fracked and conventional oil and gas wells in the state from 2014 to 2018. The rate of flow of escaping methane from fracked wells (18.5 percent) was great than that from conventional wells. Extrapolating these findings to the nation as a whole, where over three million wells are in operation, shows that methane escaping from oil and gas wells undermine efforts to address climate change. "Another 15 percent of methane going into the atmosphere that we didn't know about is very significant for climate change in the short term," professor emeritus of engineering at Cornell and the study's lead author Anthony Ingraffea told *Environmental Health News*.[1715]

- April 7, 2020 – The International Energy Agency (IEA) cautioned that a sharp decline in oil and gas revenues during the pandemic may lead some companies to cut expenses by failing to fix leaks in gas pipes or cut losses by increasing the venting and flaring of unwanted gas. If so, atmospheric methane emissions may increase during the pandemic even as demand for natural gas falls off. A *Scientific American* report documents exactly this. The composition of greenhouse gases changed markedly the early months of 2020 and included a 10 percent reduction in carbon dioxide and a 50 percent reduction in carbon monoxide, as measured in New York City in March 2020 by researchers at Columbia University. In contrast to the carbon dioxide declines, attributable to the temporary slowdown in transportation and other industries, methane levels did not fall. However, lack of reliable data from global oil and gas producers, make the understanding of these trends difficult.[1716]

- April 6, 2020 –Since 1983, the National Oceanic and Atmospheric Administration's (NOAA) has tracked atmospheric methane levels through a globally distributed network of air sampling sites. In 2019, its Trends in Atmospheric Methane data project documented a dramatic leap in airborne methane levels.[1717] This project does not distinguish between the various natural and human-generated sources. However, commenting on the data, climate scientist Drew Shindell said, "The easiest way to stem methane pollution… is to limit its release from oil and gas drilling sites…. You see the benefits in the first decade or two that you make cuts. You see fewer people dying from

[1714] Anthony R. Ingraffea et al., "Reported Methane Emissions from Active Oil and Gas Wells in Pennsylvania, 2014–2018," *Environmental Science & Technology* 54, no. 9 (2020): 5783–89, https://doi.org/10.1021/acs.est.0c00863.
[1715] Kristina Marusic, "Oil and Gas Methane Emissions in US Are at Least 15% Higher than We Thought," *Environmental Health News*, April 23, 2020, https://www.ehn.org/fracking-methane-leaks-2645817287.html?rebelltitem=2#rebelltitem2.
[1716] John Fialka, "As CO2 Emissions Drop During Pandemic, Methane May Rise," *Scientific American*, April 7, 2020, https://www.scientificamerican.com/article/as-co2-emissions-drop-during-pandemic-methane-may-rise/.
[1717] E. Roston and N. S. Malik, "Methane Emissions Hit a New Record and Scientists Can't Say Why," *Bloomberg Green*, April 6, 2020, https://www.bloomberg.com/news/articles/2020-04-06/methane-emissions-hit-a-new-record-and-scientists-can-t-say-why.

heat waves. You see less powerful storms and all of the stuff that comes from climate change."[1718]

- March 31, 2020 – Pointing toward its online "Methane Tracker" as a tool to encourage both governments and the oil and gas industry to make proactive changes to reduce the emission of methane and other global greenhouse gases, the IEA highlighted the importance of new measuring capabilities provided by satellite and aircraft and the cost-effectiveness of reducing leakage during periods of reduced gas prices. The IEA wrote that methane trends held more uncertainty than carbon dioxide trends, and that "a drop in methane emissions from oil and gas cannot be taken for granted, even if oil and gas consumption falls." It is possible that a decline in revenues from oil and gas operations would lead to less effort to decrease emissions, and that low gas prices may lead to increases in flaring or venting.[1719]

- March 30, 2020 – Using an innovative, off-site approach, researchers mounted methane-measuring equipment on a nearby, downwind tower just prior to unconventional well drilling and fracturing. They documented large, frequent spikes of methane escaping from the observed well site, especially during the vertical drilling phase (316 percent greater amplitude than baseline) and the hydraulic stimulation phase (509 percent greater amplitude than baseline). Measurements of carbon-13 isotopes confirmed that the source of the methane emissions was geological. The researcher recommends this approach for passive, offsite measurement of methane leaks that can enable researchers and community members to obtain a clearer picture of the time-course of emissions at particular sites.[1720]

- March 6, 2020 – An international team of researchers used isotopic analysis and a published data set to assess what proportion of the ongoing global surge in atmospheric methane emissions is attributable to oil and gas extraction, especially from shale, as opposed to other sources of atmospheric methane, such as wetlands and cattle. They concluded that methane from shale gas and conventional natural gas do not greatly differ in their carbon-13 composition, suggesting that the isotopic signal now observable in the atmosphere is not consistent with that from fossil fuel-derived methane. This assessment contests Cornell University researcher Robert Howarth's earlier attribution of increasing global methane emissions to North American fracking operations, which is premised on the existence of an isotopic difference between shale gas and conventional gas caused by fractionation as methane slowly migrates from inside shale formations to conventional gas reserves. (See entry for August 14, 2019.) The authors stress nonetheless that "oil and

[1718] Jeremy Deaton, "Methane Levels Reach an All-Time High," *Scientific American*, April 12, 2020, https://www.scientificamerican.com/article/methane-levels-reach-an-all-time-high/.
[1719] Christophe McGlade, K. C. Michaels, and Tim Gould, "Global Methane Emissions From Oil and Gas: Insights From the Updated IEA Methane Tracker," *International Energy Agency*, March 31, 2020, https://www.iea.org/articles/global-methane-emissions-from-oil-and-gas.
[1720] Sarah J. Russell et al., "Quantifying CH4 Concentration Spikes Above Baseline and Attributing CH4 Sources to Hydraulic Fracturing Activities by Continuous Monitoring at an Off-Site Tower," *Atmospheric Environment* 228 (2020): 117452, https://doi.org/10.1016/j.atmosenv.2020.117452.

gas industry expansion remains a significant factor in the complex patterns of global atmospheric methane emissions and concentrations."[1721]

- February 29, 2020 – Annual emissions from fracking operations in Australia's Northern Territory could be as large as 22 percent of the nation's current annual emissions, according to government records obtained by the Australia Institute.[1722] Obtained under Freedom of Information procedures, the documents revealed that high production scenarios in the Territory would be "worse than the emissions of Australia's coal fleet across the National Energy Market (NEM) in 2030, and require more offsets each year than have ever been issued in Australia to date," threatening Australia's ability to meet international emissions reduction obligations. In the documents, government officials stated that emissions from fracking "could reach 39 million tonnes of carbon dioxide equivalent (MtCO2e) per year under one production scenario, and up to 117 MtCO2e per year under larger scale production."

- February 27, 2020 – Researchers at the International Institute for Applied Systems Analysis explored technical solutions for curbing methane emissions and transitioning to carbon-free energy alternatives and their costs. While technical solutions and alternative exist, adoption of new methods, policies, and approaches is only feasible through regulation or "if the future price of gas become[s] high enough to make gas recovery profitable." Specifically, extensive technical opportunities exist to control emissions "from waste and wastewater handling and from fossil fuel production and use."[1723]

- February 21, 2020 – Using measurements of carbon-14 and its isotopes from ice cores reflecting the most recent prior deglaciation period on earth (approximately 18,000 to 8,000 years before present), a team of researchers discovered that relatively little methane was emitted from "old carbon" sources, such as permafrost and methane hydrates under ice sheets.[1724] Instead, "old methane is often rapidly consumed by microorganisms living in sediments, soils, and water, which convert it to carbon dioxide before it can be released to the atmosphere."[1725] A similar pattern may hold as present global temperatures increase. Thus, the paper's lead author said, "we need to be more concerned about the anthropogenic emissions—those originating from human activities—than the natural feedbacks."[1726]

[1721] Alexei V. Milkov et al., "Using Global Isotopic Data to Constrain the Role of Shale Gas Production in Recent Increases In Atmospheric Methane," *Scientific Reports* 10 (2020): 4199, https://doi.org/10.1038/s41598-020-61035-w.
[1722] Tom Swann, "All It's Fracked Up to Be" (The Australia Institute, February 2020), https://australiainstitute.org.au/wp-content/uploads/2020/12/P875-All-its-Fracked-Up-to-Be-WEB.pdf.
[1723] Lena Höglund-Isaksson et al., "Technical Potentials and Costs for Reducing Global Anthropogenic Methane Emissions in the 2050 Timeframe –Results from the GAINS Model," *Environmental Research Communications* 2, no. 2 (2020): 025004, https://doi.org/10.1088/2515-7620/ab7457.
[1724] M. N. Dyonisius et al., "Old Carbon Reservoirs Were Not Important In the Deglacial Methane Budget," *Science* 367, no. 6480 (2020): 907–10, https://doi.org/10.1126/science.aax0504.
[1725] Joshua F. Dean, "Old Methane and Modern Climate Change," *Science* 367, no. 6480 (2020): 846–48, https://doi.org/10.1126/science.aba8518.
[1726] Lindsey Valich, "To Combat Climate Change, Human Activities More Important than Natural Feedbacks," *University of Rochester Newscenter*, February 21, 2020, https://www.rochester.edu/newscenter/combat-climate-change-human-activities-more-important-natural-feedbacks-416672/.

- February 19, 2020 – A University of Rochester-led team conducted an isotopic analysis of pre-industrial ice cores. The results showed that naturally occurring methane emissions from geological sources are relatively small (1.6 million tons per year) and contribute far less to global methane emissions than has been estimated (30 million to 60 million tons). Instead, human activities that liberate methane from geological formations—namely, fossil fuel extraction, distribution, and use—make a far greater contribution to global methane emissions and have heretofore been underestimated by 25 to 40 percent. Accordingly, reducing anthropogenic methane emissions is a firm target for mitigating climate change.[1727, 1728]

- February 12, 2020 – Researchers used drones to sample methane emissions downwind from a single fracking operation, demonstrating the utility of this method for a rapid response, highly precise, "snap shot" study in settings where access for other forms of monitoring may be restricted or where the study area is too small for satellite or high altitude aerial surveillance. High levels of methane emissions were correlated to venting at the fracking site. Such sampling can complement and supplement other methods for compiling inventories of methane emissions and can be used to study relative contributions to emissions of differing phases of fracking, including flow-back, venting, storage, and compression.[1729]

- February 3, 2020 – According to data available through the federal Energy Information Administration (EIA), flaring and venting of methane by the oil and gas industry increased in 2019 for a third year in a row. Compared to 20l8 levels, flaring and venting rose by seven percent in the Permian Basin underlying Texas and New Mexico, while the volumes of gas released or burned in North Dakota's huge Bakken oil field increased by 36 percent. Many states allow the practice, and few enforce regulations that are in place.[1730]

- January 28, 2020 – Researchers extended the use of the high-resolution, satellite-based instrumentation to measure methane emissions in multiple basins in the United States, including the Central Valley of California, the Uintah Basin in Utah, several basins in Texas, and a range of other states, including Florida. After corroborating their findings with findings from ground-based and airborne measurements, they suggest the possibility of greater accuracy, completeness, and utility through "future determination of regional

[1727] Benjamin Hmiel et al., "Preindustrial 14CH4 Indicates Greater Anthropogenic Fossil CH4 Emissions," *Nature* 578 (2020): 409–12, https://doi.org/10.1038/s41586-020-1991-8.
[1728] Warren Cornwall, "Humans Are a Bigger Source of Climate-Altering Methane, New Studies Suggest," *Science Magazine*, February 20, 2020, https://www.sciencemag.org/news/2020/02/only-humans-can-create-climate-altering-methane-burns-new-studies-suggest.
[1729] Adil Shah et al., "Unmanned Aerial Vehicle Observations of Cold Venting From Exploratory Hydraulic Fracturing in the United Kingdom," *Environmental Research Communications* 2, no. 2 (2020): 021003, https://doi.org/10.1088/2515-7620/ab716d.
[1730] Nichola Groom and Jennifer Hiller, "U.S. Oil Fields Flared and Vented More Natural Gas Again in 2019-Data," *Thomson Reuters Roundation News*, February 3, 2020, http://news.trust.org/item/20200203112531-yoq0j/.

methane emissions [via satellite] with a high time resolution and soon after the time of emission" in both the United States and internationally.[1731]

- January 11, 2020 – A report issued by New Mexico's Methane Advisory Panel, appointed by the Governor, suggests that methane venting and flaring have increased, despite conflicting claims from industry and declining numbers in EPA inventories, following changes in reporting methods. Compiling comments from multiple interested parties, "the report lays out comprehensive technical recommendations meant to guide environmental regulators as they craft a new methane rule involving everything from leaks in oil and gas storage tanks to pneumatic pumps."[1732]

- December 16, 2019 – Methane escapes from all parts of the extraction, distribution, and storage system for natural gas. Quantifying these emissions is difficult and yet dictates how quickly further investments in natural gas should end in order to meet greenhouse gas reduction targets. Researchers from the Massachusetts Institute of Technology calculated that reductions in leakage rates from natural gas infrastructure on the order of 30 to 90 percent would be required in order to meet proposed climate targets for 2030. The team projected out multiple scenarios to show the impact of differing approaches to reaching that goal, as well as the potential benefits and importance of identifying and targeting methane super-emitters. Given the difficulties of both measuring and mitigating methane emissions and given that virtually all scenarios for meeting greenhouse gas reduction targets call for ultimately phasing out natural gas by mid-century, further investments in natural gas infrastructure raise questions.[1733] "A certain amount of investment probably makes sense to improve and make use of current infrastructure, but if you're interested in really deep reduction targets, our results make it harder to make a case for that expansion right now," according to author Jessika Trancik.[1734]

- December 16, 2019 – Positing that lack of reliable measurements of accidental methane releases and intermittent emissions from high-volume point sources (super-emitters) in the oil and gas industry leads to omission of such data from emission inventories and reporting, researchers enlisted the use of a space-borne instrument to detail an extremely large methane plume observed in 2018, traceable to a natural gas well blowout in Ohio.[1735] Satellite records put the emission rate of the event in Ohio at 120 metric tons per hour, double the widely reported leak from the Aliso Canyon storage facility in

[1731] Joost A. de Gouw et al., "Daily Satellite Observations of Methane from Oil and Gas Production Regions in the United States," *Scientific Reports* 10 (2020): 1379, https://doi.org/10.1038/s41598-020-57678-4.
[1732] Michael Gerstein, "Report: Methane Venting, Flaring in Permian Doubled Since 2017," *Santa Fe New Mexican*, February 15, 2021, https://www.santafenewmexican.com/news/local_news/report-methane-venting-flaring-in-permian-doubled-since-2017/article_819dc5ac-3313-11ea-96ff-3f3802aff8b0.html.
[1733] Magdalena M. Klemun and Jessika Trancik, "Timelines for Mitigating the Methane Impacts of Using Natural Gas for Carbon Dioxide Abatement," *Environmental Research Letters* 14, no. 12 (2019): 124069, https://doi.org/10.1088/1748-9326/ab2577.
[1734] David L. Chandler, "The Uncertain Role of Natural Gas in the Transition to Clean Energy," *MIT News*, December 16, 2019, http://news.mit.edu/2019/role-natural-gas-transition-electricity-1216.
[1735] Sudhanshu Pandey et al., "Satellite Observations Reveal Extreme Methane Leakage From a Natural Gas Well Blowout," *Proceedings of the National Academy of Sciences* 116, no. 52 (2019): 26376–81, https://doi.org/10.1073/pnas.1908712116.

California in 2015, yet its full extent had gone undetected prior to investigation of the satellite's records, despite health complaints among residents closest to the well that included "throat irritation, dizziness, breathing problems."[1736] The extent of the methane released had also escaped the state's routine greenhouse gas accounting systems. Estimates of the total methane from the event, which lasted approximately 20 days, put that single source at roughly 60 kilotons of methane, equivalent to a quarter of Ohio's reported annual methane emissions and the total reported emissions of some countries. These results reinforce other recent findings that methane emissions from drilling and fracking operations are bigger and more problematic than previously assumed. The researchers urge the expanded use of such observations to identify methane hot spots in order to record these events and target them for intervention.

- December 10, 2019 – Thermal imaging equipment has allowed the nonprofit organization Earthworks to document billowing plumes of methane at oil and gas production sites in New Mexico, made visible through the infrared lens, according to the *Albuquerque Journal*.[1737] Clouds of gas emissions can signal open vents or malfunctioning equipment. Earthworks uses the information to seek reductions in emissions and, if necessary, reports emissions violations to the New Mexico Environment Department. Some measured emissions of methane in the Permian Basin in New Mexico are five times higher than EPA estimates. These findings have helped pushed Governor Michelle Lujan Grisham to pursue a first-of-its-kind state partnership with a commercial laboratory "to measure methane—accurately and in real time—using satellite tech and weather patterns."

- December 5, 2019 – After proclaiming publicly that Colorado would adopt aggressive climate goals, cut down on methane emissions through strict regulations, and keep pressure on the oil and gas industry for improved practices, elected officials were confronted with inaccuracies in the state-funded system to collect data and verify reductions in emissions. The state has declined to hire or to use data from other in-state sources such as aerial surveys by NOAA or private companies like Scientific Aviation, that can do precise real-time monitoring.[1738]

- December 4, 2019 – An international team of researchers examined the growing dependency on fossil fuels around the globe, "amidst declarations of planetary emergency and reports that the window for limiting climate change … is rapidly closing."[1739] They determined that the ongoing natural gas boom is serving a major barrier to rapid decarbonization. Natural gas is the fastest growing fossil fuel in the world. While it has

[1736] Hiroko Tabuchi, "A Methane Leak, Seen From Space, Proves to Be Far Larger Than Thought," *The New York Times*, December 16, 2019, sec. Climate Change, https://www.nytimes.com/2019/12/16/climate/methane-leak-satellite.html.
[1737] Theresa Davis, "Methane Emissions a Numbers Game in New Mexico," *Albuquerque Journal*, December 10, 2019, https://www.abqjournal.com/1399538/methane-emissions-a-numbers-game-in-new-mexico-ex-an-advisory-panel-will-discuss-what-regulations-would-be-practical-and-effective-for-the-state.html.
[1738] Grace Hood, "Colorado Talks A Mean Game On Methane. Bad Data, No Best Practices Say Otherwise," *Colorado Public Radio News*, December 5, 2019, https://www.cpr.org/2019/12/05/colorado-talks-a-mean-game-on-methane-bad-data-no-best-practices-say-otherwise/.
[1739] R. B. Jackson et al., "Persistant Fossil Fuel Growth Threatens the Paris Agreement and Planetary Health," *Environmental Research Letters* 14, no. 12 (2019): 121001, https://doi.org/10.1088/1748-9326/ab57b3.

indeed displaced coal—the use of coal in the United States has fallen by half over the past 15 years—the use of natural gas has soared so fast that the methane emissions from burning it have more than offset the decline in carbon dioxide emissions from the dwindling use of coal. The result is that carbon dioxide (or CO_2-equivalent) emissions from fossil fuels grew each year from 2017-2019. The low costs of natural gas, and new methods for transporting it, such as LNG tankers, are keeping the use of fossil fuels high even as renewable energy sources are also growing. As a result, the carbon intensity of global energy production has remained essentially unchanged since 1990. The study calls for "accelerated energy efficiency improvements and reduced consumption, rapid deployment of electric vehicles, carbon capture and storage technologies, and a decarbonized electricity grid, with new renewable capacities replacing fossil fuels," assisted by stronger global commitments and carbon pricing. "I have strong concerns about the pace of our natural gas build-out in the United States and globally because those facilities will be producing pollution for many decades," said lead author and Stanford University earth system scientist Rob Jackson.[1740]

- November 26, 2019 – Meteorologists used measurements from airborne instruments to model methane emissions across multiple oil and gas regions in Arkansas, Texas, Louisiana and Oklahoma that are estimated to contribute 40 percent of the oil and gas produced in the United States.[1741, 1742] These aerial data confirm other research showing that 1.1 to 2.5 times as much methane is being emitted by oil and gas activities than is estimated by inventories collected on the ground, such as those compiled by the EPA. Tracers, including ethane, allowed researchers to segregate methane emissions originating from the oil and gas sector from biogenic sources, such as livestock and manure. They also found that flying through massive methane plumes concentrated by regional weather front boundaries allowed them to measure methane emissions from a wide area.

- November 6, 2019 – Researchers employed the "Next Generation Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG)" to detect, geolocate, and quantify point sources of less than 10 meters in diameter that emit methane, with a focus on identifying super-emitting landfills, livestock facilities, and oil and gas infrastructure. Their results allowed the team to estimate that the emissions from point sources were equivalent to 34-46 percent of the state's 2016 methane inventory. They also found super-emitters among every sector of point sources, with 10 percent of them accounting for roughly 60 percent of point-source emissions.[1743] Regular scans for such emissions

[1740] Nicholas Kusnetz, "Natural Gas Rush Drives a Global Rise in Fossil Fuel Emissions," *Inside Climate News*, December 4, 2019, sec. Fossil Fuels, https://insideclimatenews.org/news/03122019/fossil-fuel-emissions-2019-natural-gas-bridge-oil-coal-climate-change.
[1741] A. R. Barkley et al., "Forward Modeling and Optimization of Methane Emissions in the South Central United States Using Aircraft Transects Across Frontal Boundaries," *Journal of Geophysical Research: Atmospheres* 46, no. 22 (2019): 13564–73, https://doi.org/10.1029/2019GL084495.
[1742] David Kubarek, "Airborne Measurements Point to Low EPA Methane Estimates in South Central US," *Penn State News*, January 27, 2020, https://news.psu.edu/story/605629/2020/01/27/research/airborne-measurements-point-low-epa-methane-estimates-south-central.
[1743] Riley M. Duren et al., "California's Methane Super-Emitters," *Nature* 575 (2019): 180–84, https://doi.org/10.1038/s41586-019-1720-3.

are needed, especially since sharing data about these localized "puffs" of methane with collaborating infrastructure operators in some cases led to mitigation.[1744]

- October 25, 2019 – High-resolution satellite instrumentation detected an unexpectedly large, persistent methane source in Central Asia, along with additional nearby sources of high emission.[1745] The amount of methane detected equaled the "total emissions from the Aliso Canyon disaster—the largest accidental release of greenhouse gases in U.S. history."[1746] While the exact cause of the emissions cannot be determined, venting (blowdowns) from a gas compressor station or malfunction of a valve on a pipeline seem likely. The researchers compared and confirmed their results with observations from another satellite based measuring instrument. The results point toward a potential strategy for monitoring in which "instruments with global coverage at coarse spatial resolution can first identify methane hot spots and then instruments with fine spatial resolution but limited coverage can zoom in to identify the facilities responsible for the hot spots."

- October 16, 2019 – Despite pledges from oil and gas industry executives to curb the energy-wasting practice of flaring off excess natural gas, rates of flaring have significantly increased in recent years, along with rates of venting unburned gas. In 2018, operators across three basins (the Eagle Ford and Permian basins in the Southwest and the Bakken Formation at the Canadian border) flared or vented a record 320 million cubic feet of gas, more than 40 percent above levels seen just five years ago. Oil producers often treat natural gas as a liability, flaring it rather than paying to pipe it away for sale. "Last year in Texas, venting and flaring in the Permian Basin oil field alone consumed more natural gas than states like Arizona and South Carolina use in a year."[1747]

- August 14, 2019 –Isotopic analysis can distinguish methane produced from microbes (biogenic methane) from methane emissions arising from oil and gas operations (thermogenic methane). During the final 20 years of the 20th century, as atmospheric methane concentrations rose, isotopic analysis allowed scientists to conclude that fossil fuels and not microbes were driving the increase. During a second methane surge, beginning in 2009, the isotopic evidence led some researchers to conclude that biogenic sources, such as tropical wetlands, rice culture, or animal agriculture were the most likely driver of the observed methane increases. (See entry for March 10, 2016.) However, Cornell University biogeochemist Robert Howarth proposes an alternative view, noting that previous studies did not explicitly consider shale gas, which has a lighter isotopic signature that more closely resembles that of microbial methane. Correcting the earlier analyses for this difference, Howarth concluded that shale gas production in North

[1744] Leslie Nemo, "'Super-Emitters' In California Release A Third Of The State's Methane," *Discover*, November 5, 2019, https://www.discovermagazine.com/environment/super-emitters-in-california-release-a-third-of-the-states-methane.
[1745] D. J. Varon et al., "Satellite Discovery of Anomalously Large Methane Point Sources From Oil/Gas Production," *Geophysical Research Letters* 46, no. 22 (2019): 13507–16, https://doi.org/10.1029/2019GL083798.
[1746] Carlos Anchondo, "Satellite Discovers 'Anomalously Large' Methane Plume," *E&E News*, November 26, 2019, https://web.archive.org/web/20191128174408/https://www.eenews.net/energywire/stories/1061647835.
[1747] Hiroko Tabuchi, "Despite Their Promises, Giant Energy Companies Burn Away Vast Amounts of Natural Gas," *The New York Times*, October 16, 2019, https://www.nytimes.com/2019/10/16/climate/natural-gas-flaring-exxon-bp.html.

America over the past decade may have contributed "more than half of all of the increased emissions from fossil fuels globally and approximately one-third of the total increased emissions from all sources globally over the past decade." In other words, 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."[1748] Stabilizing the climate by slashing methane emissions from the extraction, transport, storage, processing, and use of fossil fuels—particularly those obtained via fracking—is "the low-hanging fruit to slow global warming."[1749] (See also entry for March 6, 2020 above.)

- July 29, 2019 – To measure fugitive methane emissions from urban areas and identify the sources of those emissions, scientists used atmospheric observations of methane, carbon dioxide, carbon monoxide, and ethane downwind from six "old and leak-prone major cities" along the northeast coast of the United States. Their findings showed that these regions are leaking twice as much methane as indicated in EPA inventories. This discrepancy is possibly due to underestimates of natural gas leakage from urban distribution sources or from lack of inclusion of end-use emissions, or both.[1750] The amount of methane emitted by these six cities is large ("well over triple the amount emitted by gas production in the Bakken shale formation in the U.S. Midwest") and preventable. Possible sources of the leaks include natural gas pipelines, pumps, valves, water treatment systems, gas-fired power plants, and leaks from within homes and businesses.[1751]

- July 15, 2019 – Measurements of methane from a remote sensing spectrometer located just outside Los Angeles documented a correlation between methane levels and consumption of natural gas by residential and commercial consumers in the city, with measured emissions more than twice the level of estimates derived from monitoring equipment on the ground. If a causal correlation exists between the greater amount of gas burned in cold weather and higher methane levels, then the study estimates that about 1.4 percent of the commercial and residential natural gas consumption in Los Angeles is released into the atmosphere.[1752] To meet mandated reductions in emissions in California, sources of emission must be identified and quantified—in this case, the entire urban distribution system, "from storage fields to pipelines to stoves and furnaces."[1753] This

[1748] Robert W. Howarth, "Ideas and Perspectives: Is Shale Gas a Major Driver of Recent Increase in Global Atmospheric Methane?," *Biogeosciences* 16 (2019): 3033–46, https://doi.org/10.5194/bg-16-3033-2019.
[1749] Ruth Schuster, "As Fracking Poisons the Air, Israeli Scientists Propose to Engineer Cows," *Haaretz*, August 14, 2019, sec. Science & Health, https://www.haaretz.com/science-and-health/as-fracking-poisons-the-air-israeli-scientists-propose-to-engineer-cows-1.7683463.
[1750] Genevieve Plant et al., "Large Fugitive Methane Emissions From Urban Centers Along the U.S. East Coast," *Geophysical Research Letters* 46, no. 14 (2019): 8500–8507, https://doi.org/10.1029/2019GL082635.
[1751] Sid Perkins, "Major U.S. Cities Are Leaking Methane at Twice the Rate Previously Believed," *Science*, July 19, 2019, https://www.sciencemag.org/news/2019/07/major-us-cities-are-leaking-methane-twice-rate-previously-believed.
[1752] Liyin He et al., "Atmospheric Methane Emissions Correlate With Natural Gas Consumption From Residential and Commercial Sectors in Los Angeles," *Geophysical Research Letters* 46, no. 14 (2019): 8563–71, https://doi.org/10.1029/2019GL083400.
[1753] Emily Velasco, "Natural-Gas Leaks Are Important Source of Greenhouse Gas Emissions in Los Angeles," *Caltech News*, August 12, 2019, https://www.caltech.edu/about/news/natural-gas-leaks-are-important-source-greenhouse-gas-emissions-los-angeles.

approach provides a simple and relatively inexpensive method to address an often-overlooked component of global methane pollution.

- July 2, 2019 – Venting and flaring events at fracking sites release not only the greenhouse gases carbon dioxide and methane but also toxic air pollutants, including hydrogen sulfide, formaldehyde, sulfur dioxide, benzene, and volatile aromatic hydrocarbons. These events are self-reported by the industry to state agencies. Because there is almost no independent auditing, the precision and accuracy of self-reported venting and flaring volumes remain unknown. A research team from Texas A&M working in the Permian and Eagle Ford basins therefore created and attempted to match detailed maps of flared gas from both self-reported data collected on-site by the operators and satellite aerial data. Their results revealed that flaring volumes measured by satellite were at least two time greater than self-reported volumes submitted by the operators to the state. The authors note that venting and flaring reports are not mandated until after the well is drilled, fracked, and hooked up to the pipeline and also enjoy other exemptions. "Self-reported volumes significantly underestimate the volume of gas being vented or flared."[1754]

- June 7, 2019 – In a perspective published in *Science*, researchers from the National Institute of Water and Atmospheric Research in New Zealand considered the climate risks posed by rising global methane levels and their possible sources. In 2007, after a seven-year period of no change, the amount of methane in the atmosphere began to rise. The rate of increase then doubled from 2014 to the end of 2018, threatening to undermine the goals to limit planetary temperature increases, as set out in the Paris Agreement. The cause of this ongoing methane surge has four possible explanations, according to the authors: fossil fuel sources, biogenic sources, especially ruminant livestock; methane release from wetlands, particularly in the southern tropics, triggered by rising global temperatures; or a decline in the atmosphere's ability to break methane molecules apart, slowing the natural decay rate of methane.[1755]

- May 27, 2019 – In response to discussions about possible future fracking activities in Germany and the United Kingdom, researchers at the Institute for Advanced Sustainability Studies in Germany developed projections for emissions of greenhouse gases and associated local air pollutants, with a realistic scenario assuming "business-as-usual" activities and an optimistic scenario based on "the lowest emissions technically possible" including "full compliance with a stringent regulatory framework…."[1756] In addition to other harmful effects from fracking activities such as earthquakes and surface and groundwater contamination, projections of atmospheric impacts from drilling 480 wells annually in the two countries suggest that methane and carbon dioxide emissions

[1754] Katherine Ann Willyard and Gunnar W. Schade, "Flaring in Two Texas Shale Areas: Comparison of Bottom-Up With Top-Down Volume Estimates for 2012 to 2015," *Science of the Total Environment* 691 (2019): 243–51, https://doi.org/10.1016/j.scitotenv.2019.06.465.
[1755] Sara E. Mikaloff Fletcher and Hinrich Schaefer, "Rising Methane: A New Climate Challenge," *Science* 364, no. 6444 (2019): 932–33, https://doi.org/10.1126/science.aax1828.
[1756] Lorenzo Cremonese et al., "Emission Scenarios of a Potential Shale Gas Industry in Germany and the United Kingdom," *Elementa: Science of the Anthropocene* 7, no. 18 (2019), https://doi.org/10.1525/elementa.359.

with fracking are considerably higher than with conventional oil and gas production under the realistic scenario, with leakage rates only meeting current government figures under the 'optimistic' scenario, which the researchers acknowledge is "rather unlikely to be systematically employed or achieved." One of the reviewers suggested that "In light of the climate crisis, the environmental risks posed by gas emissions need to move quickly onto the agenda in policy making and in negotiations with the gas industry in order to keep the adverse effects of a European shale gas industry to an absolute minimum."[1757]

- 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.[1758]

- 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.[1759]

- 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

[1757] Rachel Cordery, "Shale Gas Fracking Could Increase Emissions," *Power Technology*, July 25, 2019, sec. News, https://www.power-technology.com/news/shale-gas-increases-harmful-emissions/.
[1758] Z. R. Barkley et al., "Estimating Methane Emissions From Underground Coal and Natural Gas Production in Southwestern Pennsylvania," *Geophysical Research Letters* 46, no. 8 (2019): 4531–40, https://doi.org/10.1029/2019GL082131.
[1759] Daniel J. G. Crow et al., "Assessing the Impact of Future Greenhouse Gas Emissions From Natural Gas Production," *Science of the Total Environment* 668 (2019): 1242–58, https://doi.org/10.1016/j.scitotenv.2019.03.048.

increases in industrial and fugitive emissions from Australia's LNG plants.[1760] LNG exports rose by one fifth in 2018.[1761] This jump represents the third consecutive year of rising greenhouse gas emissions from Australia. The expansion in LNG production and export was identified as the major contributor to this trend.[1762]

- 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°."[1763]

- 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."[1764]

- 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

[1760] Commonwealth of Australia Department of Environment and Energy, "Quarterly Update of Australia's National Greenhouse Gas Inventory for September 2018," 2018, https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-for-september-2018.
[1761] Peter Hannam, "Annual Emissions Keep Rising as Gas Jump Counters Power Sector Drop," *The Sydney Morning Herald*, February 28, 2019, sec. Climage Change, https://www.smh.com.au/environment/climate-change/annual-emissions-keep-rising-as-gas-jump-counters-power-sector-drop-20190228-p510wu.html.
[1762] Lisa Cox, "Gas Boom Fuels Australia's Third Straight Year of Rising Emissions," *The Guardian*, May 14, 2018, https://www.theguardian.com/environment/2018/may/14/gas-fuels-australias-third-straight-year-of-rising-emissions.
[1763] J. Lelieveld et al., "Effects of Fossil Fuel and Total Anthropogenic Emission Removal on Public Health and Climate," *Proceedings of the National Academy of Sciences U.S.A.* 116, no. 5 (2019): 7192–97, https://doi.org/10.1073/pnas.1819989116.
[1764] Jennifer Baillie et al., "Methane Emissions From Conventional and Unconventional Oil and Gas Production Sites in Southeastern Saskatchewan, Canada," *Environmental Research Communications* 1, no. 1 (2019): 011003, https://doi.org/1088/2515-7620/ab01f2.

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 percent, which falls above the break-even point with coal over a 20-year time span.[1765]

- 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."[1766]

- 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.[1767] 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

[1765] Xinrong Ren et al., "Methane Emissions From the Marcellus Shale in Southwestern Pennsylvania and Northern West Virginia Based on Airborne Measurements," *Journal of Geophysical Research: Atmospheres* 124 (2019): 1862–78, https://doi.org/10.1029/2018JD029690.
[1766] E. G. Nisbet et al., "Very Strong Atmospheric Methane Growth in the 4 Years 2014–2017: Implications for the Paris Agreement," *Global Biogeochemical Cycles* 33, no. 3 (2019): 318–42, https://doi.org/10.1029/2018GB006009.
[1767] Torben Røjle Christensen et al., "Tracing the Climate Signal: Mitigation of Anthropogenic Methane Emissions Can Outweigh a Large Arctic Natural Emission Increase," *Scientific Reports* 9 (2019): 1146, https://doi.org/10.1038/s41598-018-37719-9.

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 methane, the problem of methane release from the thawing Arctic tundra is likely to remain manageable."[1768]

- 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.[1769]

- 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.[1770, 1771]

- 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

[1768] International Institute for Applied Systems Analysis, "Diffusing the Methane Bomb: We Can Still Make a Difference," Press Release, February 6, 2019, https://www.sciencedaily.com/releases/2019/02/190206104538.htm.
[1769] Jordan Blum, "Permian Basin Gas Flaring Has Nearly Doubled In a Year," *Houston Chronicle*, December 4, 2018, sec. Energy, https://www.houstonchronicle.com/business/energy/article/Record-Permian-gas-flaring-has-nearly-doubled-in-13443024.php.
[1770] Matthew D. Merrill et al., "Federal Lands Greenhouse Gas Emissions and Sequestration in the United States: Estimates for 2005–14," *U.S. Geological Survey Scientific Investigations Report 2018-5131*, 2018, https://doi.org/10.3133/sir20185131.
[1771] Adam Aton, "Fossil Fuel Extraction on Public Lands Produces One Quarter of U.S. Emissions," *E&E News*, November 27, 2018, https://www.scientificamerican.com/article/fossil-fuel-extraction-on-public-lands-produces-one-quarter-of-u-s-emissions/.

industry employees.[1772]

- 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.[1773]

- 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."[1774]

- 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 include tanks without vapor recovery systems, overpressurization, undersized flaring systems, stuck or clogged valves, and "poorly designed equipment." Altogether,

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[1772] Timothy L. Vaughn et al., "Temporar 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 U.S.A.* 115, no. 46 (2018): 11712–17, https://doi.org/10.1073/pnas.1805687115.
[1773] Tara I. Yacovitch et al., "Methane Emissions in the Netherlands: The Groningen Field," *Elementa Science of the Anthropocene* 6, no. 57 (2018), https://doi.org/10.1525/elementa.308.
[1774] Marc L. Fischer et al., "Natural Gas Methane Emissions From California Homes" (California Energy Commission, 2018), https://www.energy.ca.gov/publications/2018/natural-gas-methane-emissions-california-homes.

researchers quantified 33 plumes of methane and ethane arising from these well pads.[1775]

- 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.[1776]

- 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.[1777]

- 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 fugitive leaks that are not being measured at all and/or from episodes of unreported venting.[1778]

[1775] Jacob G. Englander et al., "Aerial Interyear Comparison and Quantification of Methane Emissions Persistence in the Bakken Formation of North Dakota, USA," *Environmental Science & Technology* 52, no. 15 (2018): 8947–53, https://doi.org/10.1021/acs.est.8b01665.
[1776] Ramon A. Alvarez et al., "Assessment of Methane Emissions From the U.S. Oil and Gas Supply Chain," *Science* 361, no. 6398 (2018): 186–88, https://doi.org/10.1126/science.aar7204.
[1777] John R. Worden et al., "Reduced Biomass Burning Emissions Reconcile Conflicting Estimates of the Post-2006 Atmospheric Methane Budget," *Nature Communications* 8 (2017): 2227, https://doi.org/10.1038/s41467-017-02246-0.
[1778] Matthew R. Johnson et al., "Comparisons of Airborne Measurements and Inventory Estimates of Methane Emissions in the Alberta Upstream Oil and Gas Sector," *Environmental Science & Technology* 51, no. 21 (2017): 13008–17, https://doi.org/10.1021/acs.est.7b03525.

- 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."[1779]

- 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."[1780]

- 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

[1779] James Hansen et al., "Young People's Burden: Requirement of Negative CO2 Emissions," *Earth System Dynamics* 8 (2017): 577–616, https://doi.org/10.5194/esd-8-577-2017.
[1780] Emilio Godoy, "Mexico's Methane Emissions Threaten the Environment," *Inter Press Service News Agency*, July 8, 2017, sec. Energy, http://www.ipsnews.net/2017/07/mexicos-methane-emissions-threaten-environment/.

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.][1781]

- 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.[1782]

- 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.[1783]

- 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 emissions of short-lived gases could mitigate centuries of additional future sea-level rise."[1784]

- 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

[1781] Anna M. Robertson et al., "Variation in Methane Emission Rates from Well Pads in Four Oil and Gas Basins with Contrasting Production Volumes and Compositions," *Environmental Science & Technology* 51, no. 15 (2017): 8832–40, https://doi.org/10.1021/acs.est.7b00571.
[1782] Mackenzie L. Smith et al., "Airborne Quantification of Methane Emissions over the Four Corners Region," *Environmental Science & Technology* 51, no. 0 (2017): 5832–37, https://doi.org/10.1021/acs.est.6b06107.
[1783] J. Douglas Goetz et al., "Analysis of Local-Scale Background Concentrations of Methane and Other Gas-Phase Species in the Marcellus Shale," *Elementa: Science of the Anthropocene* 5, no. 1 (2017), https://doi.org/10.1525/elementa.182.
[1784] Kirsten Zickfeld, Susan Solomon, and Daniel M. Gilford, "Centuries of Termal Sea-Level Rise Due to Anthropogenic Emissions of Short-Lived Greenhouse Gases," *Proceedings of the National Academy of Sciences U.S.A.* 114, no. 4 (2017): 657–62, https://doi.org/10.1073/pnas.1612066114.

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.[1785]

- 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.[1786]

- 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.[1787]

- 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.[1788]

- 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 higher than previously thought.[1789] 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.[1790]

- 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

[1785] Marielle Saunois et al., "The Global Methane Budget 2000-2012," *Earth System Science Data* 8 (2016): 697–751, https://doi.org/10.5194/essd-8-697-2016.
[1786] Marielle Saunois et al., "The Growing Role of Methane in Anthropogenic Climate Change," *Environmental Research Letters* 11, no. 12 (2016): 120207, https://doi.org/10.1088/1748-9326/11/12/120207.
[1787] Committee on Climate Change, "Unconventional Oil and Gas: Compatibility With Scottish Greenhouse Gas Emissions Targets," Research and Analysis (Energy and Climate Change Directorate, Scotland, November 8, 2016), http://www.gov.scot/Resource/0050/00509324.pdf.
[1788] Christopher Sibrizzi and Peter LaPuma, "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, no. 4 (2016): 8–15.
[1789] Stefan Schwietzke et al., "Upward Revision of Global Fossil Fuel Methane Emissions Based on Isotope Database," *Nature* 538 (2016): 88–91, https://doi.org/10.1038/nature19797.
[1790] Adam Vaughan, "Fossil Fuel Industry's Methane Emissions Far Higher Than Thought," *The Guardian*, October 5, 2016, https://www.theguardian.com/environment/2016/oct/05/fossil-fuel-industrys-methane-emissions-far-higher-than-thought.

the United States is on track to miss this target, in large part because of soaring methane emissions.[1791, 1792]

- 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.)[1793, 1794, 1795]

- 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. 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.[1796] (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

[1791] Jeffery B. Greenblatt and Max Wei, "Assessment of the Climate Commitments and Additional Mitigation Policies of the United States," *Nature Climate Change* 6 (2016): 1090–93, https://doi.org/10.1038/nclimate3125.
[1792] Chris Mooney, "The U.S. Is on Course to Miss Its Emissions Goals, and One Reason Is Methane," *The Washington Post*, September 26, 2016, sec. Climate and Environment, 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.
[1793] A. L. Rice et al., "Atmospheric Methane Isotopic Record Favors Fossil Sources Flat in 1980s and 1990s With Recent Increase," *Proceedings of the National Academy of Sciences U.S.A.* 113, no. 39 (2016): 10791–96, https://doi.org/10.1073/pnas.1522923113.
[1794] C. Harvey, "Scientists May Have Solved a Key Mystery About the World's Methane Emissions," *The Washington Post*, September 13, 2016, sec. Climate and Environment, 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.
[1795] Camille von Kaenel, "Debate Rises over Real Source of Higher Methane Emissions," *Scientific American*, September 13, 2016, sec. Environment, https://www.scientificamerican.com/article/debate-rises-over-real-source-of-higher-methane-emissions/.
[1796] Jeff Johnson, "Pivotal Study on Methane Leaks From U.S. Oil and Natural Gas Wells Under Fire," *Chemical & Engineering News*, July 11, 2016, http://cen.acs.org/articles/94/i28/Pivotal-study-methane-leaks-US.html.

and gas production region in Texas as an approach to tracing methane emissions back to their sources.[1797]

- 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.[1798] Scaled to production, this emission rate is slightly lower than that estimated by EPA in its recently revised inventory.[1799, 1800] (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 fuel sector as expressed in prior inventories.[1801, 1802] 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."[1803] 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

[1797] David Allen, "Attributing Atmospheric Methane to Anthropogenic Emission Sources," *Accounts of Chemical Research* 49, no. 7 (2016): 1344–50, https://doi.org/10.1021/acs.accounts.6b00081.
[1798] Jeff Peischl et al., "Quantifying Atmospheric Methane Emissions From Oil and Natural Gas Production in the Bakken Shale Region of North Dakota," *Journal of Geophysical Research: Atmospheres* 121, no. 10 (2016): 6101–11, https://doi.org/10.1002/2015JD024631.
[1799] National Oceanic and Atmospheric Administration, "North Dakota's Bakken Oil and Gas Field Leaking 275,000 Tons of Methane per Year," Press Release (U.S. Department of Commerce, May 10, 2016), http://www.noaa.gov/news/north-dakota-s-bakken-oil-and-gas-field-leaking-275000-tons-of-methane-year.
[1800] James MacPherson, "A New Study Says the Oil-Producing Region of North Dakota and Montana Leaks 275,000 Tons of Methane Annually," *U.S. News*, May 11, 2016, http://www.usnews.com/news/science/articles/2016-05-11/study-bakken-oil-field-leaks-275-000-tons-of-methane-yearly.
[1801] U.S. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014," April 15, 2016, https://www.epa.gov/sites/production/files/2016-04/documents/us-ghg-inventory-2016-main-text.pdf.
[1802] Jeff Johnson, "Oil, Natural Gas Operations Now Top U.S. Methane Emitters," *Chemical & Engineering News*, April 25, 2016, http://cen.acs.org/articles/94/i17/Oil-natural-gas-operations-top.html?type=paidArticleContent.
[1803] U.S. Environmental Protection Agency, "EPA Publishes 21st Annual U.S. Greenhouse Gas Inventory," Press Release, April 15, 2016, https://archive.epa.gov/epa/newsreleases/epa-publishes-21st-annual-us-greenhouse-gas-inventory.html.

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.[1804] 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.[1805, 1806]

- 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 driving up global methane levels.[1807] (See also entry dated June 13, 2016 in Air Pollution section].)

- 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 unpredictably variable from site to site and from well to well. 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. Further, while some leakage was intentional or part of routine maintenance operations, unplanned releases from malfunctioning equipment were also common, as were combustion emissions from flares and compressor engine exhaust. Over 90 percent of total airborne emissions from well pads originated with vents and hatches on

[1804] Chris Mooney, "The U.S. Has Been Emitting a Lot More Methane Than We Thought, Says EPA.," *The Washington Post*, April 15, 2016, sec. Climate and Environment, https://www.washingtonpost.com/news/energy-environment/wp/2016/04/15/epa-issues-large-upward-revision-to-u-s-methane-emissions/?utm_term=.eca9c599ff09.
[1805] Thomas Sumner, "EPA Underestimates Methane Emissions," *Science News*, April 14, 2016, sec. Environment, https://www.sciencenews.org/article/epa-underestimates-methane-emissions.
[1806] Tim Profeta, "Study, EPA Spotlight Methane Emissions From Oil and Gas Industry," *National Geographic*, March 3, 2016.
[1807] Bruno Franco et al., "Evaluating Ethane and Methane Emissions Associated With the Development of Oil and Natural Gas Extraction in North America," *Environmental Research Letters* 11 (2016): 044010, https://doi.org/10.1088/1748-9326/11/4/044010.

aboveground storage tanks. These findings deeply undercut the assumption in the EPA's Oil & Gas Emission Estimation Tool that tank control systems offer 100 percent capture efficiency. The overall inability to predict which sites were super-emitters (meaning that they leaked into the air more than 200 cubic feet of methane and VOCs per hour) demonstrates that continuous, site-specific monitoring would be required to identify and remediate methane leaks from drilling and fracking operations.[1808] In a comment about the findings to *Inside Climate 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."[1809]

- 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.[1810] 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.[1811] (See entry for February 16, 2016 below.)

- 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.[1812, 1813] Since 2015, research on atmospheric methane has frequently relied on an "inverse method" to

[1808] David R. Lyon et al., "Aerial Surveys of Elevated Hydrocarbon Emissions from Oil and Gas Production Sites," *Environmental Science & Technology* 50 (2016): 4877–86, https://doi.org/10.1021/acs.est.6b00705.
[1809] Phil McKenna, "Researchers Find No Shortcuts for Spotting Wells That Leak the Most Methane," Inside Climate News, April 8, 2016, https://insideclimatenews.org/news/08042016/big-methane-leaks-superemitters-oil-gas-production-climate-change-edf/.
[1810] Hinrich Schaefer et al., "A 21st-Century Shift From Fossil-Fuel to Biogenic Methane Emissions Indicated by 13CH4," *Science* 352, no. 6281 (2016): 80–84, https://doi.org/10.1126/science.aad2705.
[1811] Phil McKenna, "The Mystery of the Global Methane Rise: Asian Agriculture or U.S. Fracking?," *Inside Climate News*, March 10, 2016, sec. Fossil Fuels, https://insideclimatenews.org/news/10032016/mysterious-global-methane-rise-asian-agriculture-or-us-fracking.
[1812] A. J. Turner et al., "A Large Increase in U.S. Methane Emissions Over the Past Decade Inferred From Satellite Data and Surface Observations," *Geophysical Research Letters* 43, no. 5 (2016): 2218–24, https://doi.org/10.1002/2016GL067987.
[1813] Bobby Magill, "Study Ties U.S. to Spike in Global Methane Emissions," *Climate Central*, February 16, 2016, http://www.climatecentral.org/news/us-60-percent-of-global-methane-growth-20037.

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." Altogether, 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.[1814]

- 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 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

[1814] Mark Omara et al., "Methane Emissions from Conventional and Unconventional Natural Gas Production Sites in the Marcellus Shale Basin," *Environmental Science & Technology* 50, no. 4 (2016): 2099–2107, https://doi.org/10.1021/acs.est.5b05503.

alternative technologies and its source code available to the public (at http://www.eeb.cornell.edu/howarth/methane/tool.htm).[1815]

- 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.[1816] 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.[1817] 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 – Climate scientists want 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 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."[1818]

[1815] Bongghi Hong and Robert W. Howarth, "Greenhouse Gas Emissions From Domestic Hot Water: Heat Pumps Compared to Most Commonly Used Systems," *Energy Science & Engineering* 42, no. 2 (2016): 123–33, https://doi.org/10.1002/ese3.112.
[1816] Daniel Zavala-Araiza et al., "Reconciling Divergent Estimates of Oil and Gas Methane Emissions," *Proceedings of the National Academy of Sciences U.S.A.* 112, no. 51 (2015), https://doi.org/10.1073/pnas.1522126112.
[1817] Lisa Song, "Texas Fracking Zone Emits 90% More Methane Than EPA Estimated," *Inside Climate News*, December 7, 2015, https://insideclimatenews.org/news/07122015/methane-emissions-texas-fracking-zone-90-higher-epa-estimate.
[1818] Gayathri Vaidyanathan, "How Bad of a Greenhouse Gas Is Methane?," *Scientific American*, December 22, 2015, https://www.scientificamerican.com/article/how-bad-of-a-greenhouse-gas-is-methane/.

- 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° 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° 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.[1819]

- 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."[1820, 1821] 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 than currently proposed carbon taxes, which typical address only carbon dioxide.[1822]

[1819] Richard Heede and Naomi Oreskes, "Potential Emissions of CO2 and Methane From Proved Reserves of Fossil Fuels: An Alternative Analysis," *Global Environmental Change* 36 (2016): 12–20, https://doi.org/10.1016/j.gloenvcha.2015.10.005.
[1820] World Meteorological Organization, "The State of Greenhouse Gases in the Atmosphere Based on Global Observations Through 2014," WMO Greenhouse Gas Bulletin 11, November 9, 2015, https://library.wmo.int/doc_num.php?explnum_id=7243.
[1821] Tom Miles, "CO2 Levels Hit Record High for 30th Year in a Row," *Scientific American*, November 9, 2015, https://www.scientificamerican.com/article/co2-levels-hit-record-high-for-30th-year-in-a-row/.
[1822] Robert W. Howarth, "Methane Emissions and Climatic Warming Risk From Hydraulic Fracturing and Shale Gas Development: Implications for Policy," *Energy and Emission Control Technologies* 3 (2015): 45–54, https://doi.org/10.2147/EECT.S61539.

Howarth also noted that the EPA "has seriously underestimated the importance of methane emissions in general—and from shale gas in particular."[1823]

- 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.[1824] 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.[1825]

- 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 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

[1823] "Two Studies Highlight Risks of Fracking-Released Methane," Weather.com, October 20, 2015, https://web.archive.org/web/20151021134023/https://weather.com/science/environment/news/studies-highlight-risks-of-methane-from-fracking.
[1824] Touché Howard, "University of Texas Study Underestimates National Methane Emissions at Natural Gas Production Sites Due to Instrument Sensor Failure," *Energy Science & Engineering* 3, no. 5 (2015): 443–55, https://doi.org/10.1002/ese3.81.
[1825] Kuishuang Feng et al., "Drivers of the US CO2 Emissions 1997–2013," *Nature Communications* 6 (2015): 7714, https://doi.org/10.1038/ncomms8714.

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.[1826]

- 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."[1827, 1828]

- 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.[1829] This study was followed by another that further documented malfunctions in the BHFS device and called 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

[1826] Robert Harriss et al., "Using Multi-Scale Measurements to Improve Methane Emission Estimates from Oil and Gas Operations in the Barnett Shale Region, Texas," *Environmental Science & Technology* 49, no. 13 (2015): 7525–26, https://doi.org/10.1021/acs.est.5b02305.
[1827] Michael Lazarus et al., "Natural Gas: Guardrails for a Potential Climate Bridge," New Climate Economy Contributing Paper (Stockholm Environment Institute, May 2015), https://mediamanager.sei.org/documents/Publications/Climate/NCE-SEI-2015-Natural-gas-guardrails-climate-bridge.pdf.
[1828] Simon Evans, "The Climate Benefits of a Gas Bridge Are Unlikely to Be Significant," *The Australian Business Review*, June 2, 2015, http://www.businessspectator.com.au/article/2015/6/2/policy-politics/climate-benefits-gas-bridge-are-unlikely-be-significant.
[1829] Touché Howard, Thomas W. Ferrara, and Amy Townsend-Small, "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, no. 7 (2015): 856–62, https://doi.org/10.1080/10962247.2015.1025925.

Texas, relied on the BHFS device for collecting data and found very low leakage rates.[1830] (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.[1831] In a later comment about this discovery, Franco said, "Since 2009, we observed increases of 5% per year here—it was completely unexpected."[1832] 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.[1833]

- 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 with climate targets. In this model, shale gas was also found to compete in an unhelpful

[1830] David T. Allen et al., "Measurements of Methane Emissions at Natural Gas Production Sites in the United States," *Proceedings of the National Academy of Sciences* 110 (2013): 17768–73, https://doi.org/10.1073/pnas.1304880110.
[1831] Bruno Franco et al., "Retrieval of Ethane From Ground-Based FTIR Solar Spectra Using Improved Spectroscopy: Recent Burden Increase Above Jungfraujoch," *Journal of Qualitative Spectroscopy and Radiative Transfer* 160 (2015): 36–49, https://doi.org/10.1016/j.jqsrt.2015.03.017.
[1832] Environmental Research Web, "Ethane Emissions Back on the Rise," May 23, 2016, http://environmentalresearchweb.org/cws/article/news/65093.
[1833] Tara I. Yacovitch et al., "Mobile Laboratory Observations of Methane Emissions in the Barnett Shale Region," *Environmental Science & Technology* 49, no. 13 (2015): 7889–95, https://doi.org/10.1021/es506352j.

way with renewable energy sources, resulting in reduced use of renewable energy sources and reduced investment in energy efficiency measures.[1834]

- 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.[1835]

- 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)."[1836]

- 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–climate modelling teams show that instead—under a scenario of abundant natural

[1834] Jan Kersting et al., "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, 2015), https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/climate_change_03_2015_the_impact_of_shale_gas_1.pdf.
[1835] Christophe McGlade and Paul Ekins, "The Geographical Distribution of Fossil Fuels Unused When Limiting Global Warming to 2° C," *Nature* 517 (2015): 187–90, https://doi.org/10.1038/nature14016.
[1836] Xiaochun Zhang, Nathan P. Myhrvold, and Ken Caldeira, "Key Factors for Assessing Climate Benefits of Natural Gas Versus Coal Electricity Generation," *Environmental Research Letters* 9, no. 11 (2014): 114022, https://doi.org/10.1088/1748-9326/9/11/114022.

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.[1837]

- 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.[1838]

- 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."[1839]

- 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 reductions are not large enough for natural gas to play an expanded role in efforts to

[1837] Haewon McJeon et al., "Limited Impact on Decadal-Scale Climate Change From Increased Use of Natural Gas," *Nature* 514 (2014): 482–482, https://doi.org/10.1038/nature13837.
[1838] Oliver Schneising et al., "Remote Sensing of Fugitive Methane Emissions From Oil and Gas Production in North American Tight Geologic Formations," *Earth's Future* 2, no. 10 (2014): 548–58, https://doi.org/10.1002/2014EF000265.
[1839] Christine Shearer et al., "The Effect of Natural Gas Supply on US Renewable Energy and CO2 Emissions," *Environmental Research Letters* 9, no. 9 (2014): 094008, https://doi.org/10.1088/1748-9326/9/9/094008.

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.[1840]

- 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."[1841]

- 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."[1842]

- 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.[1843] 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 potency compared to more recent estimates from the Intergovernmental Panel on Climate Change (IPCC).[1844]

[1840] Chris Busch and Eric Gimon, "Natural Gas versus Coal: Is Natural Gas Better for the Climate?," *The Electricity Journal* 27, no. 7 (2014): 97–111, https://doi.org/10.1016/j.tej.2014.07.007.
[1841] Climate Central, "Methane Leak Rate Proves Key to Climate Change Goals," *Scientific American*, August 5, 2014, http://www.scientificamerican.com/article/methane-leak-rate-proves-key-to-climate-change-goals/.
[1842] U.S. Environmental Protection Agency Office of Inspector General, "Improvements Needed in EPA Efforts to Address Methane Emissions From Natural Gas Distribution Pipelines," July 25, 2014, https://www.epa.gov/sites/default/files/2015-09/documents/20140725-14-p-0324_0.pdf.
[1843] Robert W. Howarth, "A Bridge to Nowhere: Methane Emissions and the Greenhouse Gas Footpring of Natural Gas," *Energy Science & Engineering* 2, no. 2 (2014): 47–60, https://doi.org/10.1002/ese3.35.
[1844] A. Childers, "EPA Understimates Fracking's Impact on Climate Change.," *Bloomberg*, May 9, 2014, http://www.bloomberg.com/news/2014-05-09/epa-underestimates-fracking-s-impact-on-climate-change.html.

- 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.[1845]

- 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.[1846, 1847]

- 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.[1848]

- 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.[1849] 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."[1850] This study also concluded that the national methane leakage rate is likely between 3.6 and 7.2 percent of production.

- 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.[1851]

[1845] Morgan R. Edwards and Jessika E. Trancik, "Climate Impacts of Energy Technologies Depend on Emissions Timing," *Nature Climate Change* 4 (2014): 347–52, https://doi.org/10.1038/NCLIMATE2204.
[1846] Dana R. Caulton et al., "Toward a Better Understanding and Quantification of Methane Emissions From Shale Gas Development," *Proceedings of the National Academy of Sciences*, 2014, https://doi.org/10.1073/pnas.1316546111.
[1847] Neela Banerjee, "EPA Drastically Underestimates Methane Released at Drilling Sites," *Los Angeles Times*, April 14, 2014, sec. Science, http://www.latimes.com/science/sciencenow/la-sci-sn-methane-emissions-natural-gas-fracking-20140414,0,2417418.story.
[1848] Suzanne Goldenberg, "Achim Steiner: Shale Gas Rush 'a Liability' in Efforts Slow Climate Change," *The Guardian*, February 26, 2014, http://www.theguardian.com/environment/2014/feb/26/achim-steiner-shale-gas-rush-climate-change-energy.
[1849] Adam R. Brandt et al., "Methane Leaks from North American Natural Gas Systems," *Science* 343, no. 6172 (2014): 733–35, https://doi.org/10.1126/science.1247045.
[1850] Coral Davenport, "Study Finds Methane Leaks Negate Benefits of Natural Gas as a Fuel for Vehicles," *The New York Times*, February 13, 2014, http://www.nytimes.com/2014/02/14/us/study-finds-methane-leaks-negate-climate-benefits-of-natural-gas.html?smid=tw-share.
[1851] Fiona Harvey and Terry Macalister, "BP Study Predicts Greenhouse Emissions Will Rise by Almost a Third in 20 Years," *The Guardian*, January 1, 2014, http://www.theguardian.com/business/2014/jan/15/bp-predicts-greenhouse-emissions-rise-third?CMP=twt_gu.

- 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.[1852]

- 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.[1853] 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. [1854]

- 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.[1855] 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."[1856]

- 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-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.[1857]

[1852] Kevin R. Gilmore, Rebekah Hupp, and Janine Glathar, "Transport of Hydraulic Fracturing Water and Wastes in the Susquehanna River Basin, Pennsylvania," *Journal of Environmental Engineering* 140, no. 5 (2014), https://doi.org/10.1061/(ASCE)EE.1943-7870.0000810.
[1853] Paul Rogers, "Top Climate Scientists Call for Fracking Ban in Letter to Gov. Jerry Brown," *The Mercury News*, November 12, 2013, http://www.mercurynews.com/ci_24509392/top-climate-scientists-call-fracking-ban-letter-gov.
[1854] Sharon McNary, "Former Advisors to Gov. Brown Request Fracking Ban," *Southern California Public Radio*, November 21, 2013, http://www.scpr.org/blogs/politics/2013/11/21/15248/former-advisors-to-gov-brown-request-fracking-ban/.
[1855] Scot M. Miller et al., "Anthropogenic Emissions of Methane in the United States," *Proceedings of the National Academy of Sciences* 110, no. 50 (2013): 20018–22, https://doi.org/10.1073/pnas.1314392110.
[1856] Michael Wines, "Emissions of Methane in U.S. Exceed Estimates, Study Finds," *The New York Times*, November 25, 2013, http://www.nytimes.com/2013/11/26/us/emissions-of-methane-in-us-exceed-estimates-study-finds.html?_r=0.
[1857] Hillard Huntington, "Changing the Game? Emissions and Market Implications of New Natural Gas Supplies," *Energy Modeling Forum*, 2013, https://emf.stanford.edu/publications/emf-26-changing-game-emissions-and-market-implications-new-natural-gas-supplies.

- 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.[1858]

- 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.[1859]

- 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.[1860]

- 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.[1861]

- 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.[1862, 1863]

- 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.[1864] 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.

[1858] Bobby Magill, "Fracking Hurts US Climate Change Credibility, Say Scientists," *The Guardian*, October 11, 2013, http://www.theguardian.com/environment/2013/oct/11/fracking-us-climate-credibility-shale-gas.
[1859] Intergovernmental Panel on Climate Change, *Climate Change 2013 – The Physical Science Basis Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. T. F. Stocker et al. (Cambridge University Press, 2014).
[1860] Justin Gillis, "U.N. Climate Panel Endorses Ceiling on Global Emissions," *The New York Times*, August 12, 2013, http://www.nytimes.com/2013/09/28/science/global-climate-change-report.html?pagewanted=all.
[1861] Fred Pearce, "Fracking Could Accelerate Global Warming," *New Scientist*, August 12, 2013, http://www.newscientist.com/article/dn24029-fracking-could-accelerate-global-warming.html#.UpEWqsQ3uSo.
[1862] Jeff Peischl et al., "Quantifying Sources of Methane Using Light Alkanes in the Los Angeles Basin, California," *Journal of Geophysical Research: Atmospheres* 118, no. 10 (2013): 4974–90, https://doi.org/10.1002/jgrd.50413.
[1863] Stephanie Paige Ogburn, "Solving the Case of California's Extra Methane," *Scientific American*, May 15, 2013, sec. Environment, http://www.scientificamerican.com/article/solving-the-case-of-californias-extra-machine/.
[1864] Eric D. Larson, "Natural Gas & Climate Change" (Climate Central, May 2013), http://assets.climatecentral.org/pdfs/NaturalGas-and-ClimateChange.pdf.

- 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.[1865]

- 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.[1866]

- 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° C, far exceeding the 2° C limit which is critical to avoid the most severe effects of climate change.[1867]

- 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."[1868]

- 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.[1869]

- 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.[1870]

- 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.[1871]

[1865] Tollefson, "Methane Leaks Erode Green Credentials of Natural Gas."
[1866] Pascal Peduzzi and Ruth Harding, "Gas Fracking: Can We Safely Squeeze the Rocks?" (United Nations Environment Programme Global Environmental Alert Service, 2012), Gas fracking: Can we safely squeeze the rocks?
[1867] World Energy Outlook, "Golden Rules for a Golden Age of Gas," Special Report (International Energy Agency, November 2012), https://www.iea.org/reports/golden-rules-for-a-golden-age-of-gas.
[1868] Fiona Harvey, "'Golden Age of Gas' Threatens Renewable Energy, IEA Warns," *The Guardian*, May 29, 2012, http://www.theguardian.com/environment/2012/may/29/gas-boom-renewables-agency-warns.
[1869] Nathan P. Myhrvold and Ken Caldeira, "Greenhouse Gases, Climate Change and the Transition From Coal to Low-Carbon Electricity," *Environmental Research Letters* 7, no. 1 (2012): 014019, https://doi.org/10.1088/1748-9326/7/1/014019.
[1870] Jeff Tollefson, "Air Sampling Reveals High Emissions From Gas Field," *Nature* 482 (2012): 139–40.
[1871] Justin Gillis, "The Puzzle of Rising Methane," *The New York Times*, December 29, 2011, http://green.blogs.nytimes.com/2011/12/29/the-puzzle-of-rising-methane/.

- 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.[1872]

- 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.[1873]

- 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.[1874, 1875]

[1872] Tom M. L. Wigley, "Coal to Gas: The Influence of Methane Leakage," *Climatic Change* 108 (2011): 601, https://doi.org/10.1007/s10584-011-0217-3.
[1873] Phil McKenna, "Thousands of Gas Leaks Under Boston and San Francisco," *New Scientist*, July 6, 2011, http://www.newscientist.com/article/mg21128203.800-thousands-of-gas-leaks-under-boston-and-san-francisco.html#.UpEbbMQ3uSp.
[1874] Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, "Methane and the Greenhouse-Gas Footprint of Natural Gas From Shale Formations," *Climatic Change* 106 (2011): 679, https://doi.org/10.1007/s10584-011-0061-5.
[1875] Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, "Venting and Leaking of Methane From Shale Gas Development: Response to Cathles et Al.," *Climatic Change* 113 (2012): 537–49, https://doi.org/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, fracking infrastructure includes transmission pipelines, compressor stations, condensers, dehydrators, processing plants, LNG terminals, gas-fired power plants, distribution pipelines, and gas-fired appliances inside homes. Fracking infrastructure includes 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.]

<u>Sand mining and processing</u>

Silica sand is used as an ingredient in fracking fluid to prop open the cracks and fissures created during the hydraulic fracturing process in order to allow bubbles of gas or oil to escape the rock. By 2015, the United States had become the world's largest producer of sand for fracking operations, with 70 percent of domestic frack sand mined in Wisconsin and Minnesota.

In the Upper Midwest, this 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 and occupational health risks that are not well understood. Silica dust is a well-known cause of disabling and potentially fatal lung diseases, including both lung cancer and silicosis, and represents a proven occupational health threat to workers so exposed in other industries.

Inhalation exposures to silica dust can occur in several ways: during sandstone mining and loading operations; from truck traffic to and from mines and sand storage depots; during crushing, washing, and drying processes; and whenever dust is visible. Precise exposures to downwind communities remain uncertain. A 2018 study found elevated levels of particulate air pollution in ambient air near two Wisconsin industrial silica sand operations at levels that may pose health risks to nearby residents. Mining operations in Wisconsin and Minnesota are also sources of noise pollution, water contamination, and loss of property value. In January 2021, a county-wide ban on frack sand mining in Winona County, Minnesota was upheld by the U.S. Supreme Court.

By 2018, the center of U.S. frack sand mining had begun to shift from western Wisconsin to western Texas where sand mines in the Permian Basin have now become a major U.S. supplier 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.

Like fracking itself, frack sand mining is a boom-and-bust industry that was hit hard by the downturn in oil and gas demand and crashing prices before and during the COVID-19 pandemic. In 2019-2020, silica sand mining companies in Wisconsin underwent a wave of bankruptcies, raising questions about whether the bonds set aside for mine restoration were sufficient. Although companies are responsible for returning their mines to farmland, prairie, or forest, the required bonds for the restoration work are sometimes backed up by subsidiary companies that may also go bankrupt.

Frack sand dust generated during fracking operations is a more complex mixture of respirable particles than crystalline silica alone. In 2020, a multi-part study led by the National Institute of Occupational and Environmental Health, examined frack sand dust toxicity on several organ systems and reported a wide range of harms. These are described below. For more on the health threats of frack sand to fracking workers, see also "Occupational health and safety hazards."

- November 15, 2022 – Wisconsin frack sand mining operations, which contracted during the 2020-2021 downturn in oil and gas extraction, rebounded in 2022, with some sand mines in southwestern Wisconsin reporting a more than 40 percent increase in sales.[1876]

- June 2, 2021 – In 2013, researchers with the National Institute for Occupational Safety and Health (NIOSH) published exposure assessment results for respirable silica dust among oil and gas workers conducting fracking operations. These results revealed, among other things, that occupational exposure limits for some fracking workers were being exceeded by a factor of ten. This paper describes the historical background of this research project, beginning in 2008 when NIOSH began a focused effort to understand the suite of occupational hazards among fracking industry workers that eventually led to the 2013 report. The authors also summarize the known risks of crystalline silica exposure for workers: lung cancer; chronic obstructive pulmonary disease; kidney disease; and incurable silicosis, which can either progress gradually or, in some cases, swiftly and fatally after only a few months of very intense exposure.[1877]

- May 24, 2021 – One of Wisconsin's biggest producers of sand for fracking, Hi-Crush Proppants, liquidated one of its four sand mines in the state after declaring bankruptcy last year.[1878]

- January 24, 2021 – The U.S. Supreme Court let stand a ban on the mining of sand for fracking operations in Winona County, Minnesota. The ban was first enacted in 2016 on the grounds that frack sand mining was incompatible with land stewardship and healthy

[1876] Rich Kremer, "Some Wisconsin Frac Sand Mines See Growing Demand from Oil, Natural Gas Companies," *Wisconsin Public Radio*, November 22, 2022, https://www.wpr.org/some-wisconsin-frac-sand-mines-see-growing-demand-oil-natural-gas-companies.
[1877] Eric J. Esswein, Bradley King, and Ryan Hill, "An Ancient Hazard in a 21st Century Workplace: The Power of Partnerships and Collaboration Investigating Respirable Crystalline Silica in Hydraulic Fracturing," NIOSH Science Blog, June 2, 2021, https://blogs.cdc.gov/niosh-science-blog/2021/06/02/oge-partnership/.
[1878] Rich Kremer, "Frac Sand Company Liquidating Western Wisconsin Mine," Wisconsin Public Radio, May 24, 2021, https://www.wpr.org/frac-sand-company-liquidating-western-wisconsin-mine.

communities. The ban was previously challenged by the industry in county and in state courts, both of which had upheld it.[1879]

- December 11, 2020 – A spate of lawsuits against frack sand mining operations in Wisconsin have targeted several proposed new mines as well as existing mines that have already been cited for multiple environmental violations, including spills of mine sludge into surface water and groundwater contamination.[1880]

- November 9, 2020 – Workers who service gas wells while they are being fracked are migratory, moving from one well pad to another after spending a few weeks at each well during the fracking stage. Because of the itinerant nature of their work, there is no registry of lung diseases in workers due to exposure to fracking sand dust. A multi-part investigation using a rat model attempted to understand whether inhalation of sand used at fracking sites could have adverse effects, even after short-term exposure bursts at concentrations that mimic those found at fracking well sites. This paper outlined the scope of the whole study. The organ systems studied included lungs, heart, kidney, brain, and the immune system. Cytotoxicity, inflammation, and molecular mechanisms were also explored. The findings showed that exposure to fracking sand dust has weaker biological effects than exposure to pure crystalline silica dust, but, nevertheless, harmful effects were seen across many organ systems even after short-term exposure.[1881]

- November 7, 2020 – As part of a multi-part investigation (see above), researchers studied the organ systems of rats exposed to fracking sand dust using an intratracheal instillation and inhalation exposure model in both living animals and in tissue studies. The major finding was that the toxicity of fracking sand dust extended to many organ systems—including the cardiovascular system, immune system, kidneys, and brain—which were harmed, for the most part, more severely than the lungs. The mechanism by which fracking sand provoked responses in organs distance from the lungs is not understood.[1882]

- October 22, 2020 – As part of a multi-part investigation (see above), researchers exposed rats to fracking sand dust and found changes in the brain. Specifically, acute inhalation of fracking sand dust altered the blood-brain barrier, elicited neuroinflammation, and caused changes in cells supporting the olfactory bulb, the hippocampus, and the cerebellum. The cerebellum also showed signs of synaptic injury.[1883]

[1879] Waterways Journal, "Supreme Court Upholds Winona Frac Sand Ban," *Waterways Journal*, January 24, 2021, https://www.waterwaysjournal.net/2021/01/24/supreme-court-upholds-winona-frac-sand-ban/.
[1880] Mike Tighe, "Suits Balloon Against Frac Sand Mining 'Running Amok,' Onalaska Lawyer Says," News8000.com, December 11, 2020, https://www.news8000.com/suits-balloon-against-frac-sand-mining-operations-running-amok-onalaska-lawyer-says/.
[1881] Jeffrey S. Fedan, "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. I. Scope of the Investigation," *Toxicology and Applied Pharmacology* 409 (2020), https://doi.org/10.1016/j.taap.2020.115329.
[1882] Stacey E. Anderson and Mark Barger, "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. IX. Summary and Significance," *Toxicology and Applied Pharmacology* 409 (2020), https://doi.org/10.1016/j.taap.2020.115330.
[1883] Krishnan Sriram et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust VII. Neuroinflammation and Altered Synaptic Protein Expression," *Toxicology and Applied Pharmacology* 409 (2020), https://doi.org/10.1016/j.taap.2020.115300.

- October 15, 2020 – As part of a multi-part investigation (see above), researchers compared the physico-chemicals properties of nine different samples of frack sand dust to pure respirable crystalline silica dust typically used in lab experiments. They also compared the pulmonary responses of rats exposed to both types of dust. The findings showed that both the physico-chemical characteristics and the biological effects of the two types of dust have distinct differences. Fracking sand dust samples had comparatively great amounts of non-silica minerals, the grains were less uniform in size, and the toxicity to lung tissue was less. Further, researchers documented significant differences in bioactivity among the various samples of frack sand dust.[1884]

- October 15, 2020 – As part of a multi-part investigation (see above), researchers examined the biological effects of inhaled fracking sand dust on the lung mechanics of laboratory rats. They found differences among nine different samples of dust collected at well pads during fracking operations. Some dusts caused temporary harm to various measures of breathing that appeared to resolve over time. A strong pro-inflammatory response, which is typical of silica dust exposure, was not evident in cases exposed to one of the nine different dust samples. However, the epithelial lining of the airways did show functional alterations.[1885]

- October 13, 2020 – In laboratory animals and humans alike, the deposition of silica dust in small airways of the lung, where they are ingested by macrophages, causes cell death and elicits dramatic and sustained inflammation. As part of a multi-part investigation (see above), researchers exposed rodent immune cells growing in culture to frack sand dust collected from a fracking site and looked for toxicity and inflammatory responses. The results confirmed that this particular sample of frack sand dust was toxic to mammalian lung cells, damaging their DNA and increasing inflammatory cytokine production.[1886]

- October 13, 2020 – As part of a multi-part investigation (see above), researchers examined the biological effects of inhaled fracking sand dust on the pulmonary inflammatory responses of laboratory rats and looked also for signs of toxicity and oxidative stress. Unexpectedly, the rats exposed via inhalation to frack sand dust showed only minimal signs of toxicity or changes in gene expression in their lung tissue. The researchers noted that the association of other minerals on the surfaces of the particles of this particular sample of frack sand dust may have "prevented, through masking, cellular interactions that would trigger an inflammatory response. It is of interest to determine whether frack sand dust collected from other hydraulic fracturing sites in the U.S. would,

[1884] Jeffrey S. Fedan et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. II. Particle Characterization and Pulmonary Effects 30 d Following Intratracheal Instillation," *Toxicology and Applied Pharmacology* 409 (2020), https://doi.org/10.1016/j.taap.2020.115282.
[1885] Kristen A. Russ et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. IV. Pulmonary Effects," *Toxicology and Applied Pharmacology* 409 (2020), https://doi.org/10.1016/j.taap.2020.115284.
[1886] Nicole S. Olgun et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. III. Cytotoxicity and Pro-Inflammatory Responses in Cultured Murine Macrophage Cells," *Toxicology and Applied Pharmacology* 408 (2020), https://doi.org/10.1016/j.taap.2020.115281.

in this rat inhalation model, have a similar toxicity profile as the dust examined in the present study."[1887]

- September 30, 2020 – As part of a multi-part investigation (see above), researchers examined the biological effects of inhaled fracking sand dust on immune responses of exposed laboratory rats. They found several impacts. Exposure to fracking sand dust significantly altered lymph node cellularity and frequency of T-cells, B-cells, and natural killer cells, among other endpoints. These changes all signal impairment of immune functioning.[1888]

- September 12, 2020 – As part of a multi-part investigation (see above), researchers examined the biological effects of inhaled fracking sand dust on the cardiovascular of exposed laboratory rats. The results showed constriction of arteries, decreased heart rate, and alterations in blood pressure. Also, of expressions of proteins in kidney tissue were indicative of injury. "Thus, it appears that inhalation of fracking sand dust does have some prolonged effects on cardiovascular and, possibly, renal function."[1889]

- July 14, 2020 – Three companies mining silica sand for fracking declared bankruptcy in the five weeks preceding this report by the *Houston Chronicle*.[1890] One of those companies described holds over $953 million of assets but carries over $699 million of debt. The pandemic was cited as dramatically cutting demand and forcing the closure of silica mines across the United States.

- June 27, 2020 – Hi-Crush Inc. closed three of its four Wisconsin silica sand mines including its largest, as a result of reduced demand. The company told the *Wisconsin State Journal* that it had reduced its workforce by about 60 percent in the past three months.[1891]

- May 18, 2020 – An update on the Atlas Sand Company's frack sand conveyer belt project appeared in the *Permian Basin Oil and Gas Magazine*.[1892] The magazine reported that public scoping process of the Bureau of Land Management (BLM) for the 16.6-mile-long conveyor belt system for moving frack sand from West Texas into Southeast New Mexico had taken place, and the BLM was preparing an environmental assessment. The

[1887] Tina M. Sager et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. V. Pulmonary Inflammatory, Cytotoxic and Oxidant Effects," *Toxicology and Applied Pharmacology* 408 (2020), https://doi.org/10.1016/j.taap.2020.115280.
[1888] Stacey E. Anderson et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. VIII. Immunotoxicity," *Toxicology and Applied Pharmacology* 408 (2020), https://doi.org/10.1016/j.taap.2020.115256.
[1889] Kristine Krajnak et al., "Biological Effects of Inhaled Hydraulic Fracturing Sand Dust. VI. Cardiovascular Effects," *Toxicology and Applied Pharmacology* 406 (2020), https://doi.org/10.1016/j.taap.2020.115242.
[1890] Sergio Chapa, "Pandemic Forces 3 Frac Sand Companies into Chapter 11 Bankruptcy," *Houston Chronicle*, July 14, 2020, sec. Energy, https://www.houstonchronicle.com/business/energy/article/pandemic-forces-bankrupt-frac-sand-company-houston-15405869.php.
[1891] Chris Hubbuch, "Frac Sand Producer Hi-Crush Pursuing Bankruptcy amid Flagging Sales," *Wisconsin State Journal*, June 27, 2020, https://madison.com/wsj/business/frac-sand-producer-hi-crush-pursuing-bankruptcy-amid-flagging-sales/article_f0c4157d-1e2c-5ee4-a984-a33d0fdd7145.html.
[1892] PBOG, "Belting It Out," *Permian Basin Oil and Gas Magazine*, May 18, 2020, https://pboilandgasmagazine.com/belting-it-out/.

BLM was "analyzing a range of alternatives and its associated environmental effects," and, once the environmental assessment was complete, a 30-day public comment period would commence. (BLM published the assessment and opened the comment period on Aug. 28, 2020, accepting comments through Sept. 28, 2020.[1893]) The plan's developer claimed the project would lead to a 47 percent reduction per year in frack sand hauling trucks on public roadways. Trucking plays a role in the sand transfers within the new project, with the 140-acre offloading facility plan calling for 24 truck loading lanes. Proposed health and safety precautions in the proposal include a cover for the belt to decrease noise, and "environmental awareness training… to instruct personnel on the protection of cultural, ecological, and other natural resources."

- April 29, 2020 – Frack sand mining plants in Wisconsin laid off workers as oil prices crashed as the pandemic took hold. Sand from western Wisconsin "has the shape and composition to be widely used in the process of extracting oil and gas from shale rock," and the mines and layoffs are concentrated there.[1894]

- January 9, 2020 – The company behind the frack sand mine proposed in Kane County, Utah announced that it was "stepping away" from the project, "citing the conclusions of 'feasibility assessments,'" reported *KUER* radio.[1895] Southern Red Sands released the announcement together with Best Friends Animal Society, a national animal shelter organization sharing a border with the company's mining claim. The animal sanctuary had been one of the project's "most vocal opponents." Other expressions of opposition to the frack sand mine included a petition that garnered over 12,000 signatures.

- January 8, 2020 – The Atlas Sand Company sought to construct a 16.5-mile conveyor belt to carry silica sand for fracking, from an offloading facility in rural West Texas to a proposed 140-acre loadout facility in southeast New Mexico.[1896] The plan was submitted in January 2020 to the Bureau of Land Management, from which the project would need a permanent, 70-foot-wide right of way across federal land. The conveyer belt would be in place of trucking, the main method of transporting sand to well sites.

- July 7, 2019 – A company proposing a massive frack sand mine in southern Utah sought 1,200 acre-feet of water per year, which would be needed to process the sand. Residents and organizations, including an animal sanctuary, expressed alarm at the Kanab City

[1893] Bureau of Land Management, "The Bureau of Land Management Invites Public to Comment on Proposed Kermit Overland Conveyor Project | Bureau of Land Management," U.S. Department of the Interior, August 28, 2020, https://www.blm.gov/press-release/bureau-land-management-invites-public-comment-proposed-kermit-overland-conveyor.
[1894] Joe Taschler, "Oil Price Destruction Makes Its Way to Wisconsin's Frac Sand Mines," *Milwaukee Journal Sentinel*, April 29, 2020, https://www.jsonline.com/story/money/business/2020/04/29/wisconsin-frac-sand-plants-lay-off-workers-amid-oil-price-crash/3044935001/.
[1895] Fuchs, D. (2020, January 9). BREAKING: Divisive Southern Utah sand mine project will not move forward. *KUER.org.* Retrieved from https://www.kuer.org/energy-environment/2020-01-09/breaking-divisive-southern-utah-sand-mine-project-will-not-move-forward
[1896] Associated Press, "Company Eyes Texas-New Mexico Fracking Sand Transport System," *Albuquerque Journal*, January 8, 2020, sec. Business, https://www.abqjournal.com/1407811/company-eyes-texas-new-mexico-fracking-sand-transport-system.html.

Council's water service agreement near finalization. Those opposed also addressed truck traffic and harmful impacts on tourism, telling the *Salt Lake City Tribune*, "such an operation is not a good fit for a county so rich in geological scenery and steeped in agricultural traditions," and "authorities seem too eager to facilitate a proposal that could have far-reaching consequences and undermine the area's amenity-based economy."[1897] (See January 9, 2020 entry for an update addressing the cancellation of this project.)

- May 13, 2019 – As another Wisconsin frack sand company faced bankruptcy, an industry analyst said that many of the 128 silica mines in the state that supply oil and gas producers might have to close due to oversupply.[1898] "Maybe half of these mines, maybe as much as 75 percent of these mines, might need to be retired or just permanently reclaimed and then it brings up the question of is there enough money set aside for reclamation and restoration," the analyst told *Wisconsin Public Radio*. Though companies are responsible for returning the land to either farmland, prairie or forest, the analyst cast said that the required bonds for the restoration, "could be suspect," because they are backed up by subsidiary companies that may also go bankrupt.

- 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.[1899] 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.[1900, 1901]

- 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.

[1897] Brian Maffly, "Worried about Truck Traffic and Losing Valuable Water, Southern Utah Residents Fight Plan to Mine Frack Sand," *The Salt Lake Tribune*, July 7, 2019, https://www.sltrib.com/news/environment/2019/07/07/worried-about-truck/.
[1898] Rich Kremer, "Frac Sand Producer In Wisconsin Faces Bankruptcy As Industry Shifts," *Wisconsin Public Radio*, May 13, 2019, https://www.wpr.org/frac-sand-producer-wisconsin-faces-bankruptcy-industry-shifts.
[1899] Winona Daily News Staff & Associated Press, "Challenge to Winona County's Frac Sand Ban to Be Heard by State Supreme Court next Month," *Winona Daily News*, March 7, 2019, https://www.winonadailynews.com/news/local/challenge-to-winona-county-s-frac-sand-ban-to-be/article_bd2474ea-e6a7-5f9f-8108-c957de307aad.html.
[1900] Chris Rogers, "Supreme Court Takes Frac Sand Case," *Winona Post*, October 31, 2018, https://www.winonapost.com/news/supreme-court-takes-frac-sand-case/article_2dd27a1a-e531-57d2-9be5-07297188b40e.html.
[1901] Dan Browning, "Appeals Court Upholds Winona County Ban on Frac Sand Mining," *Star Tribune*, July 30, 2018, https://www.startribune.com/minnesota-appeals-court-upholds-winona-county-ban-on-frac-sand-mining/489529801/.

Wisconsin sand companies then closed mines again, with one company laying off 37 employees.[1902]

- 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.[1903]

- 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.[1904] 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.[1905]

- March 12, 2018 – Significantly higher $PM_{2.5}$ levels than background were identified in ambient air around two Wisconsin industrial silica sand operations, by a team of University of Wisconsin-Eau Claire researchers led by environmental public health toxicologist and silica sand researcher Crispin Pierce.[1906] Average $PM_{2.5}$ concentrations found both above and below the EPA standard were likely due to: "site-specific considerations such as degree of year-round activity; proximity to other sand facilities; rail traffic; and differences between mining, processing, and transport activities." Average PM_{10} levels at both sites were above the State of California and WHO annual average standard. Though PM_{10} is not as closely associated with human health effects as the finer $PM_{2.5}$, and though required by Clean Air Act, the Wisconsin Department of Natural Resources has not collected $PM_{2.5}$. Authors concluded, "Given that no known

[1902] Rich Kremer, "2018 Was A Roller-Coaster Year For Wisconsin's Frac Sand Industry," *Wisconsin Public Radio*, December 27, 2018, https://www.wpr.org/2018-was-roller-coaster-year-wisconsins-frac-sand-industry.
[1903] Roy J Rando et al., "Retrospective Assessment of Respirable Quartz Exposure for a Silicosis Study of the Industrial Sand Industry," *Annals of Work Exposures and Health* 62, no. 8 (2018): 1021–32, https://doi.org/10.1093/annweh/wxy064.
[1904] Natalie Krebs, "In West Texas, Fracking Companies Face A Tough Challenger – The Dunes Sagebrush Lizard," *Texas Standard*, May 11, 2018, https://www.texasstandard.org/stories/in-west-texas-fracking-companies-face-a-tough-challenger-the-dunes-sagebrush-lizard/.
[1905] David Wethe, "Why This Sand From Texas Is Suddenly Worth $80 a Ton," *Bloomberg*, July 10, 2018, https://www.yahoo.com/news/why-sand-texas-suddenly-worth-134140942.html.
[1906] Crispin Pierce et al., "Monitoring of Airborne Particulates near Industrial Silica Sand Mining and Processing Facilities," *Archives of Environmental & Occupational Health* 74, no. 4 (2019): 185–96, https://doi.org/10.1080/19338244.2018.1436036.

level of particulate exposure is considered harmless, that risk has been established down to at least 5 µg/m3, and that statistically significant increases in $PM_{2.5}$ were measured in this study, health risks may be increased for residents around frac sand facilities."

- 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 near multiple adjacent frack sand operations. The industry in western Wisconsin has expanded considerably since that time.[1907]

- 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.[1908, 1909]

- 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.[1910] 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.[1911]

[1907] Thomas M. Peters et al., "Community Airborne Particulate Matter from Mining for Sand Used as Hydraulic Fracturing Proppant," *Science of The Total Environment* 609 (2017): 1475–82, https://doi.org/10.1016/j.scitotenv.2017.08.006.

[1908] Matt McKinney, "Judge's Ruling on Winona County Ban of Frac Sand Mining Stirs Interest," *Minneapolis Star-Tribune*, November 25, 2017, https://web.archive.org/web/20171126004240/https://www.startribune.com/judge-s-ruling-on-winona-county-frac-sand-ban-stirs-interest/459974433/.

[1909] Chris Rogers, "District Court Upholds County Frac Sand Ban," *Winona Post*, November 22, 2017, https://www.winonapost.com/news/district-court-upholds-county-frac-sand-ban/article_4778c8d2-290b-5644-ab0d-7b608a482be1.html.

[1910] Wisconsin Department of Natural Resources, "Industrial Sand Mining in Wisconsin Strategic Analysis for Public Review," 2016, https://dnr.wi.gov/topic/EIA/documents/ISMSA/ISMSA.pdf.

[1911] Chris Hubbuch, "DNR Releases Frac Sand Analysis to Immediate Criticism from Environmental Group," *La Crosse Tribune*, July 6, 2016, https://lacrossetribune.com/news/local/dnr-releases-frac-sand-analysis-to-immediate-criticism-from-environmental-group/article_bce8ea56-fff1-52ae-97cb-c67cfb120a1f.html.

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."[1912] 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 is allowed an additional five-year extension for engineering controls, until June 23, 2021.[1913] 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.[1914]

- 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."[1915]

- 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

[1912] Occupational Safety and Health Administration, "Occupational Exposure to Respirable Crystalline Silica," March 25, 2016, https://www.federalregister.gov/documents/2016/03/25/2016-04800/occupational-exposure-to-respirable-crystalline-silica.
[1913] Occupational Safety and Health Administration, "OSHA's Final Rule to Protect Workers from Exposure to Respirable Crystalline Silica," Final Rule, March 25, 2016, https://www.osha.gov/laws-regs/federalregister/2016-03-25-1.
[1914] Barry Meier, "New Rules Aim to Reduce Silica Exposure at Work Sites," *The New York Times*, March 24, 2016, sec. Business, https://www.nytimes.com/2016/03/24/business/new-rules-aim-to-reduce-silica-exposure-at-work-sites.html.
[1915] Thomas W. Pearson, "Frac Sand Mining and the Disruption of Place, Landscape, and Community in Wisconsin," *Human Organization* 75, no. 1 (2016): 47–58, https://doi.org/10.17730/0018-7259-75.1.47.

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.[1916] 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 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.[1917] 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."[1918]

- 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.[1919] 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.'"[1920]

- October 15, 2015 – *Inside Climate 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

[1916] A. Boerner, N. Young, and D. Young, "Health Impact Assessment of Industrial Sand Mining in Western Wisconsin" (Institute for Wisconsin's Health, Inc., 2016), https://www.heartland.org/_template-assets/documents/publications/iwhi_industrial_sand_hia.pdf.
[1917] Ho-Chunk Nation, "Concerns about Air Quality Impacts and Human Health Remain After Release of Industrial Sand Mining Health Impact Assessment," News Release, March 9, 2016, http://midwestadvocates.org/assets/resources/Frac%20Sand%20Mining/20160309HoChunkHIARelease.pdf.
[1918] E. Lindquist, "Report Downplays Frac Sand Link to Health Troubles," *Post-Bulletin*, February 4, 2016, http://www.postbulletin.com/news/local/report-downplays-frac-sand-link-to-health-troubles/article_b3023c6c-fe74-5028-a7a4-6238fa035eaa.html.
[1919] Kristin Walters et al., "PM 2.5 Airborne Particulates Near Frac Sand Operations," *Journal of Environmental Health* 78, no. 4 (2015): 8–12.
[1920] Ryan Schuessler, "Wisconsin Locals Fear Dust from Mines for Fracking Sand Even as Boom Wanes," *Al Jazeera America*, 2015, http://america.aljazeera.com/articles/2015/11/6/wisconsin-locals-fear-frac-sand-mining.html.

noise and light pollution. In other cases, communities are trying to oust pro-sand advocates from office."[1921]

- 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 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.[1922]

- 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.[1923] 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.[1924]

- May 28, 2015 – The U.S. Geological Survey reviewed the geological and economic status of sand mining for hydraulic fracturing operations in the United States. More the 70 percent of the sand used in U.S. fracking operations originates from the Upper Midwest, especially in Wisconsin and Minnesota, where an ongoing sand mining surge has paralleled the national fracking boom. More than 40 different operators are involved in the mining, processing, transportation, and distribution of frac sand to a fast-growing domestic market. U.S. frack sand is also exported and shipped throughout the world.[1925]

[1921] Zahra Hirji, "In Fracking Downturn, Sand Mining Opponents Not Slowing Down," *Inside Climate News*, October 15, 2015, https://insideclimatenews.org/news/15102015/fracking-struggles-sand-mining-opponents-momentum-minnesota-wisconsin/.
[1922] Sergio Chapa, "Demand For Sand: Frac Sand Use per Well Goes up amid Low Oil Prices," *San Antonio Business Journal*, June 30, 2015, https://www.bizjournals.com/sanantonio/blog/eagle-ford-shale-insight/2015/06/demand-for-sand-frac-sand-use-per-well-goes-up.html.
[1923] Pamela King, "Frac Sand Towns Question Whether Rules Protect Them Against Silica Pollution," *E&E News*, June 15, 2015, https://web.archive.org/web/20150621073016/http://www.eenews.net/stories/1060020192.
[1924] U.S. Department of Labor, "Dust and Its Control," 1987, https://web.archive.org/web/20111018032206/https://www.osha.gov/dsg/topics/silicacrystalline/dust/chapter_1.html.
[1925] Mary Ellen Benson, Anna B. Wilson, and Donald L. Bleiwas, "Frac Sand in the United States: A Geological and Industry Overview" (U.S. Geological Survey, May 2015), https://pubs.er.usgs.gov/publication/ofr20151107.

Pipelines and compressor stations

More than 300,000 miles of natural gas transmission pipelines traverse 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.)

Pipelines and compressor stations 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. A 2017 study identified 70 different air pollutants in compressor station emissions. A 2019 study found that 39 of the chemicals released are linked to cancer. A 2020 study found that proximity to higher amounts of volatile emissions from compressor stations were linked with higher death rates. A 2021 study found "alarming levels" of volatile organic compounds, including cancer-causing benzene, in the indoor air of homes located near a compressor station in Ohio.

Pipelines and compressor stations vent methane into the atmosphere as part of routine maintenance operations and represent a climate risk. Historically, the Federal Energy Regulatory Commission (FERC), which undertakes environmental reviews of proposed pipelines, has not considered climate impacts in its approval process. In 2021, the Commission signaled that it would begin considering greenhouse gas emissions as part of its permitting requirements but did not settle on a method for doing so.

Pipelines and compressor stations 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.

In addition to transmission pipelines, 450,000 miles of gathering lines carry raw oil and gas from the wellheads to collection and processing sites within the United States. These smaller-diameter, lower-pressure pipelines are regulated lightly or, in rural areas, not at all. In some cases, large, high-pressure gas pipelines legally qualify as gathering lines and so remain exempt from regulations despite their size. More than one-third of the nation's gathering lines are in Texas. In 2018, three gathering line explosions in Texas' Permian Basin killed several people, including a three-year-old child, and badly burned others. Nevertheless, in October 2019, the Texas Railroad Commission, which oversees oil and gas extraction in Texas, rejected a proposal to subject the state's rural gathering lines to regulation and set safety protocols.

A 2021 nationwide study found that gathering and transmission pipelines are disproportionately sited in socially vulnerable communities, especially Indigenous communities.

A 2022 study of methane emissions from natural gas gathering pipelines in the Permian Basin found leakage rates 14-52 times higher than the U.S. EPA's national estimate for gathering

lines and 4-13 times higher than the highest estimate derived from ground-based surveys. High-emitting pipelines were responsible for a large part of these aggregate emissions.

Distribution pipelines, which carry gas into individual homes and businesses, are an overlooked but significant source of methane emissions and a cause of urban tree death, according to emerging research. In October 2018, a Columbia Gas work crew in Massachusetts' Merrimack Valley over-pressurized a natural gas distribution system while replacing aging pipelines and triggered 80 simultaneous natural gas explosions, killing one teenager, injuring 23 people, destroying or damaging 130 buildings, prompting a mass evacuation, and costing the company over $1 billion.

- June 4-6, 2023 – Extreme heat and cold can cause oil and gas pipelines to corrode, deform, and fracture, raising safety concerns. A North Dakota State University modeling study and literature review investigated how extreme air temperatures influence the distribution of temperatures along oil and gas pipelines buried underground and, specifically, sought to characterize soil thermal conductivity. The results showed that the heat transfer rate of soil is modulated by depth, moisture, density, soil types, and wind speed, as well as air temperature.[1926]

- May 18, 2023 – Gas pipelines are required by law to be externally covered with a crack-resistant coating to protect against corrosion. The coatings of pipelines stored above ground for more than six months can become compromised by sun exposure, becoming less ductile and more prone to corrosion. A commentary on sun-exposed pipelines argues that many pipeline companies are essentially using expired materials, flouting federal regulations.[1927]

- November 15, 2022 – A report on 20-year trends in pipeline incidents by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration found that pipeline failures caused deaths every year during the past two decades. Between 2002-2021, gas pipeline incidents caused at least 1,000 injuries and 227 fatalities.[1928]

- November 8, 2022 – A simulation study of leakage from gas pipelines located in urban areas looked at explosion and disaster risk under different wind speeds. The researchers found that wind speed has a great influence on the concentration and distribution of gas leakage and diffusion. The higher the wind speed, the more diffusion of gas and the smaller the overpressure peak. When a fire occurs, higher wind speeds sweep flames horizontally, endangering objects further away. When an explosion occurs, lower wind

[1926] Ying Huang et al., "Weather Impact On Pipeline Temperature Distribution," in *The 8th International Conference on Civil, Structural and Transportation Engineering*, 2023, https://doi.org/10.11159/iccste23.162.
[1927] Bill Kitchen, "Pipeline Companies Use Expired Materials to Cut Costs, Flouting Regulations," *Truthout*, May 18, 2023, https://truthout.org/articles/pipeline-companies-use-expired-materials-to-cut-costs-flouting-regulations/.
[1928] Pipeline Hazardous Materials Safety Administration, "Pipeline Incident 20 Year Trends," Pipeline and Hazardous Materials Safety Administration, November 15, 2022, https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends.

speeds produce an oscillation shock wave that is more intense, and the duration of the explosion is longer.[1929]

- October 4, 2022 – Using aerial measurements, a study of methane emissions from natural gas gathering pipelines in the Permian Basin calculated a leakage rate of between 2.7 and 10 megagrams (Mg) methane per year per kilometer of pipeline, with high-emitting pipelines responsible for a large part of the aggregate emissions. This estimate is 14-52 times higher than the EPA's national estimate for gathering lines, and 4-13 times higher than the highest estimate derived from a ground-based survey of gathering lines. "Our results suggest that pipeline emissions are underestimated in current inventories and highlight the importance of a large sample size when calculating basin-wide pipeline emission factors." Serviced by compressor stations, gathering lines ferry natural gas from wells to processing plants or directly to distribution pipelines. Because they are typically located underground and in remote locations, distribution pipelines are more difficult to monitor, and they are notoriously underregulated. The authors note that the Pipeline and Hazardous Materials Safety Administration (PHMSA) has issued a rule to expand regulatory oversight of gathering pipelines, establishing annual and incident reporting requirements for all 700,000 kilometers (435,000 miles) of natural gas gathering lines in the United States, and requiring leak survey and repair requirements for more than 30,000 kilometers (18,600 miles) of gathering pipelines. This rule took effect in May 2022 although some provisions will not be enforced until 2024. "We recognize this development as a point of forward progress; however, the results from this study imply a need for increased pipeline-specific leak detection and repair programs that account for the heavy-tailed nature of the emissions distribution."[1930]

- October 3, 2022 – Using publicly available, industry-sourced data from the Federal Energy Regulatory Commission (FERC), researchers evaluated hazardous air pollutants found in five high-pressure natural gas transmission pipelines. These pollutants represent a diverse array of naturally occurring compounds that are entrained in natural gas along with methane. The results showed detectable concentrations of hazardous air pollutants (HAPs) in all five pipelines, with benzene showing the highest median concentrations. Contaminants also included hydrogen sulfide, toluene, xylene, ethylbenzene, and mercury. This study represents the first analytical assessment of this class of air pollutants within the U.S. transmission pipeline system. "By determining the concentrations of HAPs associated with transmission pipeline natural gas and associate emissions sources, this study provides a rational foundation for health-based risk assessments of emissions events from transmission infrastructure including fugitive emissions, venting or blowdowns, and loss of containment events….These data can be

[1929] Dai Wang et al., "Research on Natural Gas Leakage Diffusion of Urban Underground Pipeline and Its Explosion Hazard," *KSCE Journal of Civil Engineering* 27, no. 2 (February 2023): 590–603, https://doi.org/10.1007/s12205-022-1795-5.
[1930] Jevan Yu et al., "Methane Emissions from Natural Gas Gathering Pipelines in the Permian Basin," *Environmental Science & Technology Letters*, October 4, 2022, acs.estlett.2c00380, https://doi.org/10.1021/acs.estlett.2c00380.

utilized to estimate air quality impacts and health risks that could result from exposure to natural gas when emitted to the atmosphere.[1931]

- September 7, 2022 – A nationwide study of leaks from underground natural gas pipelines found that soil conditions can affect the migration behavior of the escaping gas. Soil moisture was the dominant influence on gas concentration and spreading distance. Wetter soil reduced diffusion and increased concentrations near the leak point. Drier soils allowed the gas to spread further. The authors attributed the pipeline leaks in this study primarily to material failure (51.4 percent) and corrosion (43.2 percent). "The study did not capture all factors necessary to understand the dynamics of subsurface gas transport and nearby atmospheric transport."[1932]

- July 29, 2022 – In February 2022, FERC revised its 1999 pipeline policy to address climate concerns, and then subsequently retreated from those reforms in the face of industry opposition. A legal analysis of FERC's decision-making on new pipeline proposals urges commissioners to prioritize the growing number of state and federal policies that mandate a transition to renewable energy. These policies determine whether a pipeline can be said to have "project need" under Section 7 of the Natural Gas Act. Failing to consider the climate impacts of pipelines is a failure to prevent burdening the ratepaying public with stranded fossil fuel assets. Also, FERC's failure to adequately address project need for pipelines arguably also violates Sections 4 and 5 of the Natural Gas Act, which require FERC to ensure that rates, charges, practices, and rules governing natural gas sales and transportation are 'just and reasonable.' FERC can no longer put to the side the clean energy transition underway in the United States and relegate the climate impacts of pipelines to a subsidiary 'environmental' assessment separate and apart from project need. Instead, because of developing local, state, and federal policies on climate change and the clean energy transition, the environmental impacts of new fossil fuel pipelines are central to whether new pipelines are in the present or future public convenience and necessity."[1933]

- July 20, 2022 – A Chinese research team proposed a life cycle method for evaluating carbon emissions from natural gas pipelines that takes into account four stages: manufacturing, construction, operation, and recycling. They then applied this method to three case studies of built natural gas pipelines in China. The team found that 80 percent of CO2 emissions are attributable to the first stage, which includes steel manufacturing. Pipeline length, diameter and wall thickness each influence related CO2 emissions. Leakage from compressor stations during pipeline operation are a leading source of

[1931] Curtis L Nordgaard et al., "Hazardous Air Pollutants in Transmission Pipeline Natural Gas: An Analytic Assessment," *Environmental Research Letters* 17, no. 10 (October 1, 2022): 104032, https://doi.org/10.1088/1748-9326/ac9295.
[1932] Younki Cho et al., "A Closer Look at Underground Natural Gas Pipeline Leaks across the United States," *Elementa: Science of the Anthropocene* 10, no. 1 (September 7, 2022): 00095, https://doi.org/10.1525/elementa.2021.00095.
[1933] Alexandra B. Klass, "Evaluating Project Need for Natural Gas Pipelines in an Age of Climate Change," Law & Economics Working Papers (University of Michigan Law School, 2022), https://repository.law.umich.edu/law_econ_current/238.

methane emissions, as is leakage from the pipeline itself. The aggregate methane leakage was equivalent to the total lifecycle CO2 emissions.[1934]

- July 15, 2021 – Two former pipeline inspectors became whistleblowers about hazards on an ethane pipeline carrying the highly volatile liquid from Marcellus Shale fracking wells in Ohio, Pennsylvania, and West Virginia to a new Shell petrochemical plant. Investigative reporting that relied on heavily redacted documents obtained through Freedom of Information Act requests documented several serious safety charges in the whistleblower complaint. Among the most serious are compromised pipeline coatings, a problem that increases the risk of corrosion. According to Pipeline and Hazardous Materials Safety Administration (PHMSA), corrosion is the cause of about 18 percent of pipeline accidents. Although the Shell contractors on the project fired the inspectors and the Occupational Safety and Health Administration (OSHA) dismissed the complaint, PHMSA investigators had, prior to the whistleblower complaint, "found that Shell had inadequate procedures for the company's inspectors to detect coating damage and other problems." The investigation documented a culture of clique behavior among the industry's inspectors—hired and paid by the industry—that effectively encouraged overlooking expensive problems but which the terminated inspectors, who are appealing OSHA's dismissal, had resisted.[1935]

- June 23, 2021 – The U.S. Court of Appeals for the District of Columbia Circuit, denied a certificate for the Spire STL pipeline in a strong opinion that criticized the Federal Energy Regulatory Commission (FERC) for failing to determine whether there was a need for the 65-mile natural gas pipeline from Illinois to Missouri. The previous year, FERC Chairman Richard Glick reopened a review of its Certificate Policy Statement, which dictates the process for determining whether a proposed pipeline is in the public interest and should therefore be approved. The federal court's ruling may have an impact on this review. However, there are precedent agreements that have historically been viewed by the commission as a proxy for pipeline need. Glick, who voted against FERC's 2019 decision to approve the Spire STL pipeline, has criticized the reliance on precedent agreements, particularly in cases where project applications only include agreements between affiliated companies.[1936]

- June 13, 2021 – Responding to community concerns, a research team investigated the relationship between proximity to a natural gas compressor station in eastern Ohio's Jefferson County and health risks to residents. The results showed that concentrations of volatile organic compounds (VOCs) were indeed elevated in the air inside of homes closer to the compressor station and had reached "alarming levels." Cancer-causing

[1934] Siyuan Xu et al., "Life Cycle Assessment of Carbon Emission from Natural Gas Pipelines," *Chemical Engineering Research and Design* 185 (September 2022): 267–80, https://doi.org/10.1016/j.cherd.2022.07.018.
[1935] Mike Soraghan, "Whistleblowers Say 'Bad Seeds' Undermine Pipeline Safety," *E&E News*, July 15, 2021, https://web.archive.org/web/20210715124012/https://www.eenews.net/articles/whistleblowers-say-bad-seeds-undermine-pipeline-safety/.
[1936] Niina H. Farah, Mike Soraghan, and Miranda Willson, "Court's 'Historic' FERC Slap-Down Shifts Pipeline War," *E&E News*, June 23, 2021, https://web.archive.org/web/20210623133723/https://www.eenews.net/stories/1063735583.

benzene was 2-17 times higher in homes located fewer than two kilometers from the compressor. Other VOCs were also detected in elevated quantities near the compressor and validated the residents' concerns. Authors recommended further study to explicate the specific pathways of exposure.[1937]

- June 3, 2021 – The Danish Environmental Protection Agency halted work on the Denmark of Baltic Pipe, a pipeline connecting Poland with Norwegian gas fields, and temporarily withdrew an environmental permit because of concerns over the impact on protected mice and bat species. The initial study had provided insufficient information on protection of the animals.[1938]

- June 1, 2021 – Using a questionnaire administered to pipeline operators, asset managers, and industry regulators in Nigeria, researchers determined the challenges to "Nigerian Pipeline Integrity Management Systems." Pipeline leaks result in environmental damage and economic loss. The results described in this peer-reviewed study showed that management plans are poorly implemented and that most pipeline failures were due to: forces such as corrosion, weather, and aging; human errors such as poor operation; and willful damage and vandalism. Authors found multiple reasons for the lack of effective implementation of pipeline integrity management in Nigeria. These included "shoddy" repair of pipelines and ancillary facilities, lack of management commitment to safety, high costs of pipeline integrity management procedures, and poor management of data.[1939]

- May 18, 2021 – As part of nationwide study, a research team found that people living in U.S. counties where gas infrastructure is located are at greater risk of exposure to water and air pollution, public health and safety issues, and other negative impacts. Further, counties with more socially vulnerable populations, especially Indigenous populations, had significantly higher densities of gathering and transmission pipelines than counties with less socially vulnerable populations. "Assuming natural gas gathering and transmission pipelines continue to be built, decision-makers and the general public should keep in mind that the network is already distributed inequitably with respect to social vulnerability, and that future projects can either maintain the inequitable status quo or shift the distribution in ways that will potentially exacerbate or ameliorate current disparities."[1940] The study's lead author said to *North Carolina Health News,* "This is what the communities themselves have been saying for a long time… For the first time,

[1937] Kaitlin A. Vollet Martin et al., "Survey of Airborne Organic Compounds in Residential Communities Near a Natural Gas Compressor Station: Response to Community Concern," *Environmental Advances* 5 (2021), https://doi.org/10.1016/j.envadv.2021.100076.
[1938] Reuters, "Concern Over Wildlife Halts Building of Norway-Poland Gas Link," Reuters, June 3, 2021, https://www.reuters.com/business/energy/denmark-halts-baltic-pipe-project-after-environmental-permit-withdrawn-2021-06-03/.
[1939] Sunday Kyrian Nsude et al., "Failures in Natural Gas Pipeline Systems: An Assessment of Pipeline Integrity Management Programs from Nigeria," *International Journal of Scientific Engineering and Applied Science* 7, no. 6 (2021), http://ijseas.com/volume7/v7i6/IJSEAS202106105.pdf.
[1940] Ryan E. Emanuel et al., "Natural Gas Gathering and Transmission Pipelines and Social Vulnerability in the United States," *GeoHealth* 5 (2021), https://doi.org/10.1029/2021GH000442.

we gathered all of this together and zoomed out and took a national look and said, 'You know what, these pipelines don't exist in a vacuum.'"[1941]

- March 19, 2021 – The Department of the Interior's Bureau of Safety and Environmental Enforcement (BSEE) has oversight of the approximately 8,600 miles of active offshore oil and gas pipelines located on the seafloor of the Gulf of Mexico. However, it does not have a robust oversight process for ensuring the integrity of these pipelines. BSEE has authorized industry to leave over 97 percent (about 18,000 miles) of all decommissioned pipeline mileage on the Gulf of Mexico seafloor since the 1960s. Further, if pipelines decommissioned-in-place are later found to pose risks, there is no funding source for removal. "GAO recommends that BSEE take actions to further develop, finalize, and implement updated pipeline regulations to address long-standing limitations regarding its ability to (1) ensure active pipeline integrity and (2) address safety and environmental risks associated with pipeline decommissioning. Interior agreed with this recommendation."[1942]

- March 19, 2021 – Following a certificate from FERC to begin operations at the Enbridge compressor station in Weymouth, Massachusetts, two incidents resulted in emergency shutdowns and large gas releases from the facility, at least one of them caused by equipment malfunction. Long-standing public opposition to the facility reflects concern about risks to public health and safety in this urban environment, environmental justice violations, and greenhouse gas emissions. In apparent response to this public pressure, the Commission voted in February 2021 to establish a "paper briefing process," a type of official comment period which has the goal of answering specific unresolved questions. This decision appeared to signal a rare instance of a willingness by the Commission to reexamine the approval of a facility already in service. More than 60 entities applied to be "intervenors," or participants, in this proceeding. On the side opposing the Enbridge compressor, applicants responded to this unusual "second chance," and the possibility of a FERC reversal of authorization for the project. Pediatric environmental health researcher Philip Landrigan, MD, said, "All of these groups are joining together and they're catalyzed by the recognition that a very poor job was done in the health impact assessment several years ago. There's a real opportunity against the background of this incomplete piece of work to overturn the decision." Brita Lundberg, MD, of Greater Boston Physicians for Social Responsibility said, "FERC specifically asked about what safety and environmental justice issues we know about now that we did not know about when the project was approved. … I find it a very hopeful sign that FERC is now offering to listen. … There is still the opportunity to do the right thing."[1943]

[1941] Greg Barnes, "New N.C. State Study Finds Socially Vulnerable Communities Bear Brunt of Pipelines," *North Carolina Health News*, June 2, 2021, https://www.northcarolinahealthnews.org/2021/06/02/new-n-c-state-study-finds-socially-vulnerable-communities-bear-brunt-of-pipelines/.
[1942] U.S. Government Accountability Office, "Offshore Oil and Gas: Updated Regulations Needed to Improve Pipeline Oversight and Decommissioning" (U.S. Government Accountability Office, March 19, 2021), https://www.gao.gov/products/gao-21-293.
[1943] Miriam Wasser, "Why A Federal Order in The Weymouth Compressor Case Has the Natural Gas World Worried," WBUR, March 19, 2021, https://www.wbur.org/news/2021/03/19/weymouth-compressor-ferc-precedent-enbridge-natural-gas.

- March 4, 2021 – Tracking methane emissions from pipelines has largely focused on structural defects and fugitive emissions. However, these sources are underestimates, as revealed by high resolution satellite monitoring that can capture episodic, intentional methane releases, including venting.[1944]

- February 24, 2021 –Members of the Massachusetts congressional delegation asked federal regulators to reconsider their decision to allow the Enbridge compressor station in Weymouth to go into service. "The site is located within a half mile of Quincy Point and Germantown – 'environmental justice communities' that suffer persistent environmental health disparities due to socioeconomic and other factors – as well as nearly 1,000 homes, a water treatment plant and a public park," the legislators wrote in the letter. "An estimated 3,100 children live or go to school within a mile of the site, and more than 13,000 children attend school within three miles of the compressor station."[1945]

- February 14, 2021 – A study tested whether key demographic and socioeconomic characteristics of a neighborhood's population—racial composition, educational attainment, poverty rate, and rurality—are associated with the probability of a proposed pipeline running through it. The study addressed planned natural gas transmission pipelines in the United States for which researchers were able to discover proposed routes, combined with 2015 census data. It found only limited, and sometimes contradictory evidence of environmental injustice regarding these proposed pipelines. It is not clear whether systemic inequalities in environmental hazards hold true for existing pipelines, as their precise routes are kept confidential by the industry and the federal government, and therefore cannot be studied in this way. The study responded to the environmental justice community's calls for an assessment of the environmental risks caused by the development of gas infrastructure, and whether those risks are equally distributed within the population. Authors of this study emphasized that their results "cannot be used as a verdict over the equity of specific pipelines without considering local contexts and group-specific experiences of marginalization." They also stated that more realistic models are needed, that risks may go beyond the census tract of the pipeline, and that the study lacks precision in the large census tracts.[1946]

- February 5, 2021 – The Coastal GasLink project, a $6.6-billion pipeline designed to carry natural gas, continued, with more than 140 kilometers of pipe laid in northern British Columbia toward a $40-billion LNG terminal on the province's North Coast for export to Asia. Although the hereditary Wet'suwet'en chiefs still oppose the pipeline, their priorities have shifted to caring for their elders during the pandemic. In British Columbia's north, First Nations people have been disproportionately hit with COVID-19,

[1944] European Space Agency, "Monitoring Methane Emissions from Gas Pipelines," Phys.org, March 4, 2021, https://phys.org/news/2021-03-methane-emissions-gas-pipelines.html.
[1945] Jessica Trufant, "Lawmakers Push Regulators to Reexamine Compressor Approval," *The Patriot Ledger*, February 24, 2021, https://www.patriotledger.com/story/news/2021/02/24/lawmakers-push-regulators-reexamine-compressor-approval/4555468001/.
[1946] Johann Strube, Brian C. Thiede, and Walter E. "Ted" Auch, "Proposed Pipelines and Environmental Justice: Exploring the Association between Race, Socioeconomic Status, and Pipeline Proposals in the United States," *Rural Sociology*, 2021, https://doi.org/10.1111/ruso.12367.

with double the confirmed cases compared to the rest of the population. There have also been outbreaks among industry employees and that has slowed construction.[1947]

- February 4, 2021 – Because of violations for erosion and sedimentation control, the Mountain Valley Pipeline has paid over a half a million dollars in fines by consent order of the West Virginia Department of Environmental Protection. Altogether there were 29 notices issued, and some of them contained multiple violations.[1948]

- February 3, 2021 – Natural gas pipelines have proliferated throughout Appalachia's Marcellus Shale region. In West Virginia alone, natural gas production increased four-fold in the past decade. Survey research on the effects of pipeline development in rural Appalachia found that residents live with the fear of disasters, toxic contamination, explosions, construction noise, and the anxiety of having no control over their own land.[1949]

- February 1, 2021 – Global Energy Monitor identifies, maps, describes, and categorizes oil and gas pipelines, and liquified natural gas (LNG) terminals throughout the world. Its online database, Global Fossil Infrastructure, shows that $1 trillion in capital expenditures are on a collision course with commitments by most large economies to transition to carbon neutrality by mid-century, representing risks for stranded assets. United States, as the world's leading developer of pipelines, is at particular risk, as is natural gas infrastructure in general: 18 of the 20 longest pipelines in development and 82.7 percent of all pipelines in development globally carry natural gas. Currently, only four major financial institutions have restricted investments in pipelines. At the same time, opposition from landowners, indigenous groups, and climate activists is causing the cancellation or delay of high-profile pipelines and is changing perceptions of pipelines as a good investment. "Closing the midstream policy gap at financial institutions is key to mitigating the effects of climate change and the increasing risk that, in a decarbonizing world, many of these midstream assets will soon be stranded."[1950]

- January 19, 2021 – Natural gas compressor stations emit loud, low-frequency noise that travels hundreds of meters and is audible to birds. A study that investigated its effects on bird reproduction introduced a recorded playback of compressor noise into nest boxes of eastern bluebirds and tree swallows. The authors measured reproductive output and success, including the number of eggs per nest, the proportion of eggs that hatched, the proportion of young that fledged, as well as proportion of eggs that produced fledglings.

[1947] Betsy Trumpener, "A Year After Wet'suwet'en Blockades, Coastal GasLink Pipeline Pushes on Through Pandemic," *CBC*, February 5, 2021, https://www.cbc.ca/news/canada/british-columbia/coastal-gaslink-pipeline-bc-wet-suwet-en-pandemic-1.5898219.
[1948] Laurence Hammack, "Mountain Valley Pipeline Cited Again for Erosion and Sedimentation Violations," *The Roanoke Times*, February 4, 2021, https://roanoke.com/news/local/mountain-valley-pipeline-cited-again-for-erosion-and-sedimentation-violations/article_496c5fd4-671c-11eb-a913-8b3e7d176b2b.html.
[1949] Erin Brock Carlson and Martina Angela Caretta, "Living with Natural Gas Pipelines: Appalachian Landowners Describe Fear, Anxiety and Loss," *The Conversation*, February 3, 2021, https://theconversation.com/living-with-natural-gas-pipelines-appalachian-landowners-describe-fear-anxiety-and-loss-152586.
[1950] James Browning et al., "Pipeline Bubble 2021: Tracking Global Oil and Gas Pipelines" (Global Energy Monitor, February 2021), https://globalenergymonitor.org/report/pipeline-bubble-2021/.

Incubation rates were lower in noisy boxes for both bluebirds and tree swallows. Also, for both species, the noise reduced hatching success by 9–15 percent compared to quiet boxes.[1951] A summary article reported that "compressor noise caused behavioral changes that led to reduced reproductive success for eastern bluebirds and tree swallows. The results indicate … that natural gas infrastructure can create an 'equal-preference ecological trap,' where birds do not distinguish between lower and higher quality territories, even when they incur reproductive costs."[1952]

- August 1, 2020 – A Michigan Technological University team collected publicly available fuel and emissions data from the entire extraction, transport, and combustion lifecycle to determine that oil and gas pipelines have the highest total embedded carbon emissions. Their method, introduced in this paper, considers all the emissions that a facility enables rather than only what it emits at a point-source, as conventional methods do. This "bottleneck method" showed that the top ten CO_2 emission bottlenecks in the U.S. are predominantly oil (47 percent) and natural gas (44 percent) pipelines.[1953] Commenting on their findings, the researchers expressed surprise at the large emissions contribution from natural gas. "For natural gas, the biggest emissions came from pipeline transport. The sheer length of pipelines—the Transcontinental Gas Pipeline (Transco) alone branches into more than 16,900 kilometers (10,500 miles) of pipeline from Texas to New York—means there are lots of places to emit gas."[1954]

- July 31, 2020 – In early May 2020, a cloud of methane 12 miles wide and drifting over five counties in Florida was picked up in an analysis of satellite data. For more than two months, its source remained a mystery until the state's Department of Environmental Protection confirmed that three hundred metric tons of methane had been intentionally released from a compressor station near Gainesville during an emergency shutdown. The facility is part of the Florida Gas Transmission Pipeline, a joint venture between Energy Transfer and Kinder Morgan.[1955]

- July 20, 2020 – The Dakota Access pipeline was ordered to cease operations by a federal judge after a ruling found that the U.S. Army Corps of Engineers had violated the National Environmental Policy Act in permitting it. In the same month, the lesser-known Tesoro High Plains pipeline was also ordered shut down for the first time in its 67 years of operation after a determination that the pipeline was trespassing on Native American

[1951] Danielle P. Williams et al., "Experimental Playback of Natural Gas Compressor Noise Reduces Incubation Time and Hatching Success in Two Secondary Cavity-Nesting Bird Species," *Ornithological Applications* 123 (2021): 1–11, https://doi.org/10.1093/ornithapp/duaa066.
[1952] Jeff Mulhollem, "Songbirds' Reproductive Success Reduced by Natural Gas Compressor Noise," PennState News, February 18, 2021, https://news.psu.edu/story/647898/2021/02/18/research/songbirds-reproductive-success-reduced-natural-gas-compressor-noise.
[1953] Alexis S. Pascaris and Joshua M. Pearce, "U.S. Greenhouse Gas Emission Bottlenecks: Prioritization of Targets for Climate Liability," *Energies* 13, no. 15 (2020), https://doi.org/10.3390/en13153932.
[1954] Sarah Derouin, "The Surprising Source of Greenhouse Gas Emissions," *Eos*, March 1, 2021, https://eos.org/articles/the-surprising-source-of-greenhouse-gas-emissions.
[1955] Naureen S. Malik, "Florida Offers Pipeline Clue in Mystery of Giant Methane Leak - Bloomberg," *Bloomberg*, July 31, 2020, https://www.bloomberg.com/news/articles/2020-07-31/florida-offers-pipeline-clue-in-mystery-of-giant-methane-leak.

land.[1956] Together, the two pipelines ship over a third of fracked crude from the Bakken shale formation to market. "Their travails signal the ebbing of the oil industry's sway in the U.S. heartland and underscore the growing heft and savvy of challengers who've become emboldened to demand higher compensation and safeguards."

- July 17, 2020 – Subsidence and the development of sinkholes have occurred alongside pipeline construction for the transport of natural gas liquids from the Marcellus Shale fields in western Pennsylvania to an export terminal in Delaware County. Sunoco's Mariner East pipeline development had "catastrophic" potential, according to the state's Public Utility Commission in 2018, though they later changed that determination. Pipeline leaks of natural gas liquids can be more dangerous than methane leaks because the liquids turn into gases once they escape. Heavier than air, these gases then sink to the ground rather than dissipate, are highly volatile, and can easily explode.[1957]

- June 30, 2020 – The D.C. Circuit Court ruled that the Federal Energy Regulatory Commission (FERC) can no longer use "tolling orders" to prevent opponents of proposed pipeline projects from going to court while the Commission considers their appeals while allowing construction to proceed.[1958] Under the Natural Gas Act, landowner opponents of pipelines must file a petition at FERC and wait for the Commission to resolve it before going to court, which it must do within 30 days. But the agency routinely issues so-called tolling orders to extend that review period indefinitely while land seizures and construction often move forward. The DC Circuit Court decision coalesced around a simple conclusion: The Natural Gas Act didn't give FERC the authority to issue tolling orders and stall litigation.

- June 27, 2020 – A gas pipeline crew drilling horizontally under the Blanco River in Texas' Hill Country spilled 36,000 gallons of drilling fluid into the Trinity Aquifer, contaminating at least six water wells drawing from it. Reporting on the incident three months following, the *Houston Chronicle* interviewed residents whose wells were contaminated, including those who had opposed the 30-mile Permian Highway fracked gas pipeline from the time of its announcement. Those interviewed reported challenges for maintaining personal hygiene during the pandemic, dependency on bottled water, and startling results from water testing that turned up detections of arsenic, lead, and other metals at levels beyond maximum allowable concentrations in public drinking water supplies. Ultimately, Kinder Morgan offered to install a rainwater collection system on the properties. Some of the property owners have gone on to sue the company for

[1956] Catherine Ngai, "A Pipeline Is Quietly Ordered Shut in New Signal of Shale's Woes," *Bloomberg Green*, July 20, 2020, https://www.bloomberg.com/news/articles/2020-07-20/another-oil-pipeline-ordered-shut-signals-shale-s-woes.
[1957] Susan Phillips, "More Sinkholes Develop alongside Mariner East Construction in Chester County," *State Impact Pennsylvania*, July 17, 2020, https://stateimpact.npr.org/pennsylvania/2020/07/17/mariner-east-pipeline-construction-site-of-additional-sinkholes-in-chester-county/.
[1958] Ellen M. Gilmer, "'Kafkaesque' FERC Pipeline Process Needs Revamp, Court Says (3)," *Bloomberg Law*, June 30, 2020, https://news.bloomberglaw.com/environment-and-energy/kafkaesque-pipeline-review-process-needs-revamp-court-rules.

"injecting contaminants, including a 'cocktail of carcinogens,' into the aquifer that feeds their wells."[1959]

- June 25, 2020 – Satellite data is now being used by companies, academic researchers, and some energy producers to find large methane leaks.[1960] For example, energy consultancy Kayrros recently observed a leak spewing 93 metric tonnes of methane every hour from the Yamal pipeline that carries gas from Siberia to Europe. Kayrros said its analysis of the satellite data showed concentrations of methane around compressor stations along the pipeline. According to *Reuters*, satellite discoveries of methane leaks could also lead to "more stringent regulatory regimes targeting natural gas, once seen as a 'clean' fossil fuel, as governments seek to combat climate change."

- June 21, 2020 – New Jersey Natural Gas stopped work on its pipeline in Monmouth County following an "inadvertent return, or the unintended discharge of drilling mud to the surface through a natural crack or fissure in the bedrock being drilled."[1961] This inadvertent return damaged a home and flooded its basement by sending drilling mud into a fissure leading to the home's foundation. A statement from the homeowner read, "I was almost too terrified to investigate after what had felt like an explosion in my house… I discovered huge cracks in my foundation, my basement floor, and even my walls. As I watched in horror water and sludge came pouring in through the cracks, I ran to the construction site and begged them to stop." The sludge also flowed into a nearby stream. A 2018 lawsuit to overturn the pipeline's approvals was still pending in the Appellate Division of State Superior Court.

- June 19, 2020 – In Michigan, the Canadian company Enbridge reported additional damage to its Line 5 pipeline running through the Straits of Mackinac. That line has since been shut down. The damage included a damaged screw anchor support that had shifted from its original position, 150 feet from spots on the pipeline where protective coating had worn away, according to the Governor's office. The Michigan Attorney General's office issued a statement saying, "Yet again, Enbridge has confirmed what we already know—Line 5 is a clear and present danger to our Great Lakes and to the millions of Michiganders who rely on those lakes for recreation, business and tourism."[1962]

- June 10, 2020 – Using data collected from an advanced mobile leak detection (AMLD) platform in twelve metropolitan areas, a research team estimated methane emissions from local gas distribution systems. An historically underreported source of greenhouse gases,

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[1959] Jay Root, "A Pipeline Poisons the Wells in Hill Country," *Houston Chronicle*, June 27, 2020, sec. Investigations, https://www.houstonchronicle.com/news/investigations/article/A-pipeline-poisons-the-wells-in-Hill-Country-15371071.php.
[1960] Shadia Nasralla, "Satellites Reveal Major New Gas Industry Methane Leaks," *Reuters*, June 25, 2020, sec. Environment, https://www.reuters.com/article/us-climatechange-methane-satellites-insi-idUSKBN23W3K4.
[1961] Steve Strunsky, "Drilling Work Halted on Natural Gas Pipeline after Mishap Damages N.J. Couple's House," *NJ.Com*, June 21, 2020, sec. Burlington, https://www.nj.com/burlington/2020/06/work-halted-on-natural-gas-pipeline-after-drilling-sludge-damages-nj-couples-house.html.
[1962] Melissa Frick, "Enbridge Reports 'Significant Damage' on Line 5 Pipeline to State," *MLive.Com*, June 20, 2020, sec. News, https://www.mlive.com/news/2020/06/enbridge-reports-significant-damage-on-line-5-pipeline-to-state.html.

distribution pipelines are the low-pressure network of service lines that carry natural gas into individual homes and business. The results of this study fill in an important data gap as most recent national assessments of methane emissions from the US gas supply chain did not take local gas distribution systems into account at all. The team found that the age and the material of the pipelines and their interaction affected leakage rate. Overall, emissions were far greater than those of previous studies. The mean of their emissions estimates was 0.55 teragrams of CO_2 equivalent per year, a value 3.85 times greater than the current EPA estimate.[1963]

- May 26, 2020 – A 30-inch diameter gas pipeline that runs between southern Mississippi and Pennsylvania exploded in Kentucky in August 2019, killing one person and injuring several others. A Pipeline Hazardous Materials Safety Administration (PHMSA) investigation found that the company had missed evidence of defects in the pipeline in 2011, the year of its last inspection. The pipeline is operated by Texas Eastern Transmission LP, a subsidiary of Enbridge.[1964]

- May 14, 2020 – The nation's gathering pipelines that carry raw natural gas from the wellhead to processing plants are served by gathering stations, each of which includes a compressor along with associated separators and tanks. Many include dehydrators, which remove water from the gas, and equipment to remove hydrogen sulfide gas and other contaminants. In a study funded by the oil and gas industry, a research team estimated the collective methane emissions from the nation's 5,200 gathering stations by compiling 85 hours of data from a representative sample of 180 stations, as provided to them by industry partners. Measurements were taken using optimal gas imaging cameras and Bacharach Hi Flow samplers. The team reported a 45 percent lower mean methane emissions rate than a previous study, likely because the gathering stations included in the current study were smaller and lower throughput. The authors argue that their sample was more representative of the gathering station population nationally. Their results also showed that the whole gas emission rates from the components on gathering stations were comparable to, although somewhat higher than, emission factors used by EPA's greenhouse gas reporting program. However, when the activity data of the gathering stations were factored in, the study's estimate of total methane emissions (1,290 gigagrams/year) was just 66 percent of the current estimates used in the EPA's Greenhouse Gas Inventory (1,955 gigagrams/year). The authors propose a replicable method that incorporates activity data to update emissions estimates from gathering stations. The field data and the EPA data together show that significantly more methane was released from gathering stations as part of normal operations (venting, flaring, compressor exhaust, maintenance blowdowns) than via accidental fugitive leaks from equipment.[1965]

[1963] Zachary D. Weller, Steven P. Hamburg, and Joseph C. von Fischer, "A National Estimate of Methane Leakage from Pipeline Mains in Natural Gas Local Distribution Systems," *Environmental Science & Technology* 54, no. 14 (2020): 8958–67, https://doi.org/10.1021/acs.est.0c00437.
[1964] Bill Estep, "Report: Gas Pipeline in Fatal Kentucky Explosion Had Defects Operator Had Not Found," *Lexington Herald Leader*, May 26, 2020, https://www.kentucky.com/news/state/kentucky/article242995236.html.
[1965] Daniel Zimmerle et al., "Methane Emissions from Gathering Compressor Stations in the U.S.," *Environmental Science & Technology* 54, no. 12 (2020): 7552–61, https://doi.org/10.1021/acs.est.0c00516.

- May 10, 2020 – Proximity to higher amounts of non-methane volatile organic compound (VOC) emissions from natural gas pipeline compressor stations were linked to higher death rates in a national, county-level ecological study.[1966] Twelve specific VOCs were also associated with significantly higher mortality rates, including styrene, 2,2,4-trimethylpentane, ethylene dichloride, and vinyl chloride. Studies of human health impacts from compressor stations have been almost completely absent from the literature, despite the expansion of natural gas infrastructure. The Indiana University team also found that counties with compressor station emissions had higher percentages of Hispanic populations and lower percentages of non-Hispanic White populations. Authors concluded that the "results of the current study, along with findings from other research, challenge the conventional wisdom that natural gas is a clean fuel that we may rely on to provide for our energy needs with little adverse effect."

- May 7, 2020 – When a Beaver County home was destroyed in a 2018 explosion, pipeline company ETC Northeast Pipeline LLC, a subsidiary of Energy Transfer, was fined a record $30 million. Subsequently, the Pennsylvania Department of Environmental Protection has issued hundreds of additional construction violation notices on the same pipeline for infractions such as slipping slopes along the pipeline route, failed erosion and sedimentation barriers, and sediment-laden water getting into streams, all violations of the company's clean water permits.[1967]

- April 27, 2020 – Public concerns about Kinder Morgan's storage of pipeline segments for the 428-mile Permian Highway Pipeline led to an investigative report by Austin, Texas radio station KXAN.[1968] Residents had noticed coated pipe segments lying out in the open despite manufacturer warnings that the epoxy coatings can degrade with prolonged exposure to sunlight. KXAN's investigation found no existing regulations that govern pipe coating exposure to UV radiation.

- April 17, 2020 – The proposed Northeast Supply Enhancement (NESE) pipeline would bring fracked gas from Pennsylvania to Long Island at a cost of a billion dollars. A report by the Institute for Energy Economics and Financial Analysis (IEEFA) described the lack of need for the gas and the significant cost to ratepayers in four New York boroughs. The report lead author called the proposal "unwise and high-risk with ratepayers expected to bear the brunt of the cost."[1969]

[1966] Michael Hendryx and Juhua Luo, "Natural Gas Pipeline Compressor Stations: VOC Emissions and Mortality Rates," *The Extractive Industries and Society* 7, no. 3 (2020): 864–69, https://doi.org/10.1016/j.exis.2020.04.011.
[1967] Reid Frazier, "The Revolution Pipeline Explosion Resulted in a Huge Fine for Energy Transfer. Now, DEP Says It's Found Hundreds of New Violations," *State Impact Pennsylvania*, May 7, 2020, https://stateimpact.npr.org/pennsylvania/2020/05/07/the-revolution-pipeline-explosion-resulted-in-a-huge-fine-for-energy-transfer-now-dep-says-its-found-hundreds-of-new-violations/.
[1968] Jody Barr, "PIPELINE EXPOSED: KXAN Investigation Uncovers Safety Concerns over Pipes Used in Kinder Morgan's Permian Highway Pipeline," *KXAN Austin*, April 27, 2020, https://www.kxan.com/investigations/pipeline-exposed-kxan-investigation-uncovers-safety-concerns-over-pipes-used-in-kinder-morgans-permian-highway-pipeline/.
[1969] Suzanne Mattei and Tom Sanzillo, "Proposed NESE Gas Pipeline May Stick New York Ratepayers with One Billion-Dollar+ Cost," *Institute for Energy Economics & Financial Analysis*, April 17, 2020, https://ieefa.org/ieefa-report-proposed-nese-gas-pipeline-may-stick-nys-ratepayers-with-one-billion-dollar-cost/.

- April 8, 2020 – A Nuclear Regulatory Commission (NRC) report concluded the Indian Point Energy Center nuclear power plant would remain safe even in case of a rupture on a nearby, newly installed 42-inch gas transmission pipeline.[1970] The study called a rupture "unlikely" and stated that even if one were to occur, "the nuclear power plant would remain protected." The study team, composed of NRC and external experts, did however criticize earlier "optimistic assumptions in analyzing potential rupture" and recommended follow up actions, stating, "**The NRC needs to improve its processes and practices for technical reviews, inspection support, petition reviews, pipeline analysis, and coordination with other agencies.**" (Emphasis in original.)[1971] Environmental groups expressed dissatisfaction with the NRC conclusion that "maintain(s) the status quo."[1972]

- April 3, 2020 – A study that investigated natural gas leaks and tree deaths found that fugitive methane exposure from leaky natural gas distribution systems threatens urban tree canopies. Researchers measured methane and oxygen concentrations in subsurface soil at the base of case (dead or dying) trees and control (healthy) trees in Chelsea, Massachusetts. About 25 percent of dead trees had increased methane in their base soil, as opposed to one percent of healthy trees. The research team found the greatest soil methane concentrations on the side of the tree pit closest to the street, nearest to where natural gas distribution pipelines are located, suggesting that "elevated soil methane may contribute to urban street tree decline and that the fugitive methane may be the result of leaking pipeline infrastructure beneath the street surface."[1973]

- March 19, 2020 – An x-ray technician working on the Mariner East pipeline in Pennsylvania was charged with fraud for falsifying documents recording x-rays of pipeline welds.[1974] The worker allegedly certified in writing that the welds had been properly x-rayed and were acceptable when these certifications were false. He eventually pled guilty in federal court.[1975] The Mariner East pipeline carries natural gas liquids, which can cause a catastrophic explosion if they leak.

[1970] U.S. Nuclear Regulatory Commission (NRC Staff, "Report of the U.S. Nuclear Regulatory Commission Expert Evaluation Team on Concerns Pertaining to Gas Transmission Lines Near the Indian Point Nuclear Power Plant," April 8, 2020, https://www.nrc.gov/docs/ML2010/ML20100F635.pdf.
[1971] Jeremy Dillon, "NRC Says Gas Pipeline Doesn't Pose Threat to Indian Point," *E&E News*, April 15, 2020, https://web.archive.org/web/20200423075240/https://www.eenews.net/eenewspm/2020/04/15/stories/1062883415.
[1972] Thomas C. Zambito, "NRC Says Gas Pipeline No Threat to Indian Point, Dashing Hopes for Shutdown by Groups," *The Journal News*, April 20, 2020, https://www.lohud.com/story/news/local/indian-point/2020/04/20/nrc-gas-pipeline-indian-point-reactors/5166749002/.
[1973] Claire Schollaert et al., "Natural Gas Leaks and Tree Death: A First-Look Case-Control Study of Urban Trees in Chelsea, MA USA," *Environmental Pollution* 263 (2020): 114464, https://doi.org/10.1016/j.envpol.2020.114464.
[1974] Susan Phillips, "Mariner East Worker Charged with Falsifying Documents Related to a Pipeline Weld," *State Impact Pennsylvania*, March 19, 2020, https://stateimpact.npr.org/pennsylvania/2020/03/19/mariner-east-worker-charged-with-falsifying-documents-related-to-a-pipeline-weld/.
[1975] Department of Justice U.S. Attorney's Office Western District of Pennsylvania, "Radiograph Technician on Natural Gas Pipeline Admits Falsifying Testing Results," Press Release, June 22, 2020, https://www.justice.gov/usao-wdpa/pr/radiograph-technician-natural-gas-pipeline-admits-falsifying-testing-results.

- March 9, 2020 – Residents living a quarter-mile from a compressor station in rural Washington County, Pennsylvania told the Pittsburgh *Post-Gazette* that the persistent low-frequency sound from the station "gives them headaches and feels like torture."[1976] The township does not regulate low-frequency noise. A member of the same family was recently diagnosed with multiple myeloma, a blood plasma cancer linked to benzene and other pollutants. This compressor station emitted 1.2 tons of benzene in 2018, "making it the third biggest source of the carcinogen in the seven-county southwestern Pennsylvania region," according to data obtained from the Pennsylvania Department of Energy Emissions Inventory. Washington County has 40 compressor stations pushing gas through the pipelines.

- February 13, 2020 – NRC's Office of Inspector General conducted an inquiry into NRC's hazard analysis of a natural gas pipeline then proposed to run through the grounds of the Indian Point nuclear power plant. The inquiry found that the NRC failed to properly analyze the safety impact of a potential rupture of that pipeline and did not provide an appropriate response to "relevant and on point" stakeholder concerns.[1977] Congresswoman Nita Lowey and Westchester County Executive George Latimer expressed disappointment and outrage about these failures. "NRC must immediately explain to our communities the risks they face as a result of the agency's faulty processes and take steps to protect the public from any dangers that have resulted from the pipeline's approval and installation," the congresswoman stated.[1978]

- December 3, 2019 – In a "first-of-its-kind dispute," a pipeline operator sued the Texas Railroad Commission, which regulates oil and gas drilling, over approval of gas flaring.[1979] Dallas-based Exco Operating Co. had requested and received permission to flare natural gas that comes up with the oil it pumps from the Eagle Ford Shale. Exco flared off the gas following its emergence from bankruptcy, claiming inability to afford the cost of pipeline transport of the gas. Although natural gas flaring has long been restricted in Texas, the Commission has granted exceptions with increasing frequency in the past years.

- October 24, 2019 – In a 2017 settlement with Exxon which was sealed but obtained by *Inside Climate News*, residents documented illnesses and property damage following the rupture of Exxon's Pegasus pipeline that sent heavy crude oil diluted with dangerous

[1976] David Templeton and Don Hopey, "Next Door Noise: Washington County Residents Say Their Neighbor Is Noisy, Disruptive and a Pollutor," *Pittsburgh Post-Gazette*, March 9, 2020, https://newsinteractive.post-gazette.com/smith-township-compressor-station-three-brothers/.
[1977] Office of the Inspector General, "Concerns Pertaining to Gas Transmission Lines at the Indian Point Nuclear Power Plant" (United States Nuclear Regulatory Commission, 2020), https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML20056F095.
[1978] "Lowey, Latimer Blast NRC for 'Faulty Analysis' That Led to Approval of Gas Line near Indian Point," *Mid Hudson News*, February 28, 2020, https://midhudsonnews.com/2020/02/27/lowey-latimer-blast-nrc-for-faulty-analysis-that-led-to-approval-of-gas-line-near-indian-point/.
[1979] Kiah Collier, "Pipeline Giant Sues Railroad Commission, Alleging Lax Oversight of Natural Gas Flaring," *The Texas Tribune*, December 3, 2019, https://www.texastribune.org/2019/12/03/railroad-commission-sued-lax-oversight-natural-gas-flaring/.

solvents spilling into a subdivision in Mayflower, Arkansas.[1980] Residents subsequently filed a class action lawsuit against Exxon alleging negligence in its maintenance of the 69-year-old pipeline. They faced "significant risks" after being exposed to a cocktail of chemicals including benzene, a known carcinogen; cyclohexane; naphthalene; and toluene, according to an environmental consultant hired by the plaintiffs' lawyers. The residents reportedly were awarded between $2,000 and $15,000. Exxon denied liability, claiming it "acted in conformity with generally recognized, state-of-the-art standards in the industry."

- October 10, 2019 – The Texas Railroad Commission, which oversees the state's oil and gas activity, rejected specific safety proposals drafted by its own staff for rural gathering lines and opted instead for vaguer requirements. This decision was praised by pipeline operators.[1981] Gathering lines are typically small-diameter, low-pressure pipelines carrying oil and gas from wells to processing sites, but recently industry has been building larger and higher-pressure pipelines that legally qualify as gathering lines. This new ruling allows gathering lines to escape regulations in remote, rural areas despite their size.

- June 4, 2019 – At least six pipeline explosions were caused by landslides, sinking and caving of land, and other types of land movement in the steeply sloped Appalachian mountains.[1982] Among them: TransCanada Corp's Leach Xpress natural gas pipeline exploded and demolished a house in Moundsville, West Virginia after five months in operation; a landslide caused a pipeline explosion near Aliquippa, Pa., burning down a house; and a boy and his grandfather were injured in an explosion in southeastern Ohio. An *E&E* investigation examined the gaps in comprehensive oversight: while PHMSA is responsible for the safety of construction and adherence to the agency's minimum standards, they are not involved in pipeline routes. That is handled by a different agency, FERC, which reviews how the path selection will affect the environment. The commission defers on safety issues to PHMSA. Thus, no one entity is in charge of ensuring that pipelines are built in safe places.

- May 7, 2019 – University at Albany researchers investigated health harms associated with chemical emissions from natural gas compressor stations in New York State. Between 2008 and 2014, 18 gas compressor stations (out of 74 compressors in the state) released a total of 36.99 million pounds of air pollutants, excluding methane and carbon dioxide. Thirty-nine of the chemicals released were human carcinogens. The study also included a greenhouse gas inventory, with data available for ten of the compressors.

[1980] David Hasemyer, "6 Years After Exxon's Oil Pipeline Burst in an Arkansas Town, a Final Accounting," *Inside Climate News*, October 24, 2019, https://insideclimatenews.org/news/24102019/exxon-oil-spill-neighborhood-mayflower-arkansas-sealed-depositions-illnesses-fines/.
[1981] Mike Soraghan, "Texas Commissioners Scale Back Gathering Line Proposal," *E&E News*, October 10, 2019, https://web.archive.org/web/20191010213035/https://www.eenews.net/stories/1061235103.
[1982] Mike Soraghan, "Landslides, Explosions Spark Fear in Pipeline Country," *E&E News*, June 4, 2019, https://web.archive.org/web/20190607095016/https://www.eenews.net/stories/1060472727.

Those facilities released 6.1 billion pounds of greenhouse gases release in a single year.[1983] (See also entry for October 12, 2017 below.)

- May 2, 2019 – Eight months after heavy rains and landslides led to the rupture and explosion of Energy Transfer's natural gas liquids Revolution Pipeline in Beaver County, Pennsylvania, destroying a house and knocking down power lines, PHMSA issued an advisory bulletin for operators of gas and hazardous liquid pipelines to "remind" them of the potential for damage from flooding, landslides, subsidence and other geologic hazards.[1984] The advisory bulletin reviewed specific guidance for monitoring, risk identification, and preventative and mitigative measures, as well as the many recent geological-related pipeline failures, particularly in the eastern portion of the United States. Unlike a regulation, a federal advisory is not enforceable but serves as a warning and a reminder of the regulations that are associated with pipeline safety. (See also entry for September 10, 2018 below.)

- 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 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."[1985]

- 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.[1986]

[1983] Pasquale N. Russo and David O. Carpenter, "Air Emissions from Natural Gas Facilities in New York State," *International Journal of Environmental Research and Public Health* 16, no. 9 (2019): 1591, https://doi.org/10.3390/ijerph16091591.

[1984] Pipeline Hazardous Materials Safety Administration, "Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards," *Federal Register*, May 2, 2019, https://www.federalregister.gov/documents/2019/05/02/2019-08984/pipeline-safety-potential-for-damage-to-pipeline-facilities-caused-by-earth-movement-and-other.

[1985] Mike Lee and Mike Soraghan, "Deadly Pipelines, No Rules," *E&E News*, March 4, 2019, https://web.archive.org/web/20190304182624/https://www.eenews.net/stories/1060123021.

[1986] Beth LeBlanc, "Consumers CEO: Two Natural Gas Plants Still down after Jan. 30 Fire," *The Detroit News*, February 20, 2019, https://www.detroitnews.com/story/news/local/michigan/2019/02/20/consumers-energy-two-plants-still-down-after-fire-emergency-appeal/2928041002/.

- 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.[1987, 1988] 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 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."[1989, 1990] 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

[1987] The Massachusetts Department of Environmental Protection, the Massachusetts Department of Public Health, & the Metropolitan Area Planning Council, "Health Impact Assessment of a Proposed Natural Gas Compressor Station in Weymouth, MA," January 1, 2019, https://www.mass.gov/files/documents/2019/02/14/Health-Impact-Assessment-Weymouth-Final-Report.pdf.
[1988] Jessica Trufant, "Regulators Issue Air Permit for Weymouth Compressor Station," *The Patriot Ledger, Quincy, MA*, January 11, 2019, https://www.patriotledger.com/news/20190111/regulators-issue-air-permit-for-weymouth-compressor-station.
[1989] Greater Boston Physicians for Social Responsibility, "Health Risks of A Proposed Compressor Station in Weymouth, Massachusetts," February 7, 2019, https://d279m997dpfwgl.cloudfront.net/wp/2019/02/GB-PSR-Report-on-Health-Risks-of-Proposed-Weymouth-Compressor-Station_Feb-7-2019.pdf.
[1990] Jessica Trufant, "Doctors' Group Challenges Report on Weymouth Compressor Station," *The Patriot Ledger, Quincy, MA*, February 7, 2019, https://www.patriotledger.com/news/20190207/doctors-group-challenges-report-on-weymouth-compressor-station.

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.[1991]

- 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.[1992, 1993, 1994]

- 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 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.[1995]

- 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.[1996]

- 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

[1991] U.S. Government Accountability Office, "Critical Infrastructure Protection: Actions Needed to Address Significant Weaknesses in TSA's Pipeline Security Program Management," December 18, 2018, https://www.gao.gov/products/gao-19-48.
[1992] California Public Utilities Commission (CPUC), "Order Instituting Investigation and Order to Show Cause," December 14, 2018, https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M246/K120/246120841.PDF.
[1993] California Public Utilities Commission (CPUC), "CPUC Opens Case Against PG&E for Potential Natural Gas Safety Violations," Press Release, December 14, 2018, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M250/K897/250897740.PDF.
[1994] Richard Gonzales, "PG&E Falsified Gas Pipeline Safety Records, Regulators Say," *NPR*, December 14, 2018, sec. National, https://www.npr.org/2018/12/14/677003961/pg-e-falsified-gas-pipeline-safety-records-regulators-say.
[1995] John Murawski, "Atlantic Coast Pipeline: Construction Halts for Endangered Species," *The News & Observer*, December 10, 2018, https://www.newsobserver.com/news/business/article222856155.html.
[1996] Mike Soraghan, "No Penalties for 90% of Pipeline Blasts," *E&E News*, November 15, 2018, https://web.archive.org/web/20181115220003/https://www.eenews.net/stories/1060106253.

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.[1997]

- 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.[1998]

- 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.[1999, 2000, 2001]

- 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.[2002]

- 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

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[1997] Alexey Strizhenok and Denis Korelskiy, "Estimation and Reduction of Methane Emissions at the Scheduled and Repair Outages of Gas-Compressor Units," *Journal of Ecological Engineering* 20, no. 1 (January 1, 2019): 46–51, https://doi.org/10.12911/22998993/93943.
[1998] National Transportation Safety Board, "Pipeline Over-Pressure of a Columbia Gas of Massachusetts Low-Pressure Natural Gas Distribution System," Accident report (National Transportation Safety Board, October 11, 2018), https://permanent.fdlp.gov/gpo111468/PLD18MR003-preliminary-report.pdf.
[1999] Kris Mamula and Anya Litvak, "Officials Believe Landslide May Have Triggered Massive Gas Pipeline Explosion in Beaver County | Pittsburgh Post-Gazette," *Pittsburgh Post-Gazette*, September 10, 2018, https://www.post-gazette.com/local/west/2018/09/10/gas-explosion-in-center-township-Beaver-County/stories/201809100067.
[2000] Anya Litvak, "Pipeline Ruptures Bring New Scrutiny to Pennsylvania Geology," *AP News*, October 27, 2018, sec. Pennsylvania, https://apnews.com/article/2e0005ec7db342a290199a4d8464b5a0.
[2001] Anya Litvak, "Who Gets to Say Where It's Safe to Build a Pipeline? | Pittsburgh Post-Gazette," *Pittsburgh Post-Gazette*, September 14, 2018, 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.
[2002] Kate Mishkin and Ken Ward Jr., "What Happens When a Pipeline Runs Afoul of Government Rules? Authorities Change the Rules.," *ProPublica*, August 10, 2018, https://www.propublica.org/article/west-virginia-halted-mountain-valley-pipeline?token=SstV5uby4K1aF_9o7uU0NxUx4Lmau-1g.

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.[2003]

- 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."[2004, 2005]

- 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 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."[2006] 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.[2007, 2008]Similarly, researcher working in the San Juan Basin of New Mexico found that chronic noise from drilling and fracking operations, including compressor stations,

[2003] Federal Energy Regulatory Commission, "Comments of the Attorneys General of Massachusetts, Illinois, Maryland, New Jersey, Rhode Island, Washington, and the District of Columbia," Docket, July 25, 2018, https://www.mass.gov/files/documents/2018/07/26/Multistate%20Comments-FERC%201999%20PL%20Policy%20Review.pdf.
[2004] Phil McKenna, "Public Comments on Pipeline Plans May Be Slipping Through Cracks at FERC, Audit Says," *Inside Climate News*, May 31, 2018, https://insideclimatenews.org/news/31052018/public-comments-oil-gas-pipelines-ferc-review-energy-department-inspector-general-audit/.
[2005] Office of the Inspector General at the Department of Energy, "The Federal Energy Regulatory Commission's Natural Gas Certification Process," Audit Report, May 24, 2018, https://www.energy.gov/ig/downloads/audit-report-doe-oig-18-33.
[2006] Bridget Antze and Nicola Koper, "Noisy Anthropogenic Infrastructure Interferes with Alarm Responses in Savannah Sparrows (*Passerculus Sandwichensis*)," *Royal Society Open Science* 5, no. 5 (2018): 172168, https://doi.org/10.1098/rsos.172168.
[2007] Miyako H. Warrington et al., "Noise from Four Types of Extractive Energy Infrastructure Affects Song Features of Savannah Sparrows," *The Condor* 120, no. 1 (2017): 1–15, https://doi.org/10.1650/CONDOR-17-69.1.
[2008] Claire M. Curry et al., "Noise Source and Individual Physiology Mediate Effectiveness of Bird Songs Adjusted to Anthropogenic Noise," *Scientific Reports* 8, no. 1 (2018): 3942, https://doi.org/10.1038/s41598-018-22253-5.

affected levels of stress hormones in songbirds and masked critical acoustic cues in ways that decreased the birds' ability to survive and reproduce.[2009, 2010]

- 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."[2011]

- 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."[2012]

- 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

[2009] Nathan J. Kleist et al., "Chronic Anthropogenic Noise Disrupts Glucocorticoid Signaling and Has Multiple Effects on Fitness in an Avian Community," *Proceedings of the National Academy of Sciences* 115, no. 4 (2018): E648–57, https://doi.org/10.1073/pnas.1709200115.
[2010] University of Colorado at Boulder, "Noise from Oil and Gas Operations Stresses Birds, Hinders Reproduction," News Release (AAAS EurekAlert, January 8, 2018), https://www.eurekalert.org/news-releases/896481.
[2011] Kirsten Koehler et al., "Exposure Assessment Using Secondary Data Sources in Unconventional Natural Gas Development and Health Studies," *Environmental Science & Technology* 52, no. 10 (2018): 6061–69, https://doi.org/10.1021/acs.est.8b00507.
[2012] Brittany Patterson, "MarkWest Agrees to Pay Millions in Federal Settlement Over 'Pig' Emissions," *West Virginia Public Broadcasting*, April 26, 2018, sec. WVPB News, https://www.wvpublic.org/news/2018-04-26/markwest-agrees-to-pay-millions-in-federal-settlement-over-pig-emissions.

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."[2013]

- 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.[2014]

- 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 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.[2015] Continuing this investigation, *Inside Climate 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.[2016]

- July 12, 2017 – A Canadian study found that oil and gas infrastructure, including compressor stations, contributes to habit fragmentation and increases parasitism by

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[2013] D. O. Carpenter and P. N. Russo, "Health Effects Associated with Stack Chemical Emissions from NYS Natural Gas Compressor Stations: 2008-2014," Technical Report (Southwest Pennsylvania Environmental Health Project, n.d.), http://www.environmentalhealthproject-ny.org/uploads/3/8/5/9/38599771/ny_compressor_station_report_power_point_10.11.2017.pdf.

[2014] Shobhit Mehrotra et al., "Airborne Methane Emission Measurements for Selected Oil and Gas Facilities Across California," *Environmental Science & Technology* 51, no. 21 (2017): 12981–87, https://doi.org/10.1021/acs.est.7b03254.

[2015] Kristen Lombardi and Jamie Smith Hopkins, "Natural Gas Building Boom Fuels Climate Worries, Enrages Landowners," *NPR*, July 17, 2017, https://www.npr.org/2017/07/17/536708576/natural-gas-building-boom-fuels-climate-worries-enrages-landowners.

[2016] Phil McKenna, "Pipeline Payday: How Builders Win Big, Whether More Gas Is Needed or Not," *Inside Climate News*, August 3, 2017, https://insideclimatenews.org/news/03082017/natural-gas-pipeline-boom-corporate-profit-bubble-limited-demand-climate-emissions/.

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."[2017]

- 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.[2018, 2019]

- 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."[2020]

- 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.[2021]

[2017] Jacy Bernath-Plaisted, Heather Nenninger, and Nicola Koper, "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, no. 7 (2017): 170036, https://doi.org/10.1098/rsos.170036.
[2018] Mike Soraghan, "Flow Lines Cited in More than 7K Spills," *E&E News*, May 16, 2017, https://web.archive.org/web/20170516233919/https://www.eenews.net/stories/1060054568.
[2019] Mike Lee, "Fatal Explosion Threatens More Upheaval over Drilling in Colo," *E&E News*, June 12, 2017, https://web.archive.org/web/20180828194551/https://www.eenews.net/stories/1060055846.
[2020] Bryce F. Payne et al., "Characterization of Methane Plumes Downwind of Natural Gas Compressor Stations in Pennsylvania and New York," *Science of The Total Environment* 580 (2017): 1214–21, https://doi.org/10.1016/j.scitotenv.2016.12.082.
[2021] George Joseph, "30 Years of Oil and Gas Pipeline Spills, Mapped - Bloomberg," *CityLab*, November 30, 2017, https://www.bloomberg.com/news/articles/2016-11-30/30-years-of-oil-and-gas-pipeline-spills-mapped.

- 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.[2022]

- 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.[2023] The company agreed to provide funding toward a health study but wished to retain the ability to determine the study parameters.[2024] 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.'"[2025]

- 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.[2026]

[2022] Mike De Souza, "How Canada's Pipeline Watchdog Secretly Discusses 'Ticking Time Bombs' with Industry," *Canada's National Observer*, July 5, 2016, sec. News, https://www.nationalobserver.com/2016/07/05/news/how-canada%E2%80%99s-pipeline-watchdog-secretly-discusses-ticking-time-bombs-industry.
[2023] US EPA Region 2, "Docket Nos. PFI6-3, Eastern System Upgrade Project," June 10, 2016, https://elibrary.ferc.gov/idmws/file_list.asp?document_id=14468753.
[2024] F. Mayer, "Millennium to Pay for Health Study," *The River Reporter*, April 27, 2016, https://riverreporter.com/stories/millennium-to-pay-for-health-study,1279.
[2025] David Hulse, "Highland Concerned about Study Underfunding," *The River Reporter*, June 22, 2016, https://riverreporter.com/stories/highland-concerned-about-study-underfunding,945.
[2026] Cathy Kunkel and Tom Sanzillo, "Risks Associated With Natural Gas Pipeline Expansion in Appalachia: Proposed Atlantic Coast and Mountain Valley Pipelines Need Greater Scrutiny" (Institute for Energy Economics

- 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.[2027]

- 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. 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."[2028]

- 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

and Financial Analysis, 2016), http://ieefa.org/wp-content/uploads/2016/04/Risks-Associated-With-Natural-Gas-Pipeline-Expansion-in-Appalachia-_April-2016.pdf.

[2027] U.S. Department of Health and Human Services, "Brooklyn Township PM2.5 Brooklyn Township, Susquehanna County, Pennsylvania," Health Consultation (Agency for Toxic Substances and Disease Registry, Division of Community Health Investigations, April 22, 2016), https://www.atsdr.cdc.gov/HAC/pha/BrooklynTownship/BrooklynTwnsp_pm2-5_HC_Final_04-22-2016_508.pdf.

[2028] Southwest Pennsylvania Environmental Health Project, "ATSDR Releases Investigation of Pennsylvania Compressor Station: Response to Governmental Action and Publication I," April 3, 2016, https://www.catskillcitizens.org/files/learnmore/brigichtechnicalreportfinal_1_.pdf.

to use eminent domain, and the state legislature passed legislation to block the property seizure.[2029]

- 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.[2030] "All leaks must be addressed, as even small leaks cannot be disregarded as 'safely leaking,'" concluded the report authors. In an interview with *Inside Climate 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.[2031]

- 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."[2032]

- 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."[2033] His call was supported by other elected officials, as well as public health researcher David O. Carpenter, MD, who has studied compressor station pollutants.[2034]

[2029] Phil McKenna, "Property Rights Outcry Stops Billion-Dollar Pipeline Project in Georgia," *Inside Climate News*, April 1, 2016, https://insideclimatenews.org/news/01042016/palmetto-pipeline-kinder-morgan-georgia-eminent-domain-oil-gas-republicans/.
[2030] Margaret F. Hendrick et al., "Fugitive Methane Emissions from Leak-Prone Natural Gas Distribution Infrastructure in Urban Environments," *Environmental Pollution* 213 (2016): 710–16, https://doi.org/10.1016/j.envpol.2016.01.094.
[2031] Phil McKenna, "Methane Hazard Lurks in Boston's Aging, Leaking Gas Pipes, Study Says," *Inside Climate News*, March 31, 2016, https://insideclimatenews.org/news/31032016/boston-natural-gas-pipelines-leaking-methane-climate-change-explosion/.
[2032] Candy Woodall, "Federal Agency Funded by Energy Industry Has Never Rejected a Pipeline Plan," *PennLive Patriot News*, March 7, 2016, sec. Pennsylvania Real-Time News, https://www.pennlive.com/news/2016/03/pipeline_fights_raise_big_ques.html.
[2033] Chris Gibson, "Compressor Station Needs Review," *Sullivan County Democrat*, February 26, 2016, https://www.scdemocratonline.com/stories/compressor-station-needs-review,47706?
[2034] Brian Nearing, "Gibson: Federal Natural Gas Air Pollution Safety Standards May Be Obsolete," *Times Union*, March 31, 2016, sec. Business, https://www.timesunion.com/business/article/Gibson-Federal-natural-gas-air-pollution-safety-7221271.php.

- 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.[2035]

- 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.[2036]

- 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."[2037]

- 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

[2035] U.S. Department of Health and Human Services, "Exposure Investigation, Natural Gas Ambient Air Quality Monitoring Initiative Brigich Compressor Station, Chartiers Township, Washington County, Pennsylvania," Health Consultation (Agency for Toxic Substances and Disease Registry, Division of Community Health Investigations, January 29, 2016), http://www.atsdr.cdc.gov/HAC/pha/Brigich_Compressor_Station/Brigich_Compressor_Station_EI_HC_01-29-2016_508.pdf.
[2036] Staff Reports, "County Lawmakers Call for Study on Compressor Health Risks," *Lockport Union-Sun & Journal*, December 8, 2015, https://www.lockportjournal.com/news/local_news/county-lawmakers-call-for-study-on-compressor-health-risks/article_932989cd-058a-594f-9ef2-e52827db85a6.html.
[2037] Elana Schor and Andrew Restuccia, "The Hole in Obama's Pipeline Safety Plan," *Politico*, November 9, 2015, https://www.politico.com/story/2015/11/obama-pipeline-safety-plan-oil-215617.

could be met by renewable forms of energy such as solar and wind power…"[2038] (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.[2039]

- 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."[2040]

- 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 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.[2041] 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

[2038] Joe Mahoney, "EPA: Can Local Pipeline Plans Merge?," *The Daily Star*, October 16, 2015, https://www.thedailystar.com/news/local_news/epa-can-local-pipeline-plans-merge/article_f2836510-a96b-5c2d-9892-755b94b1f640.html.
[2039] Dan Packel, "Energy Honchos Lament FERC Pipeline Approval Delays - Law360," *Law 360*, September 17, 2015, https://www.law360.com/articles/697120/energy-honchos-lament-ferc-pipeline-approval-delays.
[2040] Sarah Smith, "SNL: As US Rushes to Build Gas Lines, Failure Rate of New Pipes Has Spiked," *S&P Global*, September 9, 2015, https://www.snl.com/interactiveX/article.aspx?CDID=A-33791090-11060&ID=33791090&Printable=1.
[2041] Eduardo P. Olaguer et al., "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, no. 2 (2016): 173–83, https://doi.org/10.1080/10962247.2015.1083914.

ambient monitoring.[2042] 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."[2043]

- 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.[2044]

- 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.[2045] A related study by a University of Houston team found that emission rates from compressor stations in Texas' Barnett Shale were far higher than from well pads.[2046, 2047]

- 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."[2048]

[2042] Eduardo P. Olaguer et al., "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, no. 2 (2016): 164–72, https://doi.org/10.1080/10962247.2015.1081652.
[2043] Dianna Wray, "Scientists Discover Pipelines Belching Benzene in East Houston," *Houston Press*, February 23, 2016, https://www.houstonpress.com/news/scientists-discover-pipelines-belching-benzene-in-east-houston-8181569.
[2044] Brian Nearing, "County: Put Study before Any Permit," *Times Union*, July 16, 2015, sec. News, https://www.timesunion.com/news/article/County-Put-study-before-any-permit-6387404.php.
[2045] Derek R. Johnson, April N. Covington, and Nigel N. Clark, "Methane Emissions from Leak and Loss Audits of Natural Gas Compressor Stations and Storage Facilities," *Environmental Science & Technology* 49, no. 13 (2015): 8132–38, https://doi.org/10.1021/es506163m.
[2046] Xin Lan et al., "Characterizing Fugitive Methane Emissions in the Barnett Shale Area Using a Mobile Laboratory," *Environmental Science & Technology* 49, no. 13 (2015): 8139–46, https://doi.org/10.1021/es5063055.
[2047] Lisa Song and Zahra Hirji, "Methane Emissions in Texas Fracking Region 50% Higher Than EPA Estimates," *Inside Climate News*, July 8, 2015, https://insideclimatenews.org/news/08072015/methane-emissions-texas-fracking-region-50-higher-epa-estimates-oil-gas-drilling-barnett-shale-environmental-defense-fund/.
[2048] Tegan N. Lavoie et al., "Aircraft-Based Measurements of Point Source Methane Emissions in the Barnett Shale Basin," *Environmental Science & Technology* 49, no. 13 (2015): 7904–13, https://doi.org/10.1021/acs.est.5b00410.

- 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.[2049]

- 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.[2050]

- 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 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."[2051]

- 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."[2052]

- 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

[2049] Amy Townsend-Small et al., "Integrating Source Apportionment Tracers into a Bottom-up Inventory of Methane Emissions in the Barnett Shale Hydraulic Fracturing Region," *Environmental Science & Technology* 49, no. 13 (2015): 8175–82, https://doi.org/10.1021/acs.est.5b00057.
[2050] Kyle Adams, "Schoharie County Officials Ask New Studies on Gas Lines," *The Daily Gazette*, July 1, 2015, https://dailygazette.wufoo.com/forms/k1mmje2u1rvcynr/.
[2051] Ayana R. Anderson, "Health Effects of Cut Gas Lines and Other Petroleum Product Release Incidents — Seven States, 2010–2012," *Morbidity and Mortality Weekly Report* 64, no. 22 (June 12, 2015): 601–5.
[2052] American Medical Association, "H-135.930 Protecting Public Health from Natural Gas Infrastructure, Resolution 519, A-15," 2015, https://www.ama-assn.org/sites/default/files/media-browser/public/hod/a15-hod-resolutions.pdf.

impact to human health and the environment of natural gas pipelines and calls for a governmental assessment of these risks.[2053]

- 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.[2054]

- 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 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.[2055] 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.[2056]

- 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

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[2053] Medical Society of the State of New York, "2015 House of Delegates Actions: Public Health and Education," 2015, http://www.mssny.org/Documents/HOD/Actions/ActionPHE.pdf.
[2054] David R. Brown, Celia Lewis, and Beth I. Weinberger, "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* 50, no. 5 (2015): 460–72, https://doi.org/10.1080/10934529.2015.992663.
[2055] Southwest Pennsylvania Environmental Health Project, "Summary on Compressor Stations and Health Impacts," February 24, 2015, https://sape2016.files.wordpress.com/2014/01/summary_report_compressor_stations_swpaehp.pdf.
[2056] Kathryn McKain et al., "Methane Emissions from Natural Gas Infrastructure and Use in the Urban Region of Boston, Massachusetts," *Proceedings of the National Academy of Sciences* 112, no. 7 (2015): 1941–46, https://doi.org/10.1073/pnas.1416261112.

considerable variation in emissions among the 45 compressor stations measured. Surprisingly, substantial emissions were found even when compressors were not operating.[2057]

- 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.[2058]

- 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 of natural gas pipeline in the United States and 175,000 miles of hazardous liquid pipeline (which includes crude oil).[2059]

- 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

[2057] R. Subramanian et al., "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, no. 5 (2015): 3252–61, https://doi.org/10.1021/es5060258.
[2058] Mike Wereschagin, "Rural Gas Gathering Pipelines Kindle Concerns about Safety Laws | TribLIVE.Com," *Trib Live*, December 27, 2014, https://archive.triblive.com/news/rural-gas-gathering-pipelines-kindle-concerns-about-safety-laws/#axzz3NAHfzYF8.
[2059] Kyle Siler-Evans et al., "Analysis of Pipeline Accidents in the United States from 1968 to 2009," *International Journal of Critical Infrastructure Protection* 7, no. 4 (2014), https://doi.org/10.1016/j.ijcip.2014.09.002.

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.[2060]

- 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.[2061] This resolution follows on the heels of similar resolutions expressing health concerns about the AIM project from both Westchester and Putnam County legislatures.[2062, 2063]

- 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."[2064]

- July 14, 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.[2065]

[2060] New York State Madison County Health Department, "Comments to the Federal Energy Regulatory Committee Concerning Docket No. CP14-497-000, Dominion Transmission, Inc," October 15, 2014.
[2061] Rockland County Legislature, "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," September 16, 2014, https://sape2016.files.wordpress.com/2014/05/rockland-aim-resolution.pdf.
[2062] Board of Legislators County of Westchester, State of New York, "Resolution RES-2014-80 Algonquin Incremental Marketing Project Resolution," July 21, 2014, https://sape2016.files.wordpress.com/2014/05/080414-wcbol-resolution-no-80-2014-requesting-due-diligence-on-environment-p.pdf.
[2063] Putnam County Legislature, "Resolution #104, Resolution Regarding the Algonquin Incremental Market (AIM) Project," May 9, 2014, https://sape2016.files.wordpress.com/2014/05/putnam-county-resolutions-104-163-and-182-1.pdf.
[2064] Khanh T. Tran, "AERMOD Modeling of NO2 Impacts of the Barto Compressor Station," Final Report (AMI Environmental, January 24, 2013), https://crawler.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Regulations%20and%20Clean%20Air%20Plans/AERMOD%20NO2%20Modeling%20of%20Barto%20Compressor%20Station%20-%20Jan%2024%202013.pdf.
[2065] Eastern Research Group, "Fort Worth Natural Gas Air Quality Study Final Report," July 14, 2011, https://www.fortworthtexas.gov/departments/development-services/gaswells/air-quality-study/final.

Gas storage

Gas storage facilities include not only manmade holding tanks but also geological formations, most notably, aquifers, abandoned salt caverns, mines, and depleted oil fields left over from drilling operations. These unlined cavities were not created with the intent to store pressurized hydrocarbon gases, nor are they engineered for this purpose. Leakage from these facilities has resulted in water contamination, air pollution and explosions.

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 relocated, thousands were sickened, and two public schools closed. As determined by a 2019 final report, the root cause of the Aliso Canyon blowout was a corroded well casing and lack of a shut-off valve in a half-century-old well.

Data released in 2018 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. Many natural gas storage facilities approached capacity in 2020 as low demand and low prices created an enduring supply glut.

While not as common as depleted oil fields, salt cavern gas storage facilities suffer a disproportionate number of serious problems, including loss of cavern integrity and consequent gas migration.

- May 20, 2021 –Nova Scotia's geology includes salt formations along the Shubenacadie River where Alton Gas is proposing to build a gas storage facility. Despite a centuries-old treaty which gives the indigenous Mi'kmaq people rights to this land and river, they were not consulted during the permitting process. Mi'kmaq elders objecting to the construction predict certain destruction of land and river life from construction and maintenance of the gas storage facility. Critics also fear dire safety issues for indigenous women living in the area and along the 85-mile corridor that is proposed to connect the storage facility to the proposed LNG terminal 85 miles away."[2066]

- April 30, 2021 – A $25 million public health research study on impacts of the 2015 gas leak at Aliso Canyon is the result of a $120 million settlement between Southern Gas California Co., Los Angeles County, the City of Los Angeles, and the state agencies. The

[2066] Karen Edelstein, "Gas Storage Plan vs. Indigenous Rights in Nova Scotia" (FracTracker Alliance, May 20, 2021), https://www.fractracker.org/2021/05/gas-storage-plan-vs-indigenous-rights-in-nova-scotia/.

Los Angeles *Daily News* reported widespread community dissatisfaction with the direction of the study, which was spearheaded by the public health department with guidance from a scientific oversight committee and a community advisory group (CAG). The public health department released a study draft identifying key areas the health study should address, which the CAG has described as too broad and underdeveloped. "The CAG unanimously agrees that the loose draft language of the study's goals and priorities invites a mediocre study by encouraging the use of data proxies and environmental abstractions," said Craig Galanti, a member of CAG. Criticizing a reliance on publicly available, utility-derived data for a modeling study, the group cited a 2018 report by the California Council on Science and Technology which concluded that such air quality monitoring missed the first few days of the blowout, when exposures to the highest concentrations likely occurred. In addition, the CAG expressed the need for a clinically-based, human-subject focused study. "CAG members say if the health study doesn't include the chemical list, a cancer surveillance study, accurate air monitoring and benzene exposure data, it wouldn't be complete."[2067]

- April 7, 2021 – A 2019 blowout of 100,000 cubic feet of natural gas from Southern California's Playa del Rey oilfield served as a reminder of the long legacy of fossil fuel extraction and storage on the west side of Los Angeles. Playa del Rey's sandstone formation thousands of feet underground holds natural gas in an operation similar to that of Aliso Canyon. Both storage fields, reported the *Los Angeles Times*, have a long history of leaks. Opposition to Playa del Rey's gas storage field is growing, including among elected officials, in the form of municipal resolutions to close the facility and a call from the Los Angeles County Board of Supervisors to study the feasibility of closure. Though it has less than three percent of the storage capacity of Aliso Canyon, 45,000 people live within a mile of Playa del Rey field, compared with 6,500 within a mile of Aliso. Four thousand people live directly above the Playa del Rey storage field. A 2019 Harvard study singled out the field as particularly risky. [See July 8, 2019 entry below.][2068]

- January 12, 2021 – A study of surface deformation caused by the convergence of multiple underground gas storage facilities focused on the increasing use of salt caverns for gas storage, and resultant changes in pressure inside those caverns due to injection, unloading, and additional leaching. These can cause significant cavern disruption which can lead to deformation and subsidence. The study described an effective multi-parameter method for determining changes in rock mass deformation for salt caverns, as well for predicting the surface deformation for a large field of salt caverns.[2069]

- October 28, 2020 – Using Bayesian analysis, researchers calculated the frequency of accidents, incidents, failures, and other problematic events at U.S. underground natural

[2067] Olga Grigoryants, "Residents, Activists Express No Confidence in L.A. County's Aliso Canyon Gas Leak Health Study," *Los Angeles Daily News*, April 30, 2021, https://www.dailynews.com/2021/04/30/residents-activists-express-no-confidence-in-l-a-countys-aliso-canyon-gas-leak-health-study/.
[2068] Sammy Roth, "The Next Aliso Canyon Could Happen on L.A.'s Westside," *Los Angeles Times*, April 7, 2021, https://www.latimes.com/business/story/2021-04-07/aliso-canyon-natural-gas-playa-del-rey.
[2069] Krzysztof Tajduś et al., "Surface Deformations Caused by the Convergence of Large Underground Gas Storage Facilities," *Energies* 14, no. 2 (2021), https://doi.org/10.3390/en14020402.

gas storage facilities for each of the 31 states that host such facilities. Depleted oil and gas fields, which are, by far, the most common type of underground gas storage facility in the United States and have been in operation for the longest time, showed the highest number of problematic occurrences. Aquifer storage, though not as common, has led to contamination of drinking water wells on neighboring properties. Many occurrences have been linked with salt-cavern storage over a relatively small number of facility-years, and these include serious problems such as loss of cavern volume, loss of cavern integrity, gas migration into adjacent brine caverns, and elevated cavern pressures, which can endanger surface wellheads and related infrastructure of the brine caverns. "States having the largest number of occurrences at the lowest, nuisance-group level of severity are California and Pennsylvania (for oil-and-gas storage), Iowa and Illinois (for aquifer storage), and Texas (for salt-cavern storage)." [See also entry below for November 5, 2019.][2070]

- July 29, 2020 – A natural gas storage facility exploded in Mont Belvieu, Texas after a contractor struck an underground pipeline.[2071] The facility belonging to Lone Star NGL, a subsidiary of Dallas-based Energy Transfer LP, stores and processes natural gas liquids, including propane, butane and ethane. Five hundred and thirty-five miles of pipeline from the Permian Basin, Barnett Shale and East Texas transport natural gas liquids to the Mont Belvieu storage and fractionation facility. A company spokeswoman said that the company planned an investigation.

- June 30, 2020 – SoCalGas executives sought to delay by six months the next round of mechanical integrity tests on wells used to access the Aliso Canyon gas storage field, site of the 2015 four-month blowout releasing 100,000 metric tons of methane.[2072] These tests were required after a root cause analysis had determined that the blowout was caused by a faulty well casing at the facility, linked to microbial corrosion caused by contact with groundwater. (See entry for May 16, 2019.) California regulators instituted new regulations following the disaster, including the requirement that all wells undergo mechanical integrity tests at least once every two years. SoCalGas asked the state to suspend the requirement, citing the pandemic. The request was denied.

- June 9, 2020 – Use of the SoCalGas Aliso Canyon gas storage field has vastly expanded during California Governor's Newsome's tenure, despite a stated commitment to close the facility following the 2015 massive blowout.[2073] SoCalGas withdrew 20 billion cubic

[2070] Richard A. Schultz and David J. Evans, "Occurrence Frequencies and Uncertainties for US Underground Natural Gas Storage Facilities by State," *Journal of Natural Gas Science and Engineering* 84 (2020), https://doi.org/10.1016/j.jngse.2020.103630.
[2071] Julian Gill and Erin Douglas, "Natural Gas Storage Facility Explodes in Mont Belvieu," *Houston Chronicle*, July 29, 2020, sec. Houston, https://www.houstonchronicle.com/news/houston-texas/houston/article/Explosion-reported-at-Mont-Belvieu-industrial-15444117.php.
[2072] Sammy Roth, "Remember the Aliso Canyon Disaster? SoCalGas Just Tried to Delay Safety Tests," *Los Angeles Times*, June 30, 2020, sec. Climate & Environment, https://www.latimes.com/environment/story/2020-06-30/remember-the-aliso-canyon-disaster-socalgas-just-tried-to-delay-safety-tests.
[2073] Sammy Roth, "SoCalGas Ramps up Use of Aliso Canyon, Site of Worst Gas Leak in U.S. History," *Los Angeles Times*, June 9, 2020, sec. Climate & Environment, https://www.latimes.com/environment/story/2020-06-09/socalgas-ramps-up-use-of-aliso-canyon-site-of-worst-gas-leak.

feet of gas from the facility in winter 2019-2020, up from 14 billion the winter before, and one billion in 2017-2018. "The more the gas company uses the storage field, the higher the risk of additional leaks," said USC engineering professor Najmedin Meshkati, who authored a study examining the causes. (See December 1, 2017 entry.)

- May 20, 2020 – The *Texas Observer* reported on threats to the state's drinking water from changing oil and gas storage practices in Texas during a time of supply glut, negative prices for oil, and a growing scarcity of Gulf Coast storage tank capacity. As producers sought to store their excess oil and gas in underground salt caverns, in the same way the U.S. Strategic Petroleum Reserve stores their crude, the Texas Railroad Commission, which regulates oil and gas producers in that state, granted permission for such storage up for to five years. Commissioners also lifted the requirement to hold public hearings. Environmental groups and scientists decried the absence of formal opportunity for public comment, particularly concerned about the threat to the nine aquifers across Texas, which provide 60 percent of the state's water and underlie the oil fields. "Is it going to stay there and not leak into the aquifer?…The environmental concerns are the biggest issue here," according to Ramanan Krishnamoorti, petroleum engineer at the University of Houston.[2074] The agency's history of indifference toward potential contamination of aquifers is longstanding. "In 2014, the commission sided with Marathon Oil Company when a local groundwater conservation district raised concerns about the company injecting drilling waste into a productive South Texas aquifer. In its most recent annual report on groundwater contamination in Texas, a group of state agencies tasked with studying the issue found roughly 630 cases of groundwater contamination linked to 'total petroleum hydrocarbons' in 2018." *The Observer* noted that another risk of gas and oil storage in salt caverns is explosion. One such accident in 1992 in Brenham, TX killed a six-year-old boy and injured 13 others.

- May 18, 2020 – Gas storage has reached capacity as natural gas exceeds demand, and prices plummet, according to *Oilprice.com.*[2075] In Europe as in the United States, these trends have been exacerbated by mild weather in winter 2019-2020, more renewable energy production, and a crash in industrial demand for gas amid the pandemic. Although prospects for gas are better than oil because of the electrical generation industry, demand for gas will continue to decrease significantly if Europe embraces a green recovery and renewable energy sources are pressured to expand.

- April 15, 2020 – Using advanced remote sensing and in situ observations of near-surface atmospheric methane combined with wind data, researchers studied twelve active underground gas storage facilities in California, including Aliso Canyon, between January 2016 and November 2017 to determine net annual methane emissions.[2076] The

[2074] Christopher Collins, "With Storage Space Evaporating, the Oil and Gas Industry Will Get to Put Its Products Back Underground," *The Texas Observer*, May 20, 2020, https://www.texasobserver.org/underground-storage-oil-rule-rollback/.
[2075] Irina Slav, "Natural Gas Drillers Face Price Meltdown As Storage Fills Fast," *OilPrice.Com*, May 18, 2020, https://oilprice.com/Energy/Crude-Oil/Natural-Gas-Drillers-Face-Price-Meltdown-As-Storage-Fills-Fast.html.
[2076] Andrew K Thorpe et al., "Methane Emissions from Underground Gas Storage in California," *Environmental Research Letters* 15, no. 4 (2020): 045005, https://doi.org/10.1088/1748-9326/ab751d.

team, consisting of scientists from CalTech, Stanford, Lawrence Berkeley National Laboratory, and other institutions, said their "analysis reveals significant discrepancies with the State's accounting of UGS emissions as well as under reporting by individual facilities which if unresolved could impede efforts to meet future mitigation targets," and they found this conclusion to be consistent for both of their estimation techniques. The study's 2016 estimations of net annual methane emissions for the seven facilities that did report were approximately five times higher than they reported. Methane has been targeted for emissions mitigation by the State of California, including legislation focused on natural gas leak detection and repair and identification of emission hotspots. This study's findings included that, even since the massive Aliso Canyon release, researchers found persistent venting from the shutdown stack and episodic venting from equipment. Results from other facilities included highly variable emissions, and this variability "remains one of the most challenging aspects of UGS emissions quantification, underscoring the need for more systematic and persistent methane monitoring."

- April 10, 2020 – Ethane, a byproduct of fracked shale gas and needed to produce plastics, is often stored in underground caverns. Cracker plants, which would use the ethane, are being constructed and proposed along the Ohio River around Pittsburgh, Pennsylvania, to use the wet fracked gas from Pennsylvania and Ohio. A 2017 an Appalachian Oil and Natural Gas Research Consortium study identified regions in West Virginia, Pennsylvania, and Ohio for constructing caverns in underground salt beds or limestone rock, as well as in abandoned gas fields, for storing natural gas liquids. An *Inside Climate News* piece provided this background, as well as the mechanics of underground gas storage, for examining the history and hazards of Mont Belvieu, 30 miles northeast of Houston, the world's largest natural gas liquids underground storage area.[2077] Mont Belvieu has a history of environmental calamities, and the complex's operator continues to be the target of enforcement actions. In view of that history, the Ohio River underground storage facilities are being promoted as very different from the accident-prone and violation-ridden Mont Belvieu. "We just want to be a warehouse," said David Hooker, president of Mountaineer NGL Storage, which is developing a site along the Ohio River in Monroe County.

- March 24, 2020 – In 2016 Nova Scotia's environment minister, Margaret Miller, permitted a gas storage facility on the banks of the Shubenacadie River. Alton Gas, a subsidiary of Calgary-based energy company AltaGas, proposed to store up to 10 billion cubic feet of natural gas in underground caverns. The Sipekne'katik First Nation sued to stop the project both because it is Aboriginal land and because the process would cause significant pollution of the river. The storage cavern would be created by flushing nearby salt deposits with water from the Shubenacadie River. As reported by the CBC, the Nova

[2077] James Bruggers, "For the Ohio River Valley, an Ethane Storage Facility in Texas Is Either a Model or a Cautionary Tale," *Inside Climate News*, April 10, 2020, https://insideclimatenews.org/news/10042020/ethane-plant-appalachia-mont-belvieu-texas/.

Scotia Supreme Court agreed to a delay of at least 120 days and has ordered the province to resume consultations with Sipekne'katik First Nation.[2078]

- March 20, 2020 – In 2016, Congress passed the Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act requiring the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) to promulgate underground natural gas storage safety regulations following the massive 2015 Aliso Canyon gas leak. In February 2020, PHMSA issued its Final Rule, which weakened existing safety regulations applicable to underground natural gas storage facilities, including limiting the type of accidents or routine maintenance activities that had previously been deemed reportable. Only well plugging or abandonment or maintenance costing more than $200,000 now require reporting to PHMSA. According to the legal news digest, *JD Supra*, "the Final Rule provides clarifications to the Interim Final Rule in ways that should benefit storage operators," and the agency resisted in its rule "calls to impose additional safety requirements on storage operators at least for the foreseeable future."[2079]

- January 24, 2020 – Porter Ranch residents presented in Superior Court the damages they sustained from the massive Aliso Canyon gas storage site gas leak and the actions they would have taken to protect themselves and their property if SoCalGas had not delayed in notifying authorities and residents. A state appeals court panel had ruled that residents were entitled to this hearing addressing "whether petitioners can prove damages from the three-day delay in reporting the leak, as charged in the criminal complaint." At 2016 settlement talks between prosecutors and SoCalGas, residents complained of not being part of the proceedings and left unable to seek restitution. Many residents are still sick and property still contaminated, according to the residents' attorney.[2080]

- January 7, 2020 – *NBC Los Angeles* reported that Los Angeles County Board of Supervisors unanimously called on California Governor Gavin Newsom to expedite the closure of the Aliso Canyon natural gas storage facility in Porter Ranch, site of the largest methane leak in U.S. history.[2081] Supervisor Kathryn Barger said, "We do not know what the long-term impacts of the gas leak will be… The only way to preserve the health and safety of the residents around Aliso Canyon is for it to close." Operator of the site, SoCalGas continued to maintain that the site is needed to provide an affordable electric energy supply. Fearing expansion at another SoCalGas storage facility in the Los Angeles

[2078] Taryn Grant, "Siding with First Nation, N.S. Judge Overturns Alton Gas Approval | CBC News," *CBC*, March 24, 2020, https://www.cbc.ca/news/canada/nova-scotia/alton-gas-nova-scotia-supreme-court-appeal-decision-1.5508130.
[2079] James Bowe Jr. and William Rice, "PHMSA Issues Final Rule on Underground Natural Gas Storage Safety Establishing a Phased-in, Multi-Year Timeframe for Integrity Management," *JD Supra*, March 21, 2020, https://www.jdsupra.com/legalnews/phmsa-issues-final-rule-on-underground-60203/.
[2080] Tom Bray, "Aliso Canyon Gas Leak Victims Argue for Restitution; No Ruling Yet," *Daily News*, January 24, 2020, https://www.dailynews.com/2020/01/24/aliso-canyon-gas-leak-victims-argue-for-restitution-no-ruling-yet.
[2081] City News Service, "LA County Calls on Governor to Expedite Closure of Aliso Canyon," *NBC Los Angeles*, January 7, 2020, https://www.nbclosangeles.com/news/local/la-county-calls-on-governor-to-expedite-closure-of-aliso-canyon/2286869/.

area, a Supervisor successfully added an amendment to the Board's call to the governor, requesting a feasibility study of closing the Playa del Rey facility.

- November 19, 2019 – California Governor Gavin Newsom called on California's utilities regulator to identify ways to accelerate the pace to state reliance on renewables, with the objective of closing the Aliso Canyon gas storage facility. Renewable energy sources like solar and wind play increasing roles in California's energy landscape, but natural gas still accounts for the largest single source of in-state generation, at 46.5 percent. Environmental groups criticized the Governor's call for additional study, citing an independent energy consulting group's finding that natural gas injections at Aliso Canyon were not needed in the short-term. For the long-term, the report said that advances in energy efficiency and carbon-free storage will make Aliso Canyon obsolete. At the time of this San Diego *Tribune* report, Aliso Canyon gas storage was permitted at about 39 percent of maximum capacity, after the initial resumption in July 2017.[2082]

- November 5, 2019 – The first probabilistic analysis of natural gas accidents—variously referred to as events, incidents, accidents, or failures across studies—at underground gas storage facilities in the United States found in its review an occurrence rate "larger than has been previously reported."[2083] The researchers predicted, "The probability of one serious or catastrophic leakage occurrence to the ground surface within the next 10 years, assuming constant number of facilities, is approximately 0.1–0.3% for any facility type." Using a Bayesian statistical approach, an inference method that integrates new data with existing knowledge, researchers said that their study "demonstrates the value of collecting new historical data for occurrences as well as comparing the newly acquired data to earlier databases." The study's characterization of risks to plan improved risk management and regulatory policy of underground gas storage facilities included cause, severity, and uncertainty for depleted oil-and-gas field storage, aquifer storage, and solution-mined salt cavern storage. Depleted oil-and-gas field storage showed the largest probabilities and the smallest uncertainties for accidents.

- October 15, 2019 – As the October 2019 Saddleridge Fire burned and a fire broke out and burned for 24 hours next to the Aliso Canyon gas storage facility, residents of Porter Ranch, California prepared for mandatory evacuation, *Knock LA* reported.[2084] Since and before the oil field was repurposed for gas storage in 1973, fires have been frequent at and around the facility, some caused by ruptured gas lines and others triggered by earthquakes. Although the local department of health failed to warn residents to wear respirator masks until 12 hours after the evacuation, a physician in the area advised residents to use respirators for protection against particulate matter that included not only

[2082] Rob Nikolewski, "Newsom Looks to Accelerate Time Line for Closing Aliso Canyon Natural Gas Facility," *San Diego Union-Tribune*, November 20, 2019, sec. Energy, https://www.sandiegouniontribune.com/business/energy-green/story/2019-11-19/newsom-looks-to-accelerate-time-line-for-closing-aliso-canyon-natural-gas-facility.
[2083] Richard A. Schultz et al., "Characterization of Historical Methane Occurrence Frequencies from U.S. Underground Natural Gas Storage Facilities with Implications for Risk Management, Operations, and Regulatory Policy," *Risk Analysis* 40, no. 3 (2020): 588–607, https://doi.org/10.1111/risa.13417.
[2084] Patty Crost Glueck, "As The North SFV Burns, Worries About The Aliso Canyon Gas Storage Facility Ignites," *Knock LA*, October 15, 2019, https://knock-la.com/as-the-north-sfv-burns-worries-about-the-aliso-canyon-gas-storage-facility-ignites-ec12a3b38027/.

soot from burned vegetation, but also from burning contaminants released during the Aliso Canyon blowout. The piece referenced the recent study (See Jun 26, 2019 entry below) that found "a broad range of hazardous air pollutants (HAPs)" co-emitted during the Aliso Canyon blowout and during "final well kill attempts." Two deaths were reported in the aftermath of the fire: that of a park ranger and a Porter Ranch resident, both of heart attacks, known health consequences of particulate matter exposure.

- July 31, 2019 – A *ProPublica* investigation explored the political connections behind the proposed Appalachian Storage and Trading Hub, a $10 billion dollar mammoth underground storage facility for ethane and other byproducts used in plastics manufacturing.[2085] West Virginia state officials see the reserves that form the largest natural gas field in the world as "a path to renewed political and economic relevance for the Mountain State, which they envision rivaling the Gulf Coast as a center for processing natural gas and producing plastics." However, such a large facility is beyond what the region could support and carries a range of risks. West Virginia leaders sought a $1.9 billion federal loan guarantee, one of the largest ever considered, and which could leave taxpayers on the hook in the event the project fails, as well as looking to the federal government for a "streamlined" review process. The hub's prospects were considered weakened by "uncertainty and turmoil" of the U.S.-China trade war.

- July 8, 2019 – Tens of thousands of U.S. homes and residents are located within a proposed underground gas storage (UGS) "Wellhead Safety Zone" of active UGS wells, according to a multi-institution study comparing methods of estimating this hazard.[2086] In some cases homes and residents were within a state's oil and gas well surface setback distance. Lead author Drew Michanowicz, of the Center for Climate, Health and Global Environment at the Harvard T.H. Chan School of Public Health said to *West Virginia Public Radio*, "Our results were somewhat surprising in that a lot of these wells are in residential suburban areas, which in terms of the entire natural gas supply chain is definitely a unique kind of land use conflict."[2087] The researchers applied a new method of allocating an average person per household to geospatially-identified residential housing unit. This new method showed 65 percent of UGS wells occupying residential urban and suburban areas, and across the six states studied, 41 percent of underground storage wells were located within one city block of at least one home. As reported by *West Virginia Public Radio*, "in Ohio, more than half of the state's underground storage wells are located within one block of a residence" and "affected an estimated 12,000 Ohio homes and over 30,000 residents." The new method provided more precise estimates than the previous standard method, but by either benchmark, there is "a substantial degree of land use conflict between populations and UGS wells" in Ohio.

[2085] Keith Schneider, "West Virginia Bets Big on Plastics, and on Backing of Trump Administration," *ProPublica*, 2019, https://www.propublica.org/article/appalachian-storage-and-trading-hub-ethane-west-virginia-plastics-backing-of-trump-administration.

[2086] Drew R. Michanowicz et al., "Population Allocation at the Housing Unit Level: Estimates around Underground Natural Gas Storage Wells in PA, OH, NY, WV, MI, and CA," *Environmental Health* 18, no. 1 (December 2019): 58, https://doi.org/10.1186/s12940-019-0497-z.

[2087] Brittany Patterson, "Study Finds Thousands Live Near Underground Natural Gas Storage Wells," *WVPB*, July 9, 2019, sec. WVPB News, https://www.wvpublic.org/news/2019-07-09/study-finds-thousands-live-near-underground-natural-gas-storage-wells.

- Jun 26, 2019 – Scientists from the United Kingdom, China, and the United States conducted a study of links between particulate matter (PM), hazardous air pollutants (HAPS), and methane emissions, during the Aliso Canyon gas storage facility blowout.[2088] Samples obtained during the massive methane release showed a unique gas and particle concentration in ambient air and a characteristic "fingerprint" of metals in the indoor dust samples, similar to samples taken at the blowout site. These analyses, together with health surveys of several households, provided plausible explanations for health symptoms that persisted post-remediation. Various kill-well attempts were a source of multiple toxic air pollutants, such as various sizes of PM and volatile organic compounds (VOCs). Of note in their analyses, the researchers found that long-term averaged HAPs levels were normal, but short samplings, such as the individual 5-minute "trigger" samples, identified elevated concentrations, several above health benchmarks. Speaking to *CleanTechnica*, lead author UCLA environmental health scientist Diane A. Garcia-Gonzales said, "Our findings demonstrate that uncontrolled leaks or blowout events at natural gas storage facilities can release pollutants with the potential to cause not only environmental harm, but also adverse health consequences in surrounding communities."[2089] Adding to the complicated picture, researchers lacked baseline measurements, the full range of toxins emitted during the active blowout may not have been sampled, and the study may not have addressed all potentially biologically relevant pollutants; elevations in HAPs benzene, known to cause cancer, and hexane and xylene, neurotoxins also harmful to human health, all correlated with elevated methane levels.

- May 16, 2019 – A root cause analysis of the 2015 Aliso Canyon blowout determined that surface corrosion on the outside of well casing was the immediate cause of the disaster that sent uncontrolled releases of methane into the air for 111 days. Prolonged contact with groundwater and microbes, most likely methanogenic Archaea, was the underlying cause of the corrosion. Additional contributing factors identified in this final report include lack of detailed follow-up investigations after other failure events in the Aliso Canyon storage field; lack of investigations following the discovery of corrosion in other wells; lack of any form of risk assessment focused on wellbore integrity management; lack of understanding of groundwater depths; and lack of a dual mechanical barrier system in the wellbore.[2090]

- 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

[2088] Diane A. Garcia-Gonzales et al., "Associations among Particulate Matter, Hazardous Air Pollutants and Methane Emissions from the Aliso Canyon Natural Gas Storage Facility during the 2015 Blowout," *Environment International* 132 (2019): 104855, https://doi.org/10.1016/j.envint.2019.05.049.
[2089] Charles W. Thurston, "New Study Calls For Monitoring Old Oil & Gas Wells For Air Emissions," *CleanTechnica*, June 27, 2019, https://cleantechnica.com/2019/06/27/new-study-calls-for-monitoring-old-oil-gas-wells-for-air-emissions/.
[2090] Blade Energy Partners, "Root Cause Analysis of the Uncontrolled Hydrocarbon Release from Aliso Canyon, SS-25," Main Report, May 16, 2019, https://www.socalgas.com/sites/default/files/SoCalGas-75-Served-03-15-21.pdf.

degree of gas leakage risks, no matter what kind of construction process is used to create the gas storage reservoir.[2091]

- December 17, 2018 – 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.[2092]

- 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.[2093]

- 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 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

[2091] Xiao Wei and Zhang Zhichao, "Study on the Production Mode and Leakage Risk of Gas Storage Well Completion," *IOP Conference Series: Earth and Environmental Science* 233 (2019): 042007, https://doi.org/10.1088/1755-1315/233/4/042007.
[2092] Michael MacDonald, "More Delays for Underground Cavern Gas Storage Plan North of Halifax," *CBC*, December 17, 2018, https://www.cbc.ca/news/canada/nova-scotia/delays-underground-cavern-gas-storage-alton-natural-gas-1.4949423.
[2093] Xiangsheng Chen et al., "Study on Sealing Failure of Wellbore in Bedded Salt Cavern Gas Storage," *Rock Mechanics and Rock Engineering* 52, no. 1 (2019): 215–28, https://doi.org/10.1007/s00603-018-1571-5.

caverns would be required to assess possible leaks.[2094, 2095]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.[2096]

- 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."[2097]

- 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.[2098] These statistics update an earlier estimate by Harvard University researcher Drew Michanowicz, who, consulting earlier databases, had pegged the number of Aliso-type wells at about 2,700.[2099] (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

[2094] State of New York Department of Environmental Conservation, "Finger Lakes LPG Storage, LLC - Decision of the Commissioner, Final Supplemental Environmental Impact Statement, and SEQRA Findings Statement, July 12, 2018," July 12, 2018, https://www.dec.ny.gov/hearings/114139.html.
[2095] Jeff Platsky, "Crestwood Acknowledges Possible Leaks in Proposed LPG Storage in Seneca Lake Mines," *Press & Sun-Bulletin*, May 21, 2018, https://www.pressconnects.com/story/news/local/2018/05/21/crestwood-seneca-lake-gas-storage/629768002/.
[2096] Jon Campbell, "Crestwood's Seneca Lake Propane Storage Facility Rejected by DEC," *Press & Sun-Bulletin*, July 12, 2018, https://www.pressconnects.com/story/news/2018/07/12/dec-rejects-plan-crestwood-propane-storage-facility-seneca-lake/779605002/.
[2097] Tongtao Wang et al., "Geomechanical Investigation of Roof Failure of China's First Gas Storage Salt Cavern," *Engineering Geology* 243 (2018): 59–69, https://doi.org/10.1016/j.enggeo.2018.06.013.
[2098] U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, "Gas Distribution, Gas Gathering, Gas Transmission, Hazardous Liquids, Liquefied Natural Gas (LNG), and Underground Natural Gas Storage (UNGS) Annual Report Data | PHMSA," 2018, https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids.
[2099] Drew Michanowicz, "Op-Ed: The Aliso Canyon Gas Leak Was a Disaster. There Are 10,000 More Storage Wells out There Just like It," *Los Angeles Times*, May 14, 2018, sec. Opinion, https://www.latimes.com/opinion/op-ed/la-oe-michanowicz-aliso-canyon-gas-leak-20180514-story.html.

introductory guide to provide basic information about the Mahomet Aquifer and natural gas storage in east-central Illinois.[2100] (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.[2101]

- 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."[2102] 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."[2103]

- 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

[2100] R. Locke et al., "An Introductory Guide to the Mahomet Aquifer and Natural Gas Storage in East Central Illinois" (Prairie Research Institute, 2018), 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.
[2101] Jane C. S. Long et al., "Long-Term Viability of Underground Natural Gas Storage in California: An Independent Review of Scientific and Technical Information," Technical Report (California Council of Science and Technology, January 18, 2018), https://ccst.us/reports/long-term-viability-of-underground-natural-gas-storage-in-california-an-independent-review-of-scientific-and-technical-information/.
[2102] Maryam Tabibzadeh et al., "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*, 2017, https://doi.org/10.7569/JSEE.2017.629515.
[2103] Zen Vuong, "Who Should Be Held Responsible for the Aliso Canyon Gas Leak?," *USC News*, February 15, 2018, https://news.usc.edu/136300/who-should-be-held-responsible-for-the-aliso-canyon-gas-leak/.

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.[2104]

- 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.[2105]

- 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.[2106, 2107]

- 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.[2108]

[2104] U.S. Government Accountability Office, "Natural Gas Storage: Department of Transportation Could Take Additional Steps to Improve Safety Enforcement Planning," Report to Congressional Requesters, November 22, 2017, https://www.gao.gov/assets/690/688553.pdf.
[2105] Rich Nemec, "PHMSA Pauses Stricter Natural Gas Storage Rules for Clarification," *Natural Gas Intelligence*, June 21, 2017, sec. Regulatory, https://www.naturalgasintel.com/phmsa-pauses-stricter-natural-gas-storage-rules-for-clarification/.
[2106] Drew R Michanowicz et al., "A National Assessment of Underground Natural Gas Storage: Identifying Wells with Designs Likely Vulnerable to a Single-Point-of-Failure," *Environmental Research Letters* 12, no. 6 (2017): 064004, https://doi.org/10.1088/1748-9326/aa7030.
[2107] Institute of Physics, "Study Uncovers Widespread Leak Risk for US Underground Natural Gas Storage Wells," *Phys.Org*, May 24, 2017, https://phys.org/news/2017-05-uncovers-widespread-leak-underground-natural.html.
[2108] California Air Resources Board, "Determination of Total Methane Emissions from the Aliso Canyon Natural Gas Leak Incident | California Air Resources Board," October 21, 2016, https://ww2.arb.ca.gov/resources/documents/determination-total-methane-emissions-aliso-canyon-natural-gas-leak-incident.

- 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.[2109]

- 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.[2110]

- 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.[2111]

- 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.[2112] (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.)

- 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.[2113] This is the first

[2109] U.S. Department of Energy and U.S. Department of Transportation's Pipeline & Hazardous Materials Safety Administration, "Ensuring Safe and Reliable Underground Natural Gas Storage: Final Report of the Interagency Task Force on Natural Gas Storage Safety," October 18, 2016, https://energy.gov/sites/prod/files/2016/10/f33/Ensuring%20Safe%20and%20Reliable%20Underground%20Natural%20Gas%20Storage%20-%20Final%20Report.pdf.
[2110] Susan Abram, "SoCalGas Slammed for Poor Cleanup of Porter Ranch Homes," *Daily News*, July 13, 2016, https://www.dailynews.com/health/20160713/socalgas-slammed-for-poor-cleanup-of-porter-ranch-homes.
[2111] Dana Bartholomew, "Gas Company, Pollution Agency at Odds over Cost of Porter Ranch Health Study," *Daily News*, July 9, 2016, https://www.dailynews.com/government-and-politics/20160709/gas-company-pollution-agency-at-odds-over-cost-of-porter-ranch-health-study.
[2112] Timothy Cama, "Obama Signs Pipeline Safety Bill," *TheHill*, June 22, 2016, https://thehill.com/policy/energy-environment/284479-obama-signs-pipeline-safety-bill.
[2113] D. R. Thompson et al., "Space-based Remote Imaging Spectroscopy of the Aliso Canyon CH_4 Superemitter," *Geophysical Research Letters* 43, no. 12 (2016): 6571–78, https://doi.org/10.1002/2016GL069079.

time a natural gas leak has been visible from space, according to the authors of the study.[2114]

- 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.[2115]

- 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."[2116]

- 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."[2117]

- 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.[2118] 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 faulty valves, flanges and leaky wellheads and a 230th leak at an abandoned well; eight were deemed hazardous.[2119]

[2114] Chris Mooney, "This Gas Leak Was so Massive That NASA Saw It from Space," *Washington Post*, June 15, 2016, https://www.washingtonpost.com/news/energy-environment/wp/2016/06/15/this-gas-leak-was-so-massive-that-nasa-saw-it-from-space/.
[2115] Ivan Penn, "Costs Related to Aliso Canyon Leak Reach an Estimated $665 Million," *Los Angeles Times*, May 4, 2016, sec. Business, https://www.latimes.com/business/la-fi-aliso-canyon-costs-20160504-snap-story.html.
[2116] Ivan Penn, "'This Is a Threat. This Is Not a Report.' Critics Call Blackout Warnings a Scare Tactic to Keep Aliso Canyon Open," *Los Angeles Times*, April 12, 2016, sec. Business, https://www.latimes.com/business/la-fi-gas-field-20160412-story.html.
[2117] Andrew Khouri, "Gas Leak Disrupts Porter Ranch Housing Market," *Los Angeles Times*, April 6, 2016, sec. Real Estate, https://www.latimes.com/business/realestate/la-fi-porter-ranch-sales-20160406-story.html.
[2118] California Department of Conservation, "State Oil & Gas Division Issues $75,000 Fine to Operator for Illegally Venting Natural Gas," March 18, 2016, http://www.conservation.ca.gov/index/Documents/2016-06%20DOC%20fines%20oil%20operator%20$75,000.pdf.
[2119] Paige St. John, "229 Leaks Found in State's Underground Gas Storage Facilities, Most Considered Minor," *Los Angeles Times*, March 24, 2016, sec. California, https://www.latimes.com/local/lanow/la-me-ln-gas-leaks-storage-wells-20160322-story.html.

- 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.[2120]

- 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.[2121] Aliso Canyon was already a major pollution source before the massive leak.[2122] As determined by the study and reported by major news outlets, the recent methane link is officially the worst in U.S. history.[2123, 2124]

- February 18, 2016 – Stanford and UCLA scientists reported to *Inside Climate 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 that first week at least.'" Jackson noted that even after monitoring was initiated, it was intermittent rather than continuous.[2125]

- 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-

[2120] Francesca M. Hopkins et al., "Spatial Patterns and Source Attribution of Urban Methane in the Los Angeles Basin: Mobile Survey of LA Methane," *Journal of Geophysical Research: Atmospheres* 121, no. 5 (March 16, 2016): 2490–2507, https://doi.org/10.1002/2015JD024429.
[2121] S. Conley et al., "Methane Emissions from the 2015 Aliso Canyon Blowout in Los Angeles, CA," *Science* 351, no. 6279 (2016): 1317–20, https://doi.org/10.1126/science.aaf2348.
[2122] Ingrid Lobet and Mike Reicher, "Aliso Canyon Was Major Pollution Source before Massive Leak," *Inewsource.Org*, February 14, 2016, http://inewsource.org/2016/02/14/aliso-canyon-major-pollution/.
[2123] Nsikan Akpan, "Los Angeles Methane Leak Was Officially the Worst in U.S. History, Study Says," *PBS NewsHour*, February 25, 2016, sec. Science, https://www.pbs.org/newshour/science/los-angeles-methane-leak-is-officially-the-worst-in-u-s-history.
[2124] Amina Khan, "Porter Ranch Leak Declared Largest Methane Leak in U.S. History," *Los Angeles Times*, February 26, 2016, sec. Science, https://www.latimes.com/science/sciencenow/la-sci-sn-porter-ranch-methane-20160225-story.html.
[2125] Phil McKenna, "What Will Be the Health Impact of 100+ Days of Exposure to California's Methane Leak?," *Inside Climate News*, February 18, 2016, https://insideclimatenews.org/news/18022016/health-impacts-aliso-canyon-porter-ranch-methane-leak-california-socal-gas/.

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.[2126]

- 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."[2127] 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 *Inside Climate 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."[2128]

- 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 *Inside Climate 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 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."[2129] 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

[2126] Stephanie O'Neill, "Did the Porter Ranch Gas Leak Cause Long-Term Health Damage?," Archive.kpcc.org, February 18, 2016, https://archive.kpcc.org/news/2016/02/18/57666/did-the-porter-ranch-gas-leak-cause-long-term-heal/.
[2127] Los Angeles County Department of Health, "Aliso Canyon Gas Leak: Results of Air Monitoring and Assessments of Health," February 5, 2016, http://www.publichealth.lacounty.gov/media/docs/AlisoAir.pdf.
[2128] McKenna, "What Will Be the Health Impact of 100+ Days of Exposure to California's Methane Leak?"
[2129] Phil McKenna, "New Federal Gas Storage Regulations Likely to Mimic Industry's Guidelines," *Inside Climate News*, February 8, 2016, https://insideclimatenews.org/news/08022016/federal-gas-storage-regulations-likely-mimic-industry-guidelines-aliso-canyon-phmsa-api/.

House Committee on Transportation and Infrastructure, California representatives "spoke about their efforts to speed up PHMSA's rulemaking for underground gas storage."[2130]

- 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."[2131] 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 *Inside Climate 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 the gas, and that "regulators have downplayed the significance of other contaminants that are also present in the leak."[2132]

- 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

[2130] Lisa Song, "U.S. Pipeline Agency Pressed to Regulate Underground Gas Storage," *Inside Climate News*, February 26, 2016, https://insideclimatenews.org/news/26022016/phmsa-pipeline-regulator-pressed-regulate-underground-natural-gas-storage-aliso-canyon-methane/.
[2131] Los Angeles County Department of Health, "Aliso Canyon Gas Leak: Results of Air Monitoring and Assessments of Health."
[2132] Lisa Song, "Mercaptans in Methane Leak Make Porter Ranch Residents Sick, and Fearful," *Inside Climate News*, January 25, 2016, https://insideclimatenews.org/news/25012016/porter-ranch-residents-health-effects-methane-leak-aliso-canyon-california/.

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.[2133]

- 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.[2134]

- 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."[2135] 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)."[2136]

- 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 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.[2137]

- December 30, 2015 – According to the *Los Angeles Daily News,* which unearthed November 2014 state regulatory filing documents, the Southern California Gas Company

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[2133] Susan Abram, "Doctors Treating Porter Ranch Residents Want More Gas-Leak Guidance," *Daily News*, January 19, 2016, https://www.dailynews.com/health/20160119/doctors-treating-porter-ranch-residents-want-more-gas-leak-guidance.

[2134] Dana Bartholomew, "'Plume Chaser' Researchers Fan out across San Fernando Valley to Map Reach of Porter Ranch Gas Leak," *Daily News*, January 14, 2016, https://www.dailynews.com/environment-and-nature/20160114/plume-chaser-researchers-fan-out-across-san-fernando-valley-to-map-reach-of-porter-ranch-gas-leak.

[2135] G. J. Wilcox, "Regulators Probing Whether Fracking Was Connected to Aliso Canyon Gas Well Leak," Daily News, January 14, 2016, https://www.dailynews.com/environment-and-nature/20160113/regulators-probing-whether-fracking-was-connected-to-aliso-canyon-gas-well-leak.

[2136] Jane C. S. Long et al., "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, Lawrence Berkeley National Laboratory, Pacific Institute, 2015), https://ccst.us/publications/2015/2015SB4-v1.pdf.

[2137] J. Wirfs-Brock, "Vast California Methane Leak Is Dire but Not Unique in Aging Infrastructure," *Rocky Mountain PBS News*, January 13, 2016, https://web.archive.org/web/20160120174236/http://inewsnetwork.org/2016/01/13/vast-california-methane-leak-is-dire-but-not-unique-in-aging-infrastructure/.

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."[2138]

- 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.[2139]

- 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."[2140]

- 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 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."[2141]

[2138] Mike Reicher, "SoCalGas Knew of Corrosion at Porter Ranch Gas Facility, Doc Shows," *Daily News*, December 31, 2015, https://www.dailynews.com/general-news/20151230/socalgas-knew-of-corrosion-at-porter-ranch-gas-facility-doc-shows.
[2139] California Air Resources Board, "Report on Greenhouse Gas Emissions from Aliso Canyon Leak," *Los Angeles Times*, November 20, 2015, http://documents.latimes.com/report-greenhouse-gas-emissions-aliso-canyon-leak/.
[2140] T. Barboza, "Natural Gas Leak That's Sickening Valley Residents Could Take Months to Fix," *Los Angeles Times*, November 21, 2015, sec. California, https://www.latimes.com/local/california/la-me-1121-gas-leak-20151121-story.html.
[2141] Dave Fehling, "On Edge Of Houston, Underground Caverns Store Huge Quantities Of Natural Gas Liquids," *Houston Public Media*, sec. Energy & Environment, accessed September 22, 2021, https://www.houstonpublicmedia.org/articles/news/2015/10/19/124674/on-edge-of-houston-underground-caverns-store-huge-quantities-of-natural-gas-liquids/.

- 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.[2142]

- 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.[2143]

Liquefied natural gas (LNG) facilities

Liquefied natural gas (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° F). Chilling natural gas to its liquid state shrinks its volume by a factor of 600, allowing LNG to be transported to places 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.

Increased reliance on LNG poses risks of violating internationally agreed upon climate targets. 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-

[2142] Dion Lefler, "Lawsuit Leaves Large Gas Storage Fields in Kansas Unregulated," *The Wichita Eagle*, October 5, 2011, https://www.kansas.com/news/article1071558.html.
[2143] Deborah Keeley, "Failure Rates for Underground Gas Storage: Significance for Land Use Planning Assessments," Research Report (Health and Safety Laboratory, 2008), https://www.hse.gov.uk/research/rrpdf/rr671.pdf.

chilled temperatures and prevent explosions, vaporized methane 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. In June 2022, a vapor cloud explosion and fire at the Freeport LNG facility in Texas closed the facility for eight months. No one inside the plant was injured, but lifeguards at a nearby beach were thrown from their chairs by the blast.

LNG plants create public health risks for nearby communities from toxic air pollutants including carbon monoxide, nitrogen oxides, sulfur dioxide, and volatile organic compounds.

- May 17, 2023 – A policy analysis of European energy security by the German think tank Dezernat Zukunft finds that increased reliance on LNG imports poses risks of violating climate targets, especially if Europe finances more new export facilities abroad that have no chance of becoming operational until after 2027. While European import terminals can function to provide energy security for crisis times, "in the long term, only phasing out natural gas by transitioning to efficient renewable energy systems ultimately reconciles energy and climate security."[2144]

- February 6, 2023 – Investigative reporting on air pollution from LNG export terminals found that LNG facilities are underreporting and miscalculating the amount of toxic air emissions from their facilities. These pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide and volatile organic compounds, sometimes exceeding the facilities' permitted limit.[2145]

- November 16, 2022 – A report issued by the Pipeline and Hazardous Materials Safety Commission found that procedural errors and employee fatigue caused by understaffing

[2144] Felix Heilmann et al., "LNG, Climate and Energy Security: Towards a Comprehensive Approach for Europe" (Dezernat Zukunft, May 17, 2023), https://www.dezernatzukunft.org/lng-climate-and-energy-security-towards-a-comprehensive-approach-for-europe/.
[2145] Terry L. Jones, "LNG Export Terminals Pose a Growing and Invisible Threat: Air Pollution," *Louisiana Illuminator*, February 6, 2023, https://lailluminator.com/2023/02/06/lng-export-terminals-pose-a-growing-and-invisible-threat-air-pollution/.

contributed to the June 2022 vapor cloud explosion at the Freeport LNG facility in Quintana, Texas, 70 miles south of Houston.[2146]

- July 2, 2021 – Calling its own project "impractical," Pieridae Energy said it will not proceed with its planned LNG processing and export facility in Nova Scotia with an estimated construction cost of $14 billion. Although the German government had offered the company a US $4.5 billion loan guarantee contingent on its ability to secure additional financing, the company failed to submit an application for for additional funds from the Canadian government by the agreed-upon deadline. The editor and publisher of the *Halifax Examiner* noted that the company could still alter the project—importing natural gas from Pennsylvania through existing pipelines rather than as originally planned from Alberta—but such a shift would create a dependency on the problem-plagued Enbridge compressor station in Weymouth, Massachusetts, throwing the viability of the project into doubt. "Natural gas's time has passed. The public hates it, governments won't finance it, and no one is buying."[2147]

- June 30, 2021 – Pieridae Energy, having missed a deadline to submit an application to the Canadian government for $925 million in grant, repayable contribution, or loan guarantee for its planned LNG facility in Nova Scotia, would still need to undergo environmental assessment and receive regulatory permissions even if all the necessary funding were secured. The plan's opponents are prepared to mount substantive challenges, out of concern that the LNG facility would prevent Nova Scotia from meeting emissions goals, that the large labor camp would threaten the safety of native Canadian women, and that the use of public funds to increase fossil fuel production in a time of accelerating renewable energy investments is inappropriate.[2148]

- June 22, 2021 – U.S. company New Fortress Energy (NFE) announced its intention to apply for permission for an LNG terminal in Ireland despite the country's May 2021 pause on all new LNG terminals. The project would include a power plant and battery storage facility, with an offshore LNG terminal in the Shannon estuary. A previous plan was put on hold in 2019 because of concerns over the import of fracked gas. Ireland has pledged to obtain 70 percent of energy from renewables by 2030 and has excluded the use of fracked gas. NFE claims that its project will not be dependent on fracked gas.[2149]

- June 16, 2021 – As part of the Further Consolidated Appropriations Act of 2020, PHMSA entered into an agreement with the Transportation Research Board, a major program of the National Academies of Sciences, Engineering, and Medicine (NASEM) to convene a committee of independent experts to critique the safety research and testing

[2146] IFO Group, "June 8, 2022 - Loss of Primary Containment Incident Investigation Report," October 30, 2022, 2, https://subscriber.politicopro.com/eenews/f/eenews/?id=00000184-7d8d-d7f7-a79c-ff8f6e230001.
[2147] Tim Bousquet, "The Goldboro LNG Plant Scheme Has Collapsed," *Halifax Examiner*, July 2, 2021, https://www.halifaxexaminer.ca/featured/the-goldboro-lng-plant-scheme-has-collapsed/.
[2148] Rose Murphy, "Feds Haven't Received Funding Application for Goldboro LNG Project, Says MP," CBC.Ca, June 30, 2021, https://www.cbc.ca/news/canada/nova-scotia/lng-pipeline-goldboro-nova-scotia-1.6085957.
[2149] Sarah Collins, "US Backer Revives Its Plans for €650m Shannon LNG Project," June 22, 2021, https://www.independent.ie/business/irish/us-backer-revives-its-plans-for-650m-shannon-lng-project-40567970.html.

protocols undertaken by the task force engaged in the final rulemaking process for allowing the transportation of LNG by rail tank car. Among other concerns, the committee in its report asked for a clearer rationale for how full-scale impact testing, tank fire testing, and worst-case scenarios protocols were developed. The second phase of the project, to be completed in mid-2022, will provide a more in-depth review and examination of the applicability of existing guidelines for emergency responses to LNG rail incidents, including "incidents caused by deliberate acts, human factors, or track component defects."[2150]

- June 3, 2021 – According to an engineering analysis, the force of a vapor cloud explosion (VCE) at LNG plants has likely been significantly and systematically underestimated by industry. VCEs occur when heavier hydrocarbons, which are used to cool natural gas, leak and ignite. LNG terminals, which typically hold 50 tons of these refrigerants, are usually designed with barriers at the perimeter to prevent vapor leaks from spreading off site, but, on rare occasions, as during windless conditions, such barriers can allow vapor accumulation sufficient for explosions, which can be massive. In 2019, for example, a VCE in Philadelphia threw a 38,000-pound vessel across the Schuylkill River and led to the permanent closure of that oil refinery. Although federal standards are in place for risk calculations for other types of hazards, PHMSA had accepted industry's computer model indicating that the force of a VCE would be greatly diminished by the time it reached the edge of the facility. However, an expert study not associated with the industry showed that the force of that type of incident could be 15 to 20 times higher than projections from industry modeling. PMHSA intends to develop new rules on VCEs in the coming year and yet, meanwhile, approved safety plans for three proposed LNG terminals in Louisiana (although one of three was subsequently canceled because of financial issues). Jerry Havens, the former director of the Chemical Hazards Research Center at the University of Arkansas said, "If something doesn't get corrected, there might be some terrible accidents."[2151]

- May 14, 2021 – The Irish government pledged in June 2020 to disallow the import of LNG derived from fracked gas, and Ireland's Department of the Environment, Climate and Communications (DECC) has said that no LNG projects should proceed until a review of the country's energy supply security is completed. DECC has also said that Ireland would withhold EU member state approval for EU funding for LNG import terminals in the country. A spokesperson for the agency commented, "as Ireland moves toward climate neutrality, it does not make sense to develop LNG projects importing fracked gas." This policy has led to the suspension of one planned project by a U.S. developer, but two others are still in progress: Shannon and Predator. The High Court in Ireland ruled against all development consents for the Shannon LNG project, but Shannon is preparing new applications and hopes to come online in late 2022. Predator, a

[2150] Policy Studies, Transportation Research Board, and National Academies of Sciences, Engineering, and Medicine, *Preparing for LNG by Rail Tank Car: A Review of a U.S. DOT Safety Research, Testing, and Analysis Initiative* (Washington, D.C.: Transportation Research Board, 2021), https://doi.org/10.17226/26221.
[2151] Will Englund, "Engineers Raise Alarms Over the Risk of Major Explosions at LNG Plants," *The Washington Post*, May 3, 2021, https://www.washingtonpost.com/business/2021/06/03/lng-export-explosion-vce/.

UK project, plans a floating LNG import terminal and stated it would not use LNG sourced from fracking.[2152]

- April 30, 2021 – Plans for a €40 million LNG terminal at the port of Bratislava, Slovakia are backed by unsubstantiated claims from the state-owned investor that the facility will reduce pollution and greenhouse gas emissions on the Danube and make freight transport "greener." Part of an EU plan to build a Rhine-Danube transport corridor connecting different means of transport across Europe, the terminal will be located less than one kilometer away from a densely populated area, and, according to critics, would increase traffic and cause a reduction in air quality. Concerns about the project's potential to increase Slovakia's reliance on natural gas have prompted request for an analysis of its compatibility with EU climate policies.[2153]

- April 26, 2021 – The United Kingdom approved $1 billion for a large LNG development in Mozambique that is now facing a court challenge on the grounds that the project is consistent with neither the United Kingdom's nor Mozambique's obligations under the Paris Climate Agreement. The construction phase of the project would increase Mozambique's GHG emissions by up to 10 percent and the burning of the fuel produced would cause emissions equivalent to those of the EU's total aviation sector.[2154]

- April 22, 2021 – Plans for three LNG import terminals in Germany have received strong state support, even though plans for a renewable energy transition would render over 70 percent of all gas distribution grids in that nation unnecessary. A research team examined the ways in which the continuing build-out of LNG infrastructure in Germany locks in a dependency on natural gas, allowing the industry to avoid stranded assets while also impeding the transition to renewables and substantially delaying the attainment of climate goals. They found that local and political forces work together to create momentum for LNG proposals and to keep federal opposition weak. The continued use of gas requires no change in equipment or consumer behavior while political pressure from the United States to reduce Russian gas imports and to import U.S. LNG keep climate and environment issues subordinate to short-term economic and energy security concerns. The authors recommend that policy and energy investment decisions include climate targets and the risks of locking in natural gas dependencies.[2155]

- April 15, 2021 – The Delaware River Basin Commission (DRBC), comprised of representatives of New York, New Jersey, Pennsylvania, and Delaware, as well as the commander of the U.S. Army Corp of Engineers' North Atlantic Division, has made

[2152] Stuart Elliot, "Ireland Advises Against All LNG Project Developments During Energy Review," S&P Global, May 14, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/051421-ireland-advises-against-all-lng-project-developments-during-energy-review.
[2153] Irena Jenčová, "Bratislava Port to Get Its Own €40 Million LNG Terminal," Euractiv.com, April 30, 2021, https://www.euractiv.com/section/politics/short_news/bratislava-port-to-get-its-own-e40-million-lng-terminal/.
[2154] Brendan Montague, "Britain's $1 Billion Bet Against the Climate," *Ecologist*, April 26, 2021, https://theecologist.org/2021/apr/26/britains-1billion-bet-against-climate.
[2155] Hanna Brauers, Isabell Braunger, and Jessica Jewell, "Liquefied Natural Gas Expansion Plans in Germany: The Risk of Gas Lock-In under Energy Transitions," *Energy Research & Social Science* 76 (2021), https://doi.org/10.1016/j.erss.2021.102059.

paradoxical decisions regarding fracked gas. In February 2021 the DRBC banned fracking in the area that it oversees. However, only a few months earlier, the Commission approved a dock in Gibbstown, New Jersey to export LNG from a plant in Pennsylvania, potentially placing at risk over 1.5 million people in an area ranging over 200 miles from the plant to the export dock. The Pennsylvania Department of Environmental Protection estimated that the LNG plant would produce more than one million metric tons of greenhouse gases yearly and burning the gas after delivery would produce millions more. A special permit from the Trump administration for the use of rail to transport LNG from Pennsylvania to New Jersey for this project was followed by a complete lifting of the federal ban on LNG transport by rail in densely populated areas in 2020. When New Fortress Energy built a dock in Gibbstown in 2017, the company indicated the facility would not use it for LNG export. However, a subsidiary of New Fortress applied for a permit to build the Pennsylvania LNG plant intending to export the gas from a port on the Delaware River. The subsidiary, Delaware River Partners, subsequently applied for a permit to construct another dock attached to the Gibbstown facility, which would be used for LNG export. Not only adjacent to a low-income and largely non-white "overburdened community," the location itself is a Superfund site, and dredging needed for the dock could release carcinogenic PCBs into the river. When the DRBC approved "Dock 2," the agency stated that the climate and environmental issues would need to be addressed at the state, interstate, and federal level. New Fortress still needed permits from New Jersey's Department of Environmental Protection and an export permit from the federal Department of Energy. A motion for summary judgement was filed with the New Jersey district court asking that the Army Corps of Engineers' permit be nullified because a full environmental impact assessment had not been done prior to approval. Other roadblocks to the project include the possibility that President Biden could revoke the prior administration's executive order regarding LNG rail transport.[2156]

- March 30, 2021 – Bowing to public pressure and determining that its chemical discharges would harm local wetlands, the Australian government denied the LNG import terminal at Crib Point planned by AGL Energy. Australia's biggest climate polluter, AGL Energy had already spent about $130 million on the project. AGL also plans to split its business in two, in an attempt to improve its emissions profile and reputation, by separating out its continued coal-fired power generation.[2157]

- January 22, 2021 – The accidental release of LNG from a railroad tank car can result in fire and boiling liquid expanding vapor explosions. Because of these risks, transport of LNG by rail, which is regulated by the PHMSA and the Federal Railroad Administration, had been allowed only on a case-by-case basis. However, on July 24, 2020, PHMSA finalized the LNG by rail regulation allowing the practice. The decision has been

[2156] Zoya Teirstein, "The Delaware River Basin Paradox: Why Fracking Is So Hard to Quit," *Grist*, April 15, 2021, https://grist.org/politics/the-delaware-river-basin-paradox-why-fracking-is-so-hard-to-quit/.
[2157] Australian Associated Press, "Victoria Blocks AGL's Gas Terminal on Environmental Grounds," *The Guardian*, March 30, 2021, https://www.theguardian.com/business/2021/mar/30/victoria-blocks-agl-energy-gas-terminal-crib-point-split-business.

challenged in court, but the Biden administration requested that the case be delayed until it reviews the LNG by rail rule.[2158]

- November 9, 2020 – LNG transport from Russia to Asia via the Northeast Passage has markedly increased due to climate change-induced ice melt. That sea route, from Russia past the North Pole and Alaska and south to China, historically was covered with ice for most of the year, but, when available for shipping, cuts about 2400 nautical miles off the trip. The route is now open for much longer periods each year, and there have been thousands of transits since 2015. China, expected to double its natural gas use in the next 15 years, had previously obtained most of its natural gas via pipelines from other Asian countries and southern Russia. In 2017, Russia opened an LNG export terminal on the Yamal Peninsula that offers easy access, via the Northeast Passage, to China. Traffic is expected to increase as ice melt continues. In contrast, a proposed US LNG export terminal in Oregon is on hold because of climate concerns.[2159]

- July 6, 2020 – Investors concerned about falling demand, rising competition from renewable energy, and opposition due to climate concerns have delayed financing for at least 20 of 45 major LNG projects in preconstruction development around the world.[2160] "Investing in new fossil fuel infrastructure like liquefied natural gas (LNG) terminals is increasingly an economically unsound decision," commented Andrew McDowell, the vice president of European Investment Bank (EIB). EIB will stop financing fossil fuel projects after 2021. The pandemic has also slowed LNG terminal development. The industry and some nations, however, still plan to boost LNG exports over the next 10 years. Methane, the main component of LNG, is a potent greenhouse gas, and these plans raise concerns about the possibilities of achieving the goals of the Paris climate accord.

- June 23, 2020 – The US Energy Information Administration reported that LNG export capacity would be used at less than 50 percent during June, July, and August 2020.[2161] Seventy-four US cargoes were exported in January 2020, but over 70 were canceled for June and July and more than 40 canceled for August. According to the report, "A mild winter and COVID-19 mitigation efforts have led to declining global natural gas demand and high natural gas storage inventories in Europe and Asia, reducing the need for LNG imports. Historically low natural gas and LNG spot prices in Europe and Asia have affected the economic viability of U.S. LNG exports."

- June 23, 2020 – Royal Dutch Shell's "Prelude," a floating plant designed to produce LNG from remote offshore gas fields has not been operational since January 2020

[2158] Environmental & Energy Law Program, "LNG by Rail Rule," Regulatory Tracker (Harvard Law School, January 22, 2021), https://eelp.law.harvard.edu/2021/01/lng-by-rail-rule/.
[2159] Tim McDonnell, "A Brutal New Climate Feedback Loop Is Brewing in the Arctic," *Quartz*, November 9, 2020, https://qz.com/1928866/how-the-northeast-passage-is-helping-russia-sell-more-natural-gas/.
[2160] Matthew Green, "Global LNG Projects Jeopardized by Climate Concerns, Pandemic Delays - Report," *Reuters*, July 6, 2020, sec. Environment, https://www.reuters.com/article/us-climate-change-gas-idUKKBN247303.
[2161] U.S. Energy Information Administration, "U.S. Liquefied Natural Gas Exports Have Declined by More than Half so Far in 2020 - Today in Energy - U.S. Energy Information Administration (EIA)," June 23, 2020, https://www.eia.gov/todayinenergy/detail.php?id=44196.

because of safety problems, reported *Forbes*.[2162] Shell had not revealed the cost of the project, but estimates ranged from $12 billion to $17 billion. Operational costs were estimated to be high as well. Analysts at Goldman Sachs estimated that Prelude's costs are more than double those from other new LNG projects. Oil and gas prices have fallen dramatically since the project began about 10 years ago, and an analyst at Credit Suisse said that record low LNG prices make it difficult to cover operating costs. In contrast, Shell Australia's chairman said that Shell was pleased with Prelude's progress.

- June 19, 2020 – Following President Trump's executive order signed in Houston in April 2019 to reconsider the prohibition of LNG transport by rail, the U.S. Department of Transportation (USDOT) and the Pipeline and Hazardous Material Safety Administration (PHMSA) issued a final rule in June 2020 allowing the practice.[2163] The Congressional Research Service (CRS) published a report addressing the new rule, including criticism: "perceived public safety and security risks of LNG by rail have raised concerns among state officials, the National Transportation Safety Board, and other members of Congress."[2164] The rule includes new operational safeguards and monitoring requirements for the highly combustible product including increased outer tank thickness, new braking requirements, and remote monitoring of pressure and location of each LNG car. There are also requirements that attempt to reduce security risk. The CRS report reviewed the inherent risks of LNG by rail, safety and environmental record of the industries, and policy issues including legislation actions. Ongoing concerns included inadequacy of emergency responder training, manpower, and resources to deal with an LNG rail accident. LNG burns hotter and more rapidly than gas or oil. If LNG spills but does not ignite it can cause asphyxiation or can create a vapor cloud which can burn if it contacts an ignition source. A boiling liquid expanding vapor explosion (BLEVE) could occur if a tank car was heated until rupture, resulting in a blast wave. "Cascading failures," where an LNG release and fire from one tank car can trigger succeeding cars to fail in the same manner, have occurred in rail accidents involving rail shipments of crude oil and ethanol, according to the report. Proposed legislation includes an Act to carry out further evaluation of LNG-by-rail safety, containing specific requirements, and which "would rescind any special permit or approval for the LNG transportation by rail tank car issued prior to enactment and would prohibit any regulation, special permit, or approval prior to the conclusion of a specified study period."

- May 25, 2020 – Seven LNG projects are in various stages of construction in Canada's British Columbia, where the province is expecting a fracking boom to feed the projects

[2162] Tim Treadgold, "Shell's $12 Billion LNG Experiment Becomes A Big Headache," *Forbes*, June 23, 2020, sec. Asia, https://www.forbes.com/sites/timtreadgold/2020/06/23/shells-12-billion-lng-experiment-becomes-a-big-headache/.
[2163] U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, "U.S. Department of Transportation Issues Final Rule for the Safe Transportation of Liquefied Natural Gas by Rail Tank Car | PHMSA," Press Release, June 19, 2020, https://www.phmsa.dot.gov/news/us-department-transportation-issues-final-rule-safe-transportation-liquefied-natural-gas-rail.
[2164] P. W. Parfomak and J. Frittelli, "Rail Transportation of Liquefied Natural Gas: Safety and Regulation" (Congressional Research Service, 2020).

while concomitantly trying to address methane emissions.[2165] The largest of the LNG projects under construction is expected to require double the existing fracking operations. The province must also consider significant emissions from inactive and orphan wells. As new wells are drilled to meet LNG demands, the number of unattended wells is expected to rise dramatically, which will undermine efforts to cut methane emissions. British Columbia's goal is a 45 percent reduction in methane emissions from 2014 levels, to be achieved by 2025. Controversy surrounds the province's methods of assessing methane emissions, with one evaluation indicating that emissions were 2.5 times the province's official report. British Columbia has formed a methane research group to better evaluate the problem, but, the "group's work is focused solely on upstream operations—companies that extract or produce oil and gas—meaning facilities like LNG Canada are off the hook as an end-use, downstream facility." One member of the group noted that LNG Canada receives significant government subsidies including carbon tax exemptions estimated in excess of $150 million a year: "If the government wants to reach its methane target it needs to stop subsidizing oil and gas."

- May 15, 2020 – Now recognized by the European Union (EU), the problem of high methane emissions from the oil and gas industry offsets any potential climate benefits of importing LNG over coal. The EU's goal of climate neutrality by 2050 and multi-pronged strategies to curb methane emissions of imported natural gas, considers measurement and reporting across fossil fuel sectors and supply chains, as reported by the Germany-based, cross-border focused energy journalism group, *Clean Energy Wire*.[2166] Such a strategy, codified as concrete legislation, could force U.S. LNG producers to take their methane leakage problem more seriously if they want continued access to EU markets. The United States has been a net exporter of LNG since 2016, with most of the gas coming from the Permian Basin in western Texas and southeastern New Mexico that is now the world's largest oil-producing region and the United States' second biggest gas-producing region. Recent studies have shown that flaring, venting, and leaking of natural gas are much worse in the Permian Basin than elsewhere in the United States. One recent study indicated that the amount of fugitive methane emissions from the Permian oil and gas operations nearly triples the climate impact of burning the produced gas. Natural gas production, liquefaction, and transport are all energy intensive and lead to carbon dioxide emissions as well.

- March 1, 2020 – In April 2019 Donald Trump signed an executive order instructing the US Department of Transportation to write rules allowing rail transport of LNG. A detailed piece in the National Fire Protection Association's *NFPA Journal* detailed the issues of concern to the safety community, in the period between the Trump order and the release of the final rule.[2167] Public safety organizations such as the International

[2165] Natalia Balcerzak, "'I Don't Think We Will Ever Catch up': B.C. Methane Targets out of Reach amid Growing LNG, Fracking," *The Narwhal*, May 25, 2020, https://thenarwhal.ca/climate-change-b-c-methane-targets-out-of-reach-growing-lng-fracking/.
[2166] Julian Wettengel, "Unravelling the Climate Footprint of U.S. Liquefied Natural Gas," *Clean Energy Wire*, May 15, 2020, https://www.cleanenergywire.org/news/unravelling-climate-footprint-us-liquefied-natural-gas.
[2167] Jesse Roman, "NFPA Journal - LNG By Rail, March/April 2020," *NFPA Journal*, April 2020, https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/March-April-2020/Features/LNG-Trains.

Association of Firefighters (IAFF), the National Association of Fire Marshalls, and the National Transportation Safety Board (NTSB) were "strongly opposed" to the proposed rule. "The IAFF, pointing out that LNG will quickly evaporate into an immense and potentially flammable vapor cloud when exposed to ambient air, wrote that 'it is nearly certain any accident involving a train consisting of multiple rail cars loaded with LNG will place vast numbers of the public at risk while fully depleting all local emergency response forces.'" Safety experts noted that communities and public agencies should be preparing for rail accidents and recommended the involvement of the nation's 3,000 local emergency planning committees, mandated by Congress in 1986 to develop comprehensive emergency response plans.

- January 28, 2020 – For use as a marine fuel, there was no climate benefit for 20-year global warming potential from using LNG, and the use of LNG appeared to actually worsen the climate impact of shipping, according to a working paper from the International Council on Clean Transportation.[2168] More ships are being built to use LNG, which emits 25 percent less CO_2 than usual fuel for the same amount of propulsion. The study evaluated climate impact by comparing lifecycle greenhouse gas emissions of LNG, marine gas oil, very low sulfur fuel, and heavy fuel oil when used for marine shipping. The assessment included leakage during extraction, processing, and transport, as well as downstream emissions from combustion and unburned gas. The paper emphasized that the International Maritime Organization has developed climate goals, has "signaled" that it will regulate emissions, and that "continued investment in LNG infrastructure on ships and on shore risks making it harder to transition to zero-emission vessels in the future."

- January 14, 2020 – The NTSB warned of the risk of "catastrophic" fires and explosions in response to a Trump administration draft rule to allow LNG transport by rail. Other groups, including fire marshals, the union representing rail engineers, and 16 state attorneys general, also oppose the rule. The NTSB recommended that PHMSA should require stricter safety precautions, but some rail industry groups oppose this. The executive director of the National Association of State Fire Marshals said, "The combination of a lack of information with no increased safety measures…puts the public and our first responders at even greater risk."[2169]

- January 11, 2020 – Scientists from Greece's National Centre of Scientific Research identified "scientific and harmonization gaps" at ports storing and transferring LNG.[2170] The study examined 35 legislative documents and 23 articles in an extensive review of literature regarding safety and risk assessment, and summarized regulations addressing LNG storage tanks, bunker trucks, buffer ships, and LNG fueled ships. At the time of the

[2168] Nikita Pavlenko et al., "The Climate Implications of Using LNG as a Marine Fuel | International Council on Clean Transportation," Working Paper (The International Council on Clean Transportation, January 28, 2020), https://theicct.org/publications/climate-impacts-LNG-marine-fuel-2020.
[2169] Mike Lee, "Feds Warn of 'Catastrophic' Blasts from Trump LNG Rule," *E&E News*, January 14, 2020, https://web.archive.org/web/20200114194145/https://www.eenews.net/energywire/stories/1062074737.
[2170] Olga Aneziris, Ioanna Koromila, and Zoe Nivolianitou, "A Systematic Literature Review on LNG Safety at Ports," *Safety Science* 124 (2020): 104595, https://doi.org/10.1016/j.ssci.2019.104595.

study, there were 21 operating LNG ports worldwide, and ten more with "confirmed plans to operate by 2020," but, the authors stated, "the knowledge regarding safe storage, handling and supply of LNG is still insufficient." They identified gaps including harmonization of LNG safety regulations at sea and on land, for all LNG operations at ports and within various countries. Additionally, more work needs to be done using quantitative risk methods to better define safety and hazardous zones during LNG storage and bunkering at ports. The authors identified areas for further work by the academic community and industry organizations.

- October 10, 2019 – Authors of an overview of risk analysis in the LNG sector proposed a "comprehensive classification framework," a classification strategy for LNG risk studies covering "more aspects of risk analysis process compared with the existing review articles."[2171] The storage, transport, and use of LNG carries the potential for catastrophic accident, and the field of risk analysis has been used "to identify the potential hazards, calculate the probability of accidents, as well as assessing the severity of consequences." The authors reviewed and categorized 66 papers addressing risk analysis in the LNG sector. The literature was examined with regard to methods, tools, data sources, and the type of LNG facility. The various risk analysis tools were described, along with their advantages and drawbacks. Authors said that in spite of progress in the application of LNG risk analysis in the LNG sector, further research is needed, for which they make specific recommendations. These included attention to improved data quality and the introduction of real-life electronic data, more use of dynamic versus conventional risk assessment, and the use of more powerful risk assessment tools and methods. The review of data sources revealed that "expert judgement" was the most common source, suggesting that there is a lack of good quality data for LNG risk analysis.

- September 5, 2019 – The Trump Administration has used multiple means to push Europe to buy more American LNG, according to the *Houston Chronicle*.[2172] Trump aggressively promoted the exports through speeches and meetings with heads of state, and eight federal agencies have been charged with getting overseas gas infrastructure built. US officials have acted as "go-betweens" with foreign counterparts regarding their own energy sectors, assisting US allies in developing their own gas exports. Some in Europe, however, question America's sincerity about the stated goal of helping them achieve energy security: "After the Senate passed sanctions in 2017 targeting Russia's Nord Stream 2 natural gas pipeline into Germany—a project the Trump administration has fought to block—Austria and Germany's foreign officials released a joint statement calling the vote a bid to aid American energy companies."

- July 22, 2019 – An upcoming rule from PHMSA is expected to concern "streamlining U.S. regulations and harmonizing them with those in other countries," rather than

[2171] Isaac Animah and Mahmood Shafiee, "Application of Risk Analysis in the Liquefied Natural Gas (LNG) Sector: An Overview," *Journal of Loss Prevention in the Process Industries* 63 (January 2020): 103980, https://doi.org/10.1016/j.jlp.2019.103980.
[2172] James Osborne, "Trump's Hard Sell of American LNG," *Houston Chronicle*, September 5, 2019, sec. Energy, https://www.houstonchronicle.com/business/energy/article/Trump-s-hard-sell-of-American-LNG-14414269.php.

focusing on safety and prevention of catastrophic explosions, reported *E&E News*.[2173] A PHMSA working group indicated in September 2018 that there "… is no process in place to evaluate the suitability of the software models to calculate these hazards." Five new LNG export facilities were expected to be operational by the end of 2019, and six more had been fully permitted. It remained unclear what the PHMSA will do to address the risk of explosion. Jerry Havens, a professor emeritus of chemical engineering, expressed concern that the current LNG infrastructure fails to account for the risk of catastrophe. Current LNG computational safety models are proprietary so he could not determine their accuracy, and PHMSA had no protocol to evaluate the models. Havens said that the current system might dramatically underestimate the power of a worst-case accident by a factor of ten.

- July 1, 2019 – The climate impact of proposed LNG expansion would be twice that of the current base of coal in the United States, Global Energy Monitor told *CNN*, for their coverage of a new report by the network of researchers who track fossil fuel projects.[2174] This impact is primarily related to leaks of methane, the potent greenhouse gas, and the reason that the United Nations' Intergovernmental Panel on Climate Change has called for reducing natural gas in the coming decades, *CNN* reported. Economic viability is also in doubt, according to the Global Energy Monitor report, with "plunging renewable energy costs" putting much of the $1.3 trillion of LNG investments at risk.

- 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.[2175]

- 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

[2173] Jenny Mandel, "Trump LNG Rule: Will It Address 'Catastrophic' Risks?," *E&E News*, July 22, 2019, https://web.archive.org/web/20190722172209/https://www.eenews.net/stories/1060771257.
[2174] Matt Egan, "America's Liquefied Natural Gas Boom May Be on a Collision Course with Climate Change," *CNN Business*, July 1, 2019, https://www.cnn.com/2019/07/01/business/lng-boom-environment-climate-change/index.html.
[2175] R. G. van der Vegt, "Risk Assessment and Risk Governance of Liquefied Natural Gas Development in Gladstone, Australia: Risk Assessment and Risk Governance of LNG Development," *Risk Analysis* 38, no. 9 (2018): 1830–46, https://doi.org/10.1111/risa.12977.

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° F, became brittle upon contact with -260° 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.[2176] 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.[2177] 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."[2178] In April 2018, the parties agreed to resolve the issue without administrative proceedings or litigation.[2179]

- 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."[2180] *E&E News*, reporting on the study, quoted one of the authors as saying, "The implications of our paper are that the greenhouse gas impacts from exporting U.S. natural gas…here at home and abroad, can be very, very bad."[2181]

[2176] Jenny Mandel and Mike Soraghan, "Feds Order Partial Shutdown at Cheniere LNG Export Site," *E&E News*, February 12, 2018, https://web.archive.org/web/20180212171644/https://www.eenews.net/stories/1060073537.
[2177] Mark Schleifstein, "Sabine Pass LNG Ordered to Shut down Leaking Gas Storage Tanks," *The Times-Picayune*, February 10, 2018, https://www.nola.com/news/environment/article_e93f653c-18d3-5016-abc6-47cdd7370b90.html.
[2178] Edward Klump and Mike Soraghan, "Cheniere Says No Public Danger from Sabine Pass Leaks," *E&E News*, March 22, 2018, https://web.archive.org/web/20180322180240/https://www.eenews.net/stories/1060077135.
[2179] "Cheniere Settles Sabine Pass LNG Tanks Issue with PHMSA," *LNG World News*, April 24, 2018, https://www.offshore-energy.biz/cheniere-settles-sabine-pass-lng-tanks-issue-with-phmsa/.
[2180] Alexander Q. Gilbert and Benjamin K. Sovacool, "US Liquefied Natural Gas (LNG) Exports: Boom or Bust for the Global Climate?," *Energy* 141 (December 2017): 1671–80, https://doi.org/10.1016/j.energy.2017.11.098.
[2181] Ellen M. Gilmer and Jenny Mandel, "Increased LNG Exports Would Spell Trouble for Climate – Study," *E&E News*, December 15, 2017, https://web.archive.org/web/20180730192553/https://www.eenews.net/stories/1060069129.

- 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.[2182]

- July 25, 2017 – Citing volatile market conditions, Malaysia's energy giant Petronas canceled 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 canceled 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."[2183]

- 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 global warming potential (GWP), and the highest GWP occurred when LNG was used as vehicle fuel.[2184]

[2182] K. Rhodes, "The Weakest Link: The Consistent Refusal to Consider Far-Removed Indirect Effects of the Expansion of LNG Terminals," *Energy Law Journal* 38, no. 2 (2017): 431–53.
[2183] Andrew Nikiforuk, "'Basic Economics' Kill $11-Billion LNG Project on BC's Coast," *The Tyee*, July 25, 2017, https://thetyee.ca/News/2017/07/25/LNG-Project-BC-Coast-Killed/.
[2184] Yun Zhang et al., "Life Cycle Assessment and Optimization Analysis of Different LNG Usage Scenarios," *The International Journal of Life Cycle Assessment* 23, no. 6 (2018): 1218–27, https://doi.org/10.1007/s11367-017-1347-2.

- 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.[2185]

- 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.[2186]

- 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.[2187]

- 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.[2188]

- 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 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.[2189]

[2185] World Bank Group, "Environmental, Health, and Safety Guidelines for Liquefied Natural Gas," 2017, https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Publications/Publications_Policy_EHS-LNG.
[2186] Andrea Galieriková, Tomáš Kalina, and Jarmila Sosedová, "Threats and Risks during Transportation of LNG on European Inland Waterways," *Transport Problems* 12, no. 1 (2017): 73–81, https://doi.org/10.20858/tp.2017.12.1.7.
[2187] Carla Tagliaferri et al., "Liquefied Natural Gas for the UK: A Life Cycle Assessment," *The International Journal of Life Cycle Assessment* 22, no. 12 (2017): 1944–56, https://doi.org/10.1007/s11367-017-1285-z.
[2188] Nigel N. Clark et al., "Pump-to-Wheels Methane Emissions from the Heavy-Duty Transportation Sector," *Environmental Science & Technology* 51, no. 2 (2017): 968–76, https://doi.org/10.1021/acs.est.5b06059.
[2189] Makena Coffman et al., "Economic and GHG Impacts of Natural Gas for Hawaii," *Environmental Economics and Policy Studies* 19, no. 3 (2017): 519–36, https://doi.org/10.1007/s10018-016-0157-2.

- 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.[2190]

- 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.[2191]

- 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.[2192]

- 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.[2193]

- 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 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.[2194]

[2190] Marc Santora, "Cuomo Rejects Natural Gas Port Proposed Off Long Island," *The New York Times*, November 12, 2015, sec. New York, https://www.nytimes.com/2015/11/13/nyregion/cuomo-rejects-natural-gas-port-proposed-off-long-island.html.
[2191] Maria Anderson, Kent Salo, and Erik Fridell, "Particle- and Gaseous Emissions from an LNG Powered Ship," *Environmental Science & Technology* 49, no. 20 (2015), https://doi.org/10.1021/acs.est.5b02678.
[2192] U.S. Government Accountability Office, "Federal Approval Process for Liquefied Natural Gas Exports," Congressional Report, September 2014, https://www.gao.gov/assets/gao-14-762.pdf.
[2193] Walter Chukwunonso Ikealumba and Hongwei Wu, "Some Recent Advances in Liquefied Natural Gas (LNG) Production, Spill, Dispersion, and Safety," *Energy & Fuels* 28, no. 6 (2014): 3556–86, https://doi.org/10.1021/ef500626u.
[2194] [Name Redacted], "Liquefied Natural Gas (LNG) Import Terminals: Siting, Safety, and Regulation," Congressional Research Report, December 2009.

- 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.[2195]

- 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.[2196]

- 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.[2197]

- 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 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).[2198]

- 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

[2195] Boyan Kavalov, Hrvoje Petric, and Aliki Georgakaki, "Liquefied Natural Gas for Europe: Some Important Issues for Consideration." (Publications Office, 2009), https://publications.jrc.ec.europa.eu/repository/handle/JRC47887.
[2196] Paul W. Parfomak, "Liquefied Natural Gas (LNG) Infrastructure Security: Issues for Congress," Congressional Research Report (Library of Congress, Congressional Research Service, May 2008), https://www.hsdl.org/?view&did=486464.
[2197] U.S. Government Accountability Office, "Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification," February 2007, https://www.gao.gov/new.items/d07316.pdf.
[2198] Paul W. Parfomak, "Liquefied Natural Gas (LNG) Infrastructure Security: Background and Issues for Congress" (Library of Congress, Congressional Research Service, September 9, 2003), https://apps.dtic.mil/sti/pdfs/ADA426272.pdf.

hazards (personal injury plus structural failure of equipment from prolonged exposure to extremely cold temperatures.)[2199]

Gas-fired power plants

By 2016, natural gas-fired power plants had surpassed coal-burning plants as the leading source of electrical generation in the United States.

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 carbon monoxide than coal plants.

Gas-fired combined cycle plants were formerly promoted as a bridge to reduce emissions while renewables ramp up. However, 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 and serve to delay a speedy transition to renewable energy. At the same time, the lifecycle greenhouse gas emissions of both types of gas-fired power plants have been shown to be far higher than previously estimated. In Virginia, carbon dioxide emissions from electricity generation rose rather than fell after the state retired its fleet of coal plants and embarked on a massive build-out of gas-burning plants. Gas plants are also prone to failure during cold snaps and extreme winter storms due to loss of compression and freeze-ups in the pipelines that service them.

New natural gas plants, which have an operational lifespan of 40 years, 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, as they would need to be decommissioned well before the end of their lifespan.

Gas-fired simple cycle plants that are used on demand as peakers have become obsolete as battery technology now allows for the storage of renewable energy, eliminating the need for gas plants to provide power in times of peak demand.

Natural gas power plants are a major emitter of smog-making nitrogen oxides. Emerging evidence shows a variety of health impacts to people living near gas-fired power plants.

[2199] Michael J. Murphy et al., "Clean Air Program: Summary Assessment of the Safety, Health, Environmental and System Risks of Alternative Fuel" (U.S. Department of Transportation, Federal Transit Administration, August 1, 1995), https://doi.org/10.21949/1403909.

- January 11, 2023 – From December 21 to 26, 2022, Winter Storm Elliott created blizzard conditions and record cold temperatures across the United States and Canada. More than six million households in the United States were without power for some part of the five-day storm, with the Buffalo, New York region especially hard hit as utilities struggled and, in many places, failed to deliver increased electricity during the three peak demand days. A subsequent investigation revealed that gas-fired power plants were particularly prone to failure during Winter Storm Elliot, highlighting the vulnerability of natural gas supplies to freeze up during cold snaps and storms. On Christmas Eve, more than 46,000 megawatts of capacity failed to perform with 70 percent of that total coming from gas-fired power plants. Many of these plants failed because the extreme cold disrupted the flow of gas through the pipelines that served them, as a result of freeze-ups as well as loss of compression. Frigid temperatures also impeded operations at well sites, gathering stations, and compressor stations. U.S. gas production declined markedly during the storm. Gas production in Pennsylvania fell by 20 percent, and gas production in Ohio plunged by more than 50 percent.[2200, 2201, 2202]

- July 2, 2021 – In New York State, the proposed rebuilding of the Danskammer gas-fired power plant in the environmental justice community of Newburgh prompted day-long hearings on the part of two state agencies, the Public Service Commission, which oversees the state's power plant siting laws, and the New York Department of Environmental Conservation (DEC), which permits air pollutants and other discharges. The Danskammer plant is the first large-scale gas-fired power plant to be considered by New York state authorities since the 2019 passage of the Climate Leadership and Community Protection Act (CLCPA). This legislation calls for sharp, rapid reductions in the use of all fossil fuels, including natural gas, in New York State and therefore the Danskammer plant would interfere with its attainment, according to both testimony and the DEC.[2203]

- June 18, 2021 – Energy stakeholders are split over California's inclusion of fossil fuel resources in a proposed procurement package. At issue is ensuring grid reliability due to the closure of a nuclear power plant and unreliable and aging power plants. Environmental groups maintained that modeling has not indicated a need for additional fossil fuel resources in the state.[2204]

[2200] PJM, "Winter Storm Elliot," https://www.pjm.com/-/media/committees-groups/committees/oc/2023/20230112/item-02---overview-of-winter-storm-elliott-weather-event.ashx.
[2201] Nicholas Cunningham, "Winter Storm U.S. Power Outages Reveal Fossil Gas Limits," *Gas Outlook*, January 19, 2023, https://www.pjm.com/-/media/committees-groups/committees/oc/2023/20230112/item-02---overview-of-winter-storm-elliott-weather-event.ashx.
[2202] Laila Kearney, "Grid Operator PJM Probes U.S. Power Supply Woes during December Storm," *Reuters*, January 13, 2023, https://www.reuters.com/world/us/grid-operator-pjm-probes-us-power-supply-woes-during-december-storm-2023-01-12/.
[2203] Rick Karlin, "Plan for Hudson Valley Power Plant Collides with State's New Green Law," *Albany Times Union*, July 2, 2021, https://www.timesunion.com/news/article/Public-comment-period-starts-reigniting-gas-16290500.php.
[2204] Kavya Balarman, "California Groups Clash Over Gas in 11.5 GW Procurement Proposal as CAISO Calls for Conservation," *Utility Dive*, June 18, 2021, https://www.utilitydive.com/news/california-clash-gas-11-5-gw-proposal-caiso/602039/.

- May 21, 2021 – President Biden set a 15-year deadline for a zero-emissions electric grid. A new gas plant has a projected lifespan of 40 years. This discrepancy places any new power plant into a timeslot which falls outside of that carbon neutral timeline. At least eight large utilities in the U.S. are currently building new gas plants right now, and another five are considering doing so.[2205]

- April 22, 2021 – The Danskammer power plant in Newburgh is testing New York's Climate Leadership and Community Protection Act (CLCPA), passed in 2019, and the state's commitment to reducing fossil fuel emissions, according to an investigation published jointly by *City & State New York* and *New York Focus*. An advisory panel to the Climate Action Council planned to recommend that New York declare a moratorium on new natural gas facilities.[2206]

- April 1, 2021 – Ocean water is customarily used to cool some machinery at older natural gas plants on the California coast, a practice resulting in releases of much warmer water back into the ocean, harming fish and the environment. Local politicians, including the mayor of Redondo Beach, have opposed this practice and have called for the closure of these archaic power plants. However, power shortages during the hottest summer on record in 2020 prompted the Statewide Advisory Committee on Cooling Water Intake Structures to vote to recommend a delay of the planned shutdown of the Redondo Beach gas plant until the end of 2023.[2207]

- February 2, 2021 – The federally owned electric utility corporation, Tennessee Valley Authority (TVA), is proposing to replace its aging coal plants with natural gas plants. Over the past decade and a half, the sources of TVA's electricity generation have shifted away from coal toward more natural gas and nuclear power. Among the 50 biggest U.S. utilities, TVA had the second biggest increase planned in new natural gas production, with more than 3 gigawatts of capacity in its long-range plans. TVA provides electricity to all of Tennessee as well as parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia.[2208]

- January 21, 2021 – The largest gas-fired power plant in Europe, under development by Drax in North Yorkshire in the United Kingdom would, all by itself, account for 75 percent of emissions from the UK's power sector when it becomes fully operational. The

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[2205] Josh Saul, "New Gas Plants Threaten Carbon Hangover Long Past Biden Deadline," Bloomberg Green, 21 2021, https://www.bloomberg.com/news/features/2021-05-21/lifespan-of-new-u-s-gas-plants-exceeds-net-zero-climate-goals.
[2206] Lee Harris, "Gas Plant in Newburgh Tests Limits of NY's Landmark Climate Law," *City & State New York*, April 22, 2021, https://www.cityandstateny.com/articles/policy/energy-environment/gas-plant-newburgh-tests-limits-nys-landmark-climate-law.html.
[2207] Sammy Roth, "How a Beachfront Gas Plant Explains California's Energy Problems," *Los Angeles Times*, April 1, 2021, https://www.latimes.com/environment/newsletter/2021-04-01/how-a-beachfront-gas-plant-explains-californias-energy-problems-boiling-point.
[2208] Dave Flessner, "TVA Proposes to Build New Gas Plants at Shuttered Coal Sites," *Chatanooga Times Free Press*, February 2, 2021, https://www.timesfreepress.com/news/business/aroundregion/story/2021/feb/02/tvproposes-build-new-gplants-shuttered-coal-s/540871/.

Planning Inspectorate, a U.K. executive agency on land use planning, recommended that ministers refuse permission for the plant on the grounds that it would undermine the government's commitment, as codified in the Climate Change Act 2008, to cut greenhouse emissions. However, the Inspectorate was overruled.[2209]

- September 3, 2020 – Between 2000-2018, the proportion of U.S. electricity generated by coal fell by half (from 52 percent to 27 percent) and electricity from burning natural gas more than doubled (from 16 percent to 35 percent). Over the same time period, carbon dioxide emissions from the U.S. power sectors dropped by 24 percent. However, using a commitment accounting approach, an analysis of U.S. power plants found that coal-to-gas switching in the power sector has, in fact, failed to lower greenhouse gas emissions. Commitment accounting takes into account cumulative emissions across the entire assumed operating lifecycle of coal and gas plants. Because coal plants nearing the end of their operation lifespans tend to be replaced by new gas plants that have more future longevity, substituting gas plants for coal plants has not functioned to decreased committed emissions, even when a modest upstream methane leakage rate of 3 percent is assumed. "Thus, although annual emissions have fallen, cumulative future emissions will not be substantially lower unless existing coal and gas plants operate at significantly lower rates than they have historically. Moreover, our estimates of committed emissions for U.S. coal and gas plants finds steep reductions in plant use and/or early retirements are already needed for the country to meet its targets under the Paris climate agreement—even if no new fossil capacity is added."[2210]

- July 15, 2020 – The municipality of Cornwall, New York passed a resolution opposing the expansion of the Danskammer power plant, which is seeking to retool its gas-fired peaker plant in the Hudson River Valley into a continuously operating baseload facility. In so doing, Cornwall joined 20+ other towns and cities in opposing the project.[2211] The Danskammer plant would increase nitrogen oxides, ozone, and particulate matter in the area and increase greenhouse gas emissions. Permitted through 2053, its operation would also exceed the state's timeline to reach 100 percent clean energy by 2040. Further, the downwind city of Newburgh is an environmental justice community. As noted by the City of Hudson Common Council when it passed its own resolution, the proposal, if approved, "will continue the state's reliance upon fossil fuels and will not promote the state's climate change policy."[2212] The proposal is currently under review by the New York State Public Service Commission. A decision will be made by a State Siting Board.

[2209] Damian Carrington, "Legal Bid to Stop UK Building Europe's Biggest Gas Power Plant Fails," *The Guardian*, January 21, 2021, https://www.theguardian.com/environment/2021/jan/21/climate-crisis-uk-legal-bid-stop-biggest-gas-power-station-europe-fails?CMP=twt_a-environment_b-gdneco.
[2210] Christine Shearer et al., "Committed Emissions of the U.S. Power Sector, 2000–2018," *AGU Advances* 1 (2020): e2020AV000162, https://doi.org/10.1029/2020AV000162.
[2211] Helu Wang, "Cornwall Joins the Force Opposing Danskammer Power Plant," *Times Herald-Record*, July 15, 2020, https://www.recordonline.com/story/news/2020/07/15/cornwall-joins-20-ny-municipalities-oppose-danskammer-power-plant/5427624002/.
[2212] Abby Hoover, "Hudson Joins Riverfront Cities in Opposing Power Plant Expansion," *HudsonValley360*, May 29, 2020, https://www.hudsonvalley360.com/news/columbiacounty/hudson-joins-riverfront-cities-in-opposing-power-plant-expansion/article_96be26b1-0302-56aa-8c0d-64d0036cdafb.html.

- July 8, 2020 – Samples of water, sediments, soil, and biota were analyzed for concentration of potentially toxic trace metals—arsenic, cadmium, chromium, mercury, lead, zinc—in a lagoon next to a gas and oil power plant in Lagos, Nigeria.[2213] Rigorous sampling and analysis of crabs and shrimp, which are ingested by the local population as an important food source, showed bioaccumulation of cadmium, lead, mercury, and zinc. Another pathway of exposure was via air, as atmospheric deposition of pollutants was believed to be responsible for chromium measured in proximal soil samples. And since the concentration of arsenic, cadmium, chromium, and lead in the lagoon water decreased steadily with distance away from the plant, the authors concluded that their levels in the lagoon were influenced by operations of the power plant.

- May 22, 2020 – The approval of the largest power plant in Europe, which is being developed by Drax in North Yorkshire, could account for 75 percent of the UK's power sector emissions when fully operational. The UK's planning inspectorate recommended that ministers refuse permission for the 3.6GW gas plant because it "would undermine the government's commitment, as set out in the Climate Change Act 2008, to cut greenhouse emissions" by having "significant adverse effects."[2214] This was the first time this group had ever taken such an action. Despite this recommendation, the secretary of state for business, energy and industrial strategy rejected the advice and approved the project in October 2019.

- May 22, 2020 – A new set of data visualization tools from Physicians, Scientists, and Engineers for Healthy Energy (PSE) demonstrates that peaker generating natural gas plants causing the greatest health burdens can be retired and replaced with energy storage. For each state with storage-friendly policies—California, Nevada, Arizona, New Mexico, Texas, Florida, New York, New Jersey, and Massachusetts—there is a report with data visualization. According to PSE's Director of Research Elena Krieger, "Regulators and policymakers can use our findings to inform decisions related to energy storage and clean energy targets, greenhouse gas and criteria pollutant emission reductions, and investments to improve clean energy access for under-served and vulnerable communities."[2215]

- May 20, 2020 – A review of EPA emissions data show that Virginia is an outlier for U.S. electricity emissions reductions, attributable to the state's massive build-out of natural gas plants.[2216] Although all but two of its six remaining coal plants have closed, the state's replacement with gas for electricity generation has led to soaring carbon dioxide

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[2213] Gideon A. Idowu et al., "Impact of Gas and Oil-Fired Power Plants on Proximal Water and Soil Environments: Case Study of Egbin Power Plant, Ikorodu, Lagos State, Nigeria," *SN Applied Sciences* 2, no. 8 (2020): 1352, https://doi.org/10.1007/s42452-020-3150-0.
[2214] Damian Carrington, "UK Approval for Biggest Gas Power Station in Europe Ruled Legal," *The Guardian*, May 22, 2020, sec. Environment, https://www.theguardian.com/environment/2020/may/22/uk-approval-for-biggest-gas-power-station-europe-ruled-legal-high-court-climate-planning.
[2215] William Driscoll, "Replacing Peakers with Storage to Achieve the Greatest Health Benefit," *PV Magazine*, May 22, 2020, https://pv-magazine-usa.com/2020/05/22/replacing-peakers-with-storage-to-achieve-the-greatest-health-benefit/.
[2216] Benjamin Storrow, "Coal Plants Disappear in Va. But CO2 Is Rising," *E&E News*, May 20, 2020, https://web.archive.org/web/20200527214244/https://www.eenews.net/stories/1063179963.

emissions: about four million tons in 2009 to almost 25 million tons in 2019, accounting for 80 percent of all power sector emissions in Virginia. The low cost of fracked gas served as an incentive to the power plant boom as did state legislation that encouraged utilities to build more power plants.

- May 4, 2020 – Tens of billions of dollars of shareholder risk accompanies new natural gas infrastructure according to a report reviewed by Forbes.[2217] The report by the organization Energy Innovation and the shareholder advocacy group As You Sow argues that utility investment in new natural gas infrastructure only compounds risks for investors, consumers, and society. Due to incompatibilities with climate goals, as well as intense competition from renewables, the report advocates for a clean energy transition as the more affordable, less risky option. The article reinforced the report's findings, citing studies by the National Renewable Energy Laboratory, National Oceanic and Atmospheric Administration, Evolved Energy, and Vibrant Clean Energy, which found that at least 80 percent our electricity could be generated from renewable sources without reliability or affordability issues.

- April 26, 2020 – Air pollution is strongly associated with cardiovascular disease. In one of the first studies of its kind, a research team investigated the effects of air pollution exposure among workers in natural gas-fired power plants in Nigeria and matched them with healthy controls.[2218] They found increased systolic blood pressure, increased pulse rate, and higher levels of the inflammatory marker C-reactive protein in the workers compared to the controls. The longer the workers were employed there, the more abnormal their results.

- April 8, 2020 – New York State could have met the need for electricity with renewables, storage, and energy efficiency measures following the closure of the Indian Point nuclear power plant without constructing two major gas-fired power plants, according to an analysis by PSE Healthy Energy.[2219] The report concludes expanding gas infrastructure risks creating stranded assets and threatens to undermine New York's climate goals, and that employing clean resources instead of gas "could bring co-benefits like improved local air quality from the reduction of criteria air pollutants emitted by natural gas plants and enhanced grid resiliency in the case of natural disasters or other emergencies."

- March 12, 2020 – The Leviathan natural gas fields, discovered ten years earlier off the coast of Haifa in Israel, became operational in December 2019. Hundreds of billions of dollars in revenue were anticipated. However, the economic downturn, a European Union

[2217] Michael O'Boyle, "Utility Investors Risk Billions In Rush To Natural Gas: Is It A Bridge To Climate Breakdown?," *Forbes*, March 4, 2020, sec. Energy, https://www.forbes.com/sites/energyinnovation/2020/03/04/utility-investors-risk-billions-in-rush-to-natural-gas-is-it-a-bridge-to-climate-breakdown/.
[2218] C. D. Ekpruke and V. I. Iyawe, "Cardiovascular System Response to Chronic Exposure to Emissions from Gas Turbines Power Plants," *World Journal of Cardiovascular Diseases* 10, no. 04 (2020): 208–24, https://doi.org/10.4236/wjcd.2020.104020.
[2219] Annie Dillon, "Evaluating the Potential for Renewables, Storage, and Energy Efficiency to Offset Retiring Nuclear Power Generation in New York," *PSE Healthy Energy*, April 8, 2020, https://www.psehealthyenergy.org/our-work/publications/archive/research-brief-new-york-renewables-indian-point/.

carbon tax imposed on imported fossil fuels, decreased demand, falling costs of renewables, and greater concern about climate change combined to reduce the expected windfall by a factor of ten, raising questions about further investments in gas infrastructure and in building gas-fired power plants that will be obsolete within 20 years.[2220]

- February 27, 2020 – The monthly report by an energy analyst from the Australian National University's Crawford School of Public Policy challenged the national government's investment in a program that proposes up to five new gas-powered power plants.[2221] The monthly National Energy Emissions Audit suggested instead that to increase supply, currently functioning power plants can operate at greater capacity. According to the Audit, combined-cycle gas plants in the national grid were operating at only 30 percent capacity. "In reality, gas is expensive, it's high-polluting and, as this research shows, it is under-performing… Given this, why would we underwrite new gas-fired plants?"[2222]

- January 6, 2020 – The Cayuga Power Plant in Lansing, New York ceased generating power on August 29, 2019 after plans to convert the facility from a coal plant to a natural gas peaker plant were scrapped in the face of massive public opposition and after electricity transmission upgrades made electricity generated from this plant unnecessary. An advisory committee to the Lansing Town Council will oversee the future of the site. Current plans are to convert the facility into a data center with energy storage.[2223]

- September 9, 2019 – Renewables and large storage batteries will put gas-fired powered plants out of business, according to an analysis by *Bloomberg*: "It will happen so quickly that gas plants now on the drawing boards will become uneconomical before their owners are finished paying for them."[2224]

- September 9, 2019 – An analysis by *USA Today* found as many as 177 natural gas power plants in the United States "planned, under construction or announced," with close to 2,000 currently in service. In addition to the potentially catastrophic climate implications of increased methane emissions from such plants, figures show that their cost "will be more expensive than renewable alternatives" and that incentives reward utility companies

[2220] Nir Hasson, "Israel Needs to Let Go of the Natural Gas Fantasy," *Haaretz*, March 12, 2020, https://www.haaretz.com/israel-news/.premium.MAGAZINE-israel-needs-to-let-go-of-the-natural-gas-fantasy-1.8669944?=&ts=_1584147526761.
[2221] Hugh Saddler, "No Case for More Gas: National Energy Emission Audit," *The Australia Institute*, February 27, 2020, https://australiainstitute.org.au/post/no-case-for-more-gas-national-energy-emission-audit/.
[2222] Adam Morton, "'Expensive and Underperforming': Energy Audit Finds Gas Power Running Well below Capacity," *The Guardian*, March 7, 2020, sec. Environment, https://www.theguardian.com/environment/2020/mar/08/expensive-and-underperforming-energy-audit-finds-gas-power-running-well-below-capacity.
[2223] Andrew Sullivan, "What's next for the Cayuga Power Plant?," *Ithaca Times*, January 6, 2020, https://www.ithaca.com/news/lansing/what-s-next-for-the-cayuga-power-plant/article_171878da-2d96-11ea-b326-47a464efe599.html.
[2224] David R. Baker, "Gas Plants Will Get Crushed by Wind, Solar by 2035, Study Says," *Bloomberg*, September 9, 2019, https://www.bloomberg.com/news/articles/2019-09-09/gas-plants-will-get-crushed-by-wind-solar-by-2035-study-says.

for building them instead of turning to renewable alternatives. That is, in most of the country "a combination of state-level rate-setting requirements and regional market rules" lead to compensation structures that favor coal and natural gas over renewable sources of energy.[2225]

- July 8, 2019 – *S&P Global* reported that economics are causing some utilities to consider renewable energy projects over gas-fired power plant investments.[2226] States that have placed moratoria or rejected plans for new gas-powered plants include Arizona, Colorado, California, and Virginia. Investments in new gas plants will become more risky if some form of carbon dioxide emissions price is enacted in the next few years.

- 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.[2227] 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."[2228]

- 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.[2229]

- 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

[2225] Elizabeth Weise, "As Earth Faces Climate Catastrophe, US Set to Open Nearly 200 Power Plants," *USA Today*, September 9, 2019, https://www.usatoday.com/story/news/2019/09/09/climate-change-threatens-earth-us-open-nearly-200-power-plants/2155631001/.
[2226] Jared Anderson, "Climate Policy, Economics Give Renewables a Leg up on Natural Gas in the US: WRI," *S&P Global*, July 8, 2019, https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/070819-climate-policy-economics-give-renewables-a-leg-up-on-natural-gas-in-the-us-wri.
[2227] Associated Press, "Mayor: LA Will Ditch Plan to Rebuild Natural Gas Plants," *US News & World Report*, February 11, 2019, //www.usnews.com/news/best-states/california/articles/2019-02-11/mayor-la-will-ditch-plan-to-invest-billions-in-fossil-fuels.
[2228] Nichola Groom, "Los Angeles Abandons New Natural Gas Plants in Favor of Renewables," *Reuters*, February 12, 2019, sec. Commodities, https://www.reuters.com/article/us-usa-california-natgas-idUSKCN1Q12C9.
[2229] David Wichner, "Regulators Extend Ban on New Gas Power Plants in Arizona," *Arizona Daily Star*, February 8, 2019, https://tucson.com/business/regulators-extend-ban-on-new-gas-power-plants-in-arizona/article_5d492ca0-5763-5fe5-8eac-29f63cbe2b72.html.

suggest that "a future electricity mix … would be more sustainable with a lower rather than a higher share of shale gas."[2230, 2231]

- 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 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.[2232]

- 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."[2233]

- 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.[2234]

[2230] Jasmin Cooper, Laurence Stamford, and Adisa Azapagic, "Sustainability of UK Shale Gas in Comparison with Other Electricity Options: Current Situation and Future Scenarios," *Science of The Total Environment* 619–620 (April 2018): 804–14, https://doi.org/10.1016/j.scitotenv.2017.11.140.

[2231] Josh Gabbatiss, "Scientists Find Fracking Is One of the Least Sustainable Ways to Produce Electricity," *The Independent*, January 16, 2018, sec. Climate, https://www.independent.co.uk/climate-change/news/fracking-electricity-production-energy-shale-gas-extraction-sustainable-a8160661.html.

[2232] Miguel Angel Gonzalez-Salazar, Trevor Kirsten, and Lubos Prchlik, "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 (2018): 1497–1513, https://doi.org/10.1016/j.rser.2017.05.278.

[2233] Tegan N. Lavoie et al., "Assessing the Methane Emissions from Natural Gas-Fired Power Plants and Oil Refineries," *Environmental Science & Technology* 51, no. 6 (2017): 3373–81, https://doi.org/10.1021/acs.est.6b05531.

[2234] Sandie Ha et al., "Associations Between Residential Proximity to Power Plants and Adverse Birth Outcomes," *American Journal of Epidemiology* 182, no. 3 (2015): 215–24, https://doi.org/10.1093/aje/kwv042.

- 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.[2235]

- 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 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.[2236]

- 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.[2237]

- 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

[2235] Seehyung Lee et al., "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, no. 1 (2013): 461–68, https://doi.org/10.1007/s11356-012-1144-1.
[2236] Xiaopeng Liu, Lawrence Lessner, and David O. Carpenter, "Association between Residential Proximity to Fuel-Fired Power Plants and Hospitalization Rate for Respiratory Diseases," *Environmental Health Perspectives* 120, no. 6 (2012): 807–10, https://doi.org/10.1289/ehp.1104146.
[2237] Agostino Di Ciaula, "Emergency Visits and Hospital Admissions in Aged People Living Close to a Gas-Fired Power Plant," *European Journal of Internal Medicine* 23, no. 2 (2012): e53–58, https://doi.org/10.1016/j.ejim.2011.09.013.

period, 104 cumulative excess deaths would occur due to operations of these proposed plants.[2238]

Gas-fired residential appliances

Gas flames burning inside of homes and buildings represent the terminus of the fracking pipeline and are a significant contributor to poor indoor air quality. Gas-fired appliances create several pollutants including corrosive nitrogen dioxides, deadly carbon monoxide (CO), and the carcinogens formaldehyde and benzene, for which there are no safe levels of exposure. They also inevitably leak methane. Gas stoves, whose emissions are not routinely vented to the outside worlds—as are furnaces, boilers and water heaters—represent a special risk. Nearly three-quarters of methane emissions from gas stoves take place while the stove is turned off and not in use. At the same time levels of hazardous air pollutants from everyday use of gas stoves often exceed the limits of outdoor air quality standards. Indoor concentrations are often much higher than health-protective guidelines set by the World Health Organization. Recent research strongly recommends complete elimination of gas stoves as even opening windows or running mechanical ventilation, while critical, is often not adequate in reducing gas stove pollution to safe levels. Gas stoves represent a significant exposure source to both benzene, which is created within the gas flame as a combustion byproduct, and nitrogen dioxide, which is created when the high heat generated by methane combustion cause nitrogen and oxygen in the air to combine. According to the U.S. EPA, the air inside homes with gas stoves has average concentrations of nitrogen dioxide that are 50-400 percent higher than the air inside homes with electric stoves. Nitrogen dioxide exposure is a proven cause of childhood asthma. A 2013 study found that children living in a home with a gas stove have a 42 percent increased risk of current asthma and a 24 percent increased risk of lifetime asthma. A 2022 investigation that built on this earlier research found that 13 percent of childhood asthma cases in the United States are attributable to the use of gas stoves. Recognizing that cooking with a gas stove increases household air pollution and the risk of childhood asthma, the American Medical Association has called for a transition from gas stoves to electric stoves in an equitable manner.

- March 3, 2023 – A group of public health researchers reviewed the evidence on the link between gas stoves and adverse health effects and advised that households inhabited by individuals with asthma, chronic obstructive pulmonary disease, or other respiratory diseases should, if feasible, make the transition to electric stoves, "and all other households could consider it." The group also noted that there also exists a strong climate rationale to electrify home appliances and ban natural gas hookups in new residential construction.[2239]

[2238] Richard P. Hermann, Frank Divita, and Jack O. Lanier, "Predicting Premature Mortality from New Power Plant Development in Virginia," *Archives of Environmental Health: An International Journal* 59, no. 10 (2004): 529–35, https://doi.org/10.1080/00039890409605170.
[2239] John R. Balmes et al., "Cooking with Natural Gas: Just the Facts, Please," *American Journal of Respiratory and Critical Care Medicine* 207, no. 8 (April 15, 2023): 996–97, https://doi.org/10.1164/rccm.202302-0278VP.

- January 21, 2023 – Using the annual Munich Oktoberfest as a case study, an international research team documented significant methane leaks from gas-fired cooking and heating appliances and showed that electricity for cooking and heating has been a more climate-friendly energy source at the festival since 2005 due to the increasing use of renewable electricity. The team's air monitoring results showed that Oktoberfest could reduce total carbon emissions from energy consumption by 87 percent if all gas-fired appliances were replaced with electric ones. Methane emissions from gas-fired heaters and grills originate both from leaks and from incomplete combustion. Extending the study to 25 major natural gas-consuming nations, the team determined that natural gas still generates lower carbon emissions for residential appliances than electricity in 18 of 25 countries studied due to high numbers of coal-burning power plants. However, "as the share of renewable energy in the electricity mix steadily increases…the carbon footprint of electricity will be lower than that of natural gas in these countries in the near future." In other words, the climate friendliness of electric residential appliances over gas-fired appliance will increase over time.[2240]

- January 19, 2023 – An assessment of the barriers that prevent a rapid transition to induction and electric stoves identified the need of many residents living in low-income, substandard housing to rely on gas stoves for space heating as an obstacle to electrification. Public efforts toward building electrification "must center equity and improving housing conditions for disadvantaged groups, especially those who disproportionately rely on stoves as a supplemental heating source."[2241]

- December 21, 2022 – An international team of researchers found that gas stoves are responsible for almost 13 percent of childhood asthma in the United States. Using data from the American Housing Survey on gas stove use in U.S. homes, the team quantified the populational attributable fraction for gas stove use and current childhood asthma. This epidemiological tool describes the fraction of a disease that could theoretically be prevented if exposure to a given risk factor were eliminated. Specifically, team found that 12.7 percent of current childhood asthma in the United States could be prevented if gas stoves were not present. The population attributable factor varied greatly by state. For Illinois, 21.1 percent of childhood asthma cases were attributable to gas stoves. In California, 20.1 percent. In New York, 18.8 percent. In Massachusetts, 15.4 percent. In Pennsylvania, 13.5 percent. Florida experienced the lowest burden at 3 percent. Differences between states, the authors point out, are entirely due to different state-level proportions of households that cook with gas. In Illinois, for example, nearly 80 percent of households with children cook with gas, whereas only 9 percent of households in Florida do.[2242]

[2240] Florian Dietrich et al., "Climate Impact Comparison of Electric and Gas-Powered End-User Appliances," *Earth's Future* 11, no. 2 (February 2023), https://doi.org/10.1029/2022EF002877.
[2241] Misbath Daouda et al., "Correspondence on 'Home Is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User,'" *Environmental Science & Technology* 57, no. 4 (January 31, 2023): 1848–49, https://doi.org/10.1021/acs.est.2c09423.
[2242] Talor Gruenwald et al., "Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States," *International Journal of Environmental Research and Public Health* 20, no. 1 (December 21, 2022): 75, https://doi.org/10.3390/ijerph20010075.

- November 8, 2022 – In a review of the data linking nitrogen dioxide from gas stoves to health harms, the American Public Health Association (APHA) called, in a policy statement, for the U.S. EPA, the U.S. Department of Housing and Urban Development, and the U.S. Centers for Disease Control to formerly recognize "the links among gas stove emissions, nitrogen dioxide pollution, and increased risk of illness in children, older adults, people with underlying conditions, and environmental justice communities. Furthermore, the public and health care practitioners should be educated on the health harms of gas stove emissions and promotion of mitigation solutions should be expedited." The APHA further called upon the EPA to set health-protective indoor air quality guidelines, called upon the U.S. Consumer Product Safety Commission to set performance standards for gas stoves and range hoods, and called upon local and state legislative and regulatory bodies "to adopt residential building codes with preferences for installing electric appliances and to require electric appliances for building projects receiving municipal or state funding."[2243]

- June 28, 2022 – A research team led by the Harvard T.H. Chan School of Public Health investigated hazardous air pollutants present in natural gas combusted inside of Massachusetts homes. The team identified 21 different toxic air pollutants, including benzene and toluene, within consumer-grade natural gas entering homes. Undetected leaks were common, and concentrations of hazardous air pollutants in indoor natural gas emissions were highly variable, with the highest concentrations taking place during the winter months. The team noted that hazardous air pollutants from indoor natural gas leaks are not routinely monitored or accounted for in any state or federal inventory. This study is the first to provide a detailed analysis of the hazardous air pollutants present in natural gas used in residential buildings.[2244]

- May 18, 2022 – In a resolution intended to inform physicians and health care providers about the health dangers of gas stoves, the American Medical Association (AMA) recognized the association between the use of gas stoves, indoor nitrogen dioxide levels, and childhood asthma. The resolution also urged advocacy for innovative programs to assist with the cost of transitioning from gas to electric stoves. This resolution passed into AMA policy, thereby committing the professional organization to carrying out such education and advocacy.[2245, 2246]

[2243] American Public Health Association, "Gas Stove Emissions Are a Public Health Concern: Exposure to Indoor Nitrogen Dioxide Increases Risk of Illness in Children, Older Adults, and People with Underlying Health Conditions," Policy Statement, November 8, 2022, https://www.apha.org/Policies-and-Advocacy/Public-Health-Policy-Statements/Policy-Database/2023/01/18/Gas-Stove-Emissions.

[2244] Drew R. Michanowicz et al., "Home Is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User," *Environmental Science & Technology*, June 28, 2022, acs.est.1c08298, https://doi.org/10.1021/acs.est.1c08298.

[2245] American Medical Association House of Delegates, "Draft Resolution: Informing Physicians, Health Care Providers, and the Public That Cooking with a Gas Stove Increases Household Air Pollution and the Risk of Childhood Asthma," May 18, 2022, https://www.ama-assn.org/system/files/a22-439.pdf.

[2246] American Medical Association, "Informing Physicians, Health Care Providers, and the Public That Cooking with a Gas Stove Increases Household Air Pollution and the Risk of Childhood Asthma D-135.964," 2022, https://policysearch.ama-assn.org/policyfinder/detail/gas%20stove?uri=%2FAMADoc%2Fdirectives.xml-D-135.964.xml.

- January 27, 2022 – A Stanford University study quantified methane leaks from gas-fired stoves and ovens in 53 homes. The results showed that methane was released during all phases of stove use: when it was turned off, when it was in use, and during ignition and extinguishment. The team estimated that between 0.8 and 1.3 percent of the gas used by kitchen stoves is released as unburned methane, with more than three-quarters of emissions taking place when the stove was turned off. "Using a 20-year timeframe for methane, annual methane emissions from all gas stoves in U.S. homes have a climate impact comparable to the annual carbon dioxide emissions of 500,000 cars." In addition, the team found that nitrogen dioxide emissions were linearly related to the amount of gas burned. "Our data suggest that families who don't use their range hoods or who have poor ventilation can surpass the 1-hour national standard of NO2 (100 ppb) within a few minutes of stove usage, particularly in smaller kitchens."[2247]

- May 5, 2020 – A report on the health effects of gas stoves released by a consortium of environmental advocacy groups led by the Rocky Mountain Institute includes a comprehensive compendium of the many dozens of peer-review studies documenting the health harms from gas stove pollution and dating back more than 40 years. All together, these studies show that "gas stoves may be exposing tens of millions of people to levels of air pollution in their homes that would be illegal outdoors under national air quality standards."[2248]

- March 27, 2020 – A research team measured methane emissions from gas-fired appliances at the 2018 Oktoberfest folk festival in Munich, Germany where natural gas is used to heat tents and power grills and other cooking appliances. Taking into account wind speed and direction, the team found enhancements of up to 100 parts per billion, showing that large festivals can be significant methane emitters due to both incomplete combustion and methane leakage from gas appliances.[2249]

- February 4, 2015 – An Oregon State University team used data from the National Health and Nutrition Examination Survey to identify young children living homes with a gas stove and whose parents provided information on their stove habits and data on pneumonia and cough. They found higher risks for pneumonia and cough among children living in homes with gas stoves used for home heating without ventilation.[2250]

- September 2, 2014 – A cross-sectional study that examined the association between gas stoves and chronic respiratory illness in U.S. children found that ventilation is associated

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[2247] Eric D. Lebel et al., "Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes," *Environmental Science & Technology* 56, no. 4 (February 15, 2022): 2529–39, https://doi.org/10.1021/acs.est.1c04707.
[2248] Brady Anne Seals and Andee Krasner, "Health Effects from Gas Stove Pollution" (Rocky Mountain Institute, Physicians for Social Responsibility, Mothers Out Front, and Sierra Club, 2020), https://rmi.org/insight/gas-stoves-pollution-health.
[2249] Jia Chen et al., "Methane Emissions from the Munich Oktoberfest," *Atmospheric Chemistry and Physics* 20, no. 6 (March 27, 2020): 3683–96, https://doi.org/10.5194/acp-20-3683-2020.
[2250] Eric S Coker et al., "A Cross Sectional Analysis of Behaviors Related to Operating Gas Stoves and Pneumonia in U.S. Children under the Age of 5," *BMC Public Health* 15, no. 1 (December 2015): 77, https://doi.org/10.1186/s12889-015-1425-y.

with reduction, but not elimination of, childhood asthma risk. The research team found that lung function was higher among children whose parents reported using range hoods when operating gas stoves.[2251]

- January 1, 2014 – A study of indoor air pollution from gas stoves in California homes used a mass-balance model to estimate time-dependent pollutant concentrations and exposures experienced by individual inhabitants. The researchers found that gas stoves are a significant contributor to poor indoor quality and were associated with elevated levels of nitrogen dioxide, carbon monoxide, and formaldehyde. The simulation model estimated that—in homes using gas stove without coincident use of venting range hoods—62 percent, 9 percent, and 53 percent of occupants were routinely exposed to levels of nitrogen dioxide, carbon monoxide, and formaldehyde that exceeded acute health-based standards and guidelines.[2252]

- August 20, 2013 – A meta-analysis of 41 studies on the link between indoor nitrogen oxides from exposure to gas cooking and asthma in children provided "quantitative evidence that, in children, gas cooking increases the risk of asthma and indoor NO2 increases the risk of current wheeze." The findings showed that children living in homes with gas stoves have a 42 percent increased risk of having current asthma and a 24 percent increased risk of developing asthma during their lifetime.[2253]

[2251] Molly L Kile et al., "A Cross-Sectional Study of the Association between Ventilation of Gas Stoves and Chronic Respiratory Illness in U.S. Children Enrolled in NHANESIII," *Environmental Health* 13, no. 1 (December 2014): 71, https://doi.org/10.1186/1476-069X-13-71.
[2252] Jennifer M. Logue et al., "Pollutant Exposures from Natural Gas Cooking Burners: A Simulation-Based Assessment for Southern California," *Environmental Health Perspectives* 122, no. 1 (January 2014): 43–50, https://doi.org/10.1289/ehp.1306673.
[2253] Weiwei Lin, Bert Brunekreef, and Ulrike Gehring, "Meta-Analysis of the Effects of Indoor Nitrogen Dioxide and Gas Cooking on Asthma and Wheeze in Children," *International Journal of Epidemiology* 42, no. 6 (December 1, 2013): 1724–37, https://doi.org/10.1093/ije/dyt150.

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. The contraction of the industry in 2019 and 2020, accelerated by the coronavirus pandemic, led to mass lay-offs, lost jobs and high unemployment among fracking crews and associated workers. Many of these jobs failed to rebound.

With the arrival of drilling and fracking operations, rural communities have consistently experienced steep increases in rates of crime, variously including murder, assault, rape, sex trafficking, larceny, robbery, burglary, embezzlement and auto theft. Indigenous women are disproportionately victimized by violent crimes associated with oil and gas activities. 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. Bust cycles are associated with upticks in poverty, unemployment, addiction, and erosion of social norms.

Financial and other strains on municipal services include those on law enforcement, road maintenance, emergency services, and public school district administration. In shale boom areas, school districts suffer lower test scores, lower attendance, higher teacher turnover, and exacerbated education inequities. 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. In Oklahoma and in England, fracking-induced earthquakes have negatively affected property values.

- December 1, 2022 – Holders of Pennsylvania's Marcellus shale oil and gas leases who have higher incomes or are from more socially organized communities have the skills or legal resources to negotiate for more favorable conditions in their leases, according to a discussion paper developed for the National Bureau of Economic Research. Findings include a positive association between royalty rates and environmentally protective clauses, as well as royalty rates and increasing prevalence of the most environmentally protective clauses over time. This pattern suggests that those who are able to delay signing leases gain better conditions. The researchers identify a "distributive environmental justice concern, such as those previously documented in a small oil and

gas leasing literature," whereby "wealth, race, ethnicity, and language affect the prevalence of beneficial lease clauses."[2254]

- November 28, 2022 – An *Energy News Network* investigation identified four reasons why seven of the state's Appalachian counties still have unemployment rates that exceed the state average despite promised jobs accompanying the decade-long Ohio shale gas boom. These include the short-term and itinerant nature of oil and gas jobs; the existence of fracking-related jobs in metropolitan areas rather than in the shale fields of Appalachia; limited infrastructure in oil and gas counties, which has led to less shale development; and the fact that some oil and gas jobs were taken by workers displaced from the coal industry.[2255]

- October 13, 2022 – An interdisciplinary review finds that fracking's boom-bust cycles bring unique impacts to communities, and that, while boom impacts are well studied, "there is a persistent dearth of research on… impacts during busts." The bust studies they did identify found impacts such as abandoned or idled oil and gas wells carrying risks to communities; economic impacts such as rising unemployment and upticks in poverty; decommissioned, vacant, or otherwise unused oil and gas infrastructure creating debt and maintenance challenges; increases in addiction and gender-based violence; stressed public services; and "social capital" impacts such as mental health issues and the "continued erosion of social norms and community culture" that began during boom times. The researchers identify opportunities for local governmental intervention, such as exercising leverage they may have in well permitting, and in disclosure requirements with regard to chemicals and processes. The latter may assist medical practitioners to respond to public health needs and researchers to fill knowledge gaps. The authors encourage governments to be more proactive overall on community impacts.[2256]

- July 8, 2021 – Citing a "transition towards a more renewable future" and an all-time low of only ten registered students over the previous two years, the University of Calgary in Canada suspended admission to its oil and gas engineering bachelor program.[2257]

- July 2, 2021 – Federal Reserve Bank of Dallas researchers found that the region's oil and gas industry employed fewer people by 2020 than at the beginning of the fracking boom eleven years ago, even as production quadrupled. Due to technological "efficiencies," Texas and New Mexico production rose 14 percent from December 2014 and December

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[2254] Max Harleman, Pramod Manohar, and Elaine L Hill, "Negotiations of Oil and Gas Auxiliary Lease Clauses: Evidence for Pennsylvania's Marcellus Shale," Working Paper, NBER Working Paper Series (National Bureau of Economic Research, December 2022), https://www.nber.org/papers/w30806.
[2255] Kathiann M. Kowalski, "Why Ohio's Top Oil and Gas Producing Counties Continue to Lag in Jobs," *Energy News Network*, November 28, 2022, https://energynews.us/2022/11/28/why-ohios-top-oil-and-gas-producing-counties-continue-to-lag-in-jobs/.
[2256] Meghan Klasic et al., "A Review of Community Impacts of Boom-Bust Cycles in Unconventional Oil and Gas Development," *Energy Research & Social Science* 93 (November 2022): 102843, https://doi.org/10.1016/j.erss.2022.102843.
[2257] Mark Villani, "University of Calgary Suspends Admission for Oil and Gas Engineering Program," *CTV News*, July 8, 2021, https://calgary.ctvnews.ca/mobile/university-of-calgary-suspends-admission-for-oil-and-gas-engineering-program-1.5502133.

2017 while industry employment dropped 29 percent during that time. The pandemic led to further job cuts and though recovery may add jobs, companies will "require fewer employees for more output."[2258]

- July 1, 2021 – Writing in the *MIT Technology Review*, environmental sociologist Colin Jerolmack reviewed the shaky financial ground on which the Appalachian fracking boom was based and provided a realistic view of actual fracking employment trends. He wrote, "Fracking has always been expensive; extraordinarily generous fossil-fuel subsidies helped hide the true cost." The oil and gas industry eliminated more than 100,000 jobs in 2020, and 70 percent of those may not ever return. In April 2021, the economic sector within which oil and gas jobs are tracked, the mining sector, had the highest US unemployment rate.[2259]

- June 17, 2021 – Economists determined that fracking booms in Arkansas, North Dakota, and West Virginia were associated with more crime than comparison states, and these crimes carried an estimated $15.68 million (in 2008 dollars) "annual victimization cost" per state. The methods used to estimate these costs was based on an established methodology on the cost of crimes to society. The comparison states had similar crime rates to the fracking states before the boom. The data from multiples sources used in the study covered the years 2000 to 2015. Crimes linked with fracking in the study were murder, forcible rape, robbery, aggravated assault, burglary, and embezzlement. Breaking these down by the instances and costs of specific crimes, this research showed that the 1.3 more murders per 100,000 residents led to a cost of $11.63 million, and the three additional forcible rapes per 100,000 averaged $7.45 million. The fracking boom states had 27.53 more aggravated assaults, costing about an extra $2.94 million. Researchers said their "consistent and robust results… support the hypothesis that the shale boom increases crime for relatively rural American states, especially violent crime."[2260]

- June 4, 2021 – The Enbridge Line 3 pipeline project brought an influx of thousands of workers to Minnesota "who are staying in hotels, campgrounds and rental housing along the pipeline route, often in small towns like Thief River Falls, and on or near Native reservations." The Violence Intervention Project in Thief River Falls received "more than 40 reports about Line 3 workers harassing and assaulting women and girls who live in north-western Minnesota." In addition, two workers charged in a sex trafficking sting operation were Line 3 workers from Missouri and Texas, employed by the Enbridge subcontractor Precision Pipeline. Violence prevention advocates had warned state officials in advance of the project "of the proven link between employees working in extractive industries and increased sexual violence." Indeed, Minnesota's Public Utilities Commission acknowledged in its environmental impact statement that the likelihood of

[2258] Carolyn Davis, "Permian Oil Patch Faces Economic Conundrum as Efficiencies Reduce Workforce," Natural Gas Intelligence, July 2, 2021, https://www.naturalgasintel.com/permian-oil-patch-faces-economic-conundrum-as-efficiencies-reduce-workforce/.
[2259] Colin Jerolmack, "The Fracking Boom Is Over. Where Did All the Jobs Go?," *MIT Technology Review*, July 1, 2021, https://www.technologyreview.com/2021/07/01/1027822/fracking-boom-jobs-industry/.
[2260] Shishir Shakya and Kazi Sohag, "The Fracking Boom and Crime Rates in Rural American States: Some Critical Insights," *The Extractive Industries and Society* 8, no. 3 (2021), https://doi.org/10.1016/j.exis.2021.100948.

sex trafficking or sexual abuse would increase if Line 3 were permitted and that the affected regions do not have the resources to track and prevent this violence.[2261]

- June 4, 2021 – Economists found that lower-income census tracts in Oklahoma experienced disproportionately greater negative impacts on property values from "induced" earthquakes compared to higher-income areas. Scientists attribute the dramatic increase in earthquakes in Oklahoma after 2009 to the disposal of fracking wastewater into deep injection wells. Most of these range in magnitude from 3 to 4—strong enough to be felt, though rarely causing property damage—but 30 of the 850 earthquakes in 2015 were magnitude 4 or greater. These induced earthquakes may negatively impact property values through the physical damage they cause. This study added to the literature on fracking and property values by using a unique dataset, US Geological Survey's Did You Feel It? system, by extending into the years following implementation of Oklahoma's wastewater injection rules that decreased induced earthquakes, and by addressing the environmental justice dimension, motivated by the body of research indicating lower-income groups suffer disproportionate harm from natural disasters. This study confirmed that earthquakes negatively impact the pricing of housing, including negative impacts linked with each additional earthquake in 2012, 2013, and 2014. Not only did the researchers find that lower-income households saw disproportionate impacts, but these impacts also lasted longer. The researchers "posit that poorer households incur greater proportional damage for any relative seismic event due to lower quality construction of their properties," and that these households may not be able to repair their properties in a timely way following an earthquake. Overall, the pricing impacts began to lessen in 2016 coinciding with the law mandating a reduction in induced seismic activity.[2262]

- April 26, 2021 – Pennsylvania "has an opportunity to manage the decline of its polluting energy industry while investing in sustainable, high-paying green union jobs as a replacement," according to the *Philadelphia Inquirer* Editorial Board. The Board criticized the state's continued investment in natural gas infrastructure in light of climate concerns and the failure of the industry to provide a remedy for the previous, unmanaged decline of coal and steel jobs. Citing statistics on increasing employment for solar installers and wind power technicians, the Board recommended that Pennsylvania transition fossil fuel subsidies into green jobs and called for investment in communities now shedding fracking jobs as well as in black communities that have suffered the most harm from oil and gas pollution.[2263]

- March 31, 2021 –Colorado regulations now require a minimum 2,000-foot setback between oil and gas sites and homes. However, residents living near proposed fracking sites that were approved before the law went into effect are not protected by this rule.

[2261] Hilary Beaumont, "Sexual Violence Along Pipeline Route Follows Indigenous Women's Warnings," *The Guardian*, June 4, 2021, https://www.theguardian.com/us-news/2021/jun/04/minnesota-pipeline-line-3-sexual-women-violence.
[2262] Chris Mothorpe and David Wyman, "What the Frack? The Impact of Seismic Activity on Residential Property Values," *Journal of Housing Research* 30, no. 1 (2021): 34–58, https://doi.org/10.1080/10527001.2020.1827579.
[2263] Editorial Board, "Fracking Jobs Will Disappear. Pennsylvania Has to Manage the Decline.," *Philadelphia Inquirer*, April 26, 2021, https://www.inquirer.com/opinion/editorials/fracking-biden-climate-greenhouse-gas-methane-pennsylvania-20210426.html.

New homeowners in Colliers Hill, a suburban development in Erie, found themselves just 940 feet from a well pad. As reported by the *Colorado Sun,* this Occidental Petroleum Corporation fracking operation is exempt from the setback rule, as are 200 drilled but uncompleted wells and nearly 1,600 drilling permits that had been approved in the state in the twelve months before new rules went into effect. Colliers Hill residents began demanding action from the Erie Board of Trustees and filing complaints with the state. Erie Mayor Jennifer Carroll "told them that there was little the town could do, even though it had adopted its own stringent oil and gas rules, because the road separating Colliers Hills from the wells was also the boundary between Erie and unincorporated and pro-oil development Weld County."[2264]

- March 29, 2021 – At least 20 percent of jobs in oil and gas drilling, operational support, and maintenance may be automated in the next 10 years, reported the *Houston Chronicle*. Robotics and automation will replace hundreds of thousands of oil and gas industry jobs, in addition to those lost in the pandemic. In addition to inspection, maintenance, and repairs, the industry expects robotics to "reduce the number of roughnecks required on a drilling rig by 20 to 30 percent."[2265]

- March 8, 2021 – Greene County, a Pennsylvania fracking boom region with 1,257 gas wells, may not be able to cover its costs by 2023, despite receiving $37.2 million in gas development-related impact fees over ten years as part of a state program. Newly elected Green County commissioners criticized previous impact fee expenditures as "shortsighted and wasteful" and resolved to stop using these funds to balance the budget each year, according to an investigation by *Spotlight PA*. The new commissioners said that the county never planned appropriately for the transition from the coal bust and is now paying the price as the fracking bust arrives. The county's hospitality and rental markets had expanded dramatically to accommodate temporary, out-of-town gas company workers. Now many fewer such workers are spending money on rent, hotels, and elsewhere in the local economy. Public records showed that the county spent no income from the impact fees on planning initiatives, tax reductions, water preservation, or career and technical centers.[2266]

- March 8, 2021 – The Violence Intervention Project in Thief River Falls, Minnesota experienced an increase in calls for their services since the Enbridge Line 3 pipeline construction began in December 2020. The Violence Intervention Project described the assaults experienced by their callers, as well as other instances of harassment at local businesses, in a request for reimbursement from Enbridge's public safety fund, obtained through a public records request by the *Minnesota Reformer.* State permits for Enbridge

[2264] Mark Jaffe, "This Erie Neighborhood Is Ground Zero for Colorado's Collision of Fracking and Housing," *The Colorado Sun*, March 31, 2021, https://coloradosun.com/2021/03/31/colliers-hill-erie-colorado-oxy-fracking-conflict/.
[2265] Marcy de Luna, "Robots Could Replace Hundreds of Thousands of Oil and Gas Jobs by 2030," *Houston Chronicle*, March 29, 2021, https://www.houstonchronicle.com/business/energy/article/Robots-could-replace-hundreds-of-thousands-of-oil-16061352.php.
[2266] Jamie Martines, "A Pennsylvania County Went from Bust to Boom Times with Natural Gas. Now, It's Nearly Broke.," *Spotlight PA*, March 8, 2021, https://www.spotlightpa.org/news/2021/03/pa-greene-county-broke-tax-increase-gas-payouts-businesses/.

Line 3 pipeline construction had required that the company create this fund to cover expected additional law enforcement costs as well as the human trafficking prevention plan linked with the project. The Violence Intervention Project's request—seeking reimbursement for hotel room costs for victims when its emergency shelter was full—said that finding hotel rooms has been increasingly difficult as pipeline workers occupy them, and that the cost of hotel rooms had doubled in recent months.[2267]

- February 24, 2021 – Contractors on Enbridge's Line 3 pipeline were arrested and charged in a human trafficking sting in Itasca County, Minnesota. The two men, out-of-state workers, were among seven arrested. One was charged with carrying a pistol without a permit and one count of solicitation to engage in prostitution and the other with one count of solicitation of a person believed to be a minor.[2268]

- February 18, 2021 – A policy researcher identified 23 locations in the US that have the highest rates of Missing and Murdered Indigenous Women (MMIW) cases. Within these, the researcher pinpointed 16 "hot spots," and of these, six were within 25 miles of drilling and fracking sites, and three more within 25 to 50 miles. The researcher wrote that this "analysis of the locations of fracking and other resource extraction sites in relation to the MMIW 'hot spots' highlights a need for additional research into the possible correlation of these two factors." The paper reviews the evidence showing that "man camps" change the demographics of communities near fracking "and have been connected to increased rates of violence, sexual assault, sexually transmitted diseases, prostitution, sex trafficking, and an increased presence of illicit drugs."[2269]

- February 12, 2021 – A study published by the Ohio River Valley Institute, a non-profit research center, found that jobs, personal income, and population all declined between 2008 and 2019 in the 22 Ohio, Pennsylvania, and West Virginia counties that produce 90 percent of Appalachia's natural gas. The seven eastern Ohio counties that suffered the worst impacts experienced a net job loss of more than eight percent. In addition, money that had been expected to stay in communities was spent outside the region, and, because counties were counting on job creation by oil and gas companies, they had given tax breaks and other incentives that reduced the amount of revenue they received.[2270, 2271]

[2267] Rilyn Eischens, "Shelter Reports Assaults, Harassment Linked to Line 3 Pipeline Workers," *Minnesota Reformer*, March 8, 2021, https://minnesotareformer.com/2021/03/08/shelter-reports-assaults-harassment-linked-to-line-3-pipeline-workers/.
[2268] Kevin Jacobsen, "2 Arrested in Itasca Co. Human Trafficking Bust Were Line 3 Workers," cbs3duluth.com, February 24, 2021, https://cbs3duluth.com/2021/02/24/2-arrested-in-itasca-co-human-trafficking-bust-were-line-3-workers/.
[2269] A. Skylar Joseph, "A Modern Trail of Tears: The Missing and Murdered Indigenous Women (MMIW) Crisis in the US," *Journal of Forensic and Legal Medicine* 79 (2021), https://doi.org/10.1016/j.jflm.2021.102136.
[2270] Sean O'Leary, "Appalachia's Natural Gas Counties: Contributing More to the U.S. Economy and Getting Less in Return" (Ohio River Valley Institute, February 2021), https://ohiorivervalleyinstitute.org/wp-content/uploads/2021/02/Frackalachia-Report-update-2_12_01.pdf.
[2271] Beth Harvilla, "Report: Ohio Fracking Counties Saw Declines in Jobs, Population and Income," *The Columbus Dispatch*, February 10, 2021, https://www.thisweeknews.com/story/business/2021/02/10/ohio-fracking-boom-never-translated-more-jobs-and-growth-report-says/4450698001/.

- January 29, 2021 – An investigation by the Pittsburgh *Post-Gazette* predicted that Pennsylvania counties, municipalities, state agencies, and conservation initiatives will have a difficult time making up for the expected record low impact fees to be collected. Based on natural gas prices and wells drilled, total impact fees assessed on the state's shale gas wells were predicted to fall by $56 million, to a record low of $145 million. Lower gas prices also mean lower royalties for landowners who lease land for fracking, including the state itself. The state doubled fracking permit prices in August 2020 but was receiving far fewer applications than anticipated in the fiscal year of this investigation. Because the Department of Environmental Conservation's Office of Oil and Gas Management is funded largely by well-drilling application fees, the Office was struggling to maintain its level of staffing and inspection responsibilities and could be short $17.5 million for the year.[2272]

- December 22, 2020 – UK researchers determined that earthquakes caused by fracking a first exploratory well in the Lancashire area of England led to a 3.9 to 4.7 percent housing price decrease in the region where the earthquakes occurred. Notably, no commercial fracking had yet taken place. This study specifically focused on the effects of issuing licenses that served as an official signal of potential fracking development. The results showed that the licensing itself did not affect housing prices, but when the exploratory fracking triggered small earthquakes, although they did not cause property damage, housing prices fell.[2273]

- July 30, 2020 – Oil and gas production employment in the state was expected to fall to its lowest since 2005, according to Texas Alliance of Energy Producers, which represents 2,600 independent oil and gas producers.[2274] Texas had already lost 46,100 jobs in production and oil-field services from February to June 2020, related to dropped demand during the coronavirus pandemic. The alliance noted that the oil and gas industry was contracting well before the pandemic.

- July 8, 2020 – When considered in aggregate, 25 relevant, quantitative studies all published between 2005 and 2019 provide clear evidence that U.S. drilling and fracking is linked to an increase in crime, according to a systematic review by a social scientist and legal scholar.[2275] A majority of studies found "that shale gas development increases total crime, violent crime, property crime, social disorganization crimes and violence against women." Of seventeen studies that addressed violent crime, none showed that shale gas development led to less violent crime. Of the seven studies addressing shale gas

[2272] Laura Legere, "Pain of Natural Gas Price Drop Spreads to Pa. Agencies, Communities," January 29, 2021, https://www.post-gazette.com/business/powersource/2021/01/29/natural-gas-price-royalties-shale-permits-impact-fees-Pennsylvania-DEP-DCNR/stories/202101280165.
[2273] Stephen Gibbons, Stephan Heblich, and Christopher Timmins, "Market Tremors: Shale Gas Exploration, Earthquakes, and Their Impact on House Prices," *Journal of Urban Economics* 122 (2021), https://doi.org/10.1016/j.jue.2020.103313.
[2274] Paul Takahashi, "Oil and Gas Production Jobs in Texas Could Hit Bottom This Fall," *Houston Chronicle*, July 30, 2020, sec. Energy, https://www.houstonchronicle.com/business/energy/article/Oil-and-gas-employment-forecast-to-bottom-out-15446433.php.
[2275] Paul Stretesky and Philipp Grimmer, "Shale Gas Development and Crime: A Review of the Literature," *The Extractive Industries and Society* 7, no. 3 (2020): 1147–57, https://doi.org/10.1016/j.exis.2020.06.008.

development and crime against women, five of them showed a positive link, one suggested mixed results, and one suggested there no relationship. Of those studies that included data on pre- and post- increases in shale gas production, the review found drilling and fracking leads to a 28 to 46 percent increase in crime in surrounding communities. Only one study addressed shale gas development and crime outside of the United States. Noting the "considerable consistency" in these findings, the researchers recommended that, in addition to environmental impacts, the shale gas-crime considerations "should be considered by policymakers and planners when determining whether and how shale development should be allowed."

- May 26, 2020 – In April 2020, the oil and gas industry cut a record-breaking 26,300 jobs, according to the Texas Workforce Commission. Most of the jobs lost were drilling rig operators, hydraulic fracturing crews and equipment manufacturers.[2276]

- May 11, 2020 – Oil and gas industry journalist Irina Slav examined why young professionals view employment in the oil and gas industry as a poor career choice.[2277] The average age of Society of Petroleum Engineers' members is growing older while the number of students choosing engineering majors linked to careers in oil and gas are dropping. The current industry crisis is triggering layoffs among fracking crews as well as cancelling internships among young professionals. In addition, Slav argues, the contribution of the industry to the ongoing climate crisis is a disincentive to youth. Just as laid-off oil and gas workers find work in other industries, university graduates will likewise gravitate to internships and consequent recruitment in companies "that are not victims of the whims of the most volatile commodity market in the world."

- April 7, 2020 – A survey conducted by the Louisiana Oil and Gas Association of its 450 member companies found more than 23,000 jobs in the industry to be at immediate risk due to the coronavirus pandemic and the oil glut.[2278] This would constitute 70 percent of their workforce. "To boost the oil industry, LOGA put forth several measures, which include things it has long supported: suspending severance tax collections for one year, ending government-led coastal restoration lawsuits, easing regulations at the Office of Conservation and identifying ways to expedite oil storage capacity."

- February 20, 2020 – Penn State education policy scholars found that fracking economically harms school districts and exacerbates educational inequalities.[2279] Using data from 2007-2015, they found that public school districts in Pennsylvania with

[2276] Sergio Chapa, "Texas Oil and Gas Industry Cut Record 26,300 Jobs in April," *Houston Chronicle*, May 26, 2020, sec. Energy, https://www.houstonchronicle.com/business/energy/article/Texas-oil-gas-industry-shed-record-number-of-15294860.php.
[2277] Irina Slav, "Why Young Professionals Are Steering Clear Of Oil & Gas," *OilPrice.Com*, May 11, 2020, https://oilprice.com/Energy/Energy-General/Why-Young-Professionals-Are-Steering-Clear-Of-Oil-Gas.html.
[2278] Timothy Boone, "Half of Louisiana Oil, Gas Wells Could Be Shut in, 70% of Industry Jobs Lost within 90 Days, Trade Group Survey Shows," *The Advocate*, April 7, 2020, https://www.theadvocate.com/baton_rouge/news/coronavirus/article_431c2ea0-78f9-11ea-ae04-677757648aaa.html.
[2279] Matthew Gardner Kelly and Kai A. Schafft, "A 'Resource Curse' for Education?: Deepening Education Disparities in Pennsylvania's Shale Gas Boomtowns," *Society & Natural Resources* 34, no. 1 (2021): 23–39, https://doi.org/10.1080/08941920.2020.1728000.

fracking had "lower per pupil revenues, locally-raised per pupil funding for schools, per pupil income, and per pupil property wealth," than otherwise similar districts without fracking. School districts with fracking had $1,550.50 less per pupil compared to the otherwise similar districts. They concluded that fracking "may help to maintain and entrench spatial inequality across school districts."

- December 18, 2019 – A research team quantified various aspects of equity within the populations affected by the shale gas boom in Appalachia. Their findings revealed a disproportionate burden on the poor that included higher mortality risks induced by fracking-related air pollution. Poorer residents also derived fewer economic benefits from the industry.[2280] In addition to documenting that mortality risk from natural gas pollution increased as income decreased, the team also documented inequities in employment. In states where fracking takes place, 80 percent of natural gas-related employment was concentrated in just 10 percent of counties. Though authors discussed options for incorporating equity in planning and policy related to shale gas systems, their recommendations pointed to the need for fundamental socio- technical change in energy systems, in order to reduce or relieve "disproportionate costs to the poor and to future generations." A companion study to this one is described below (November 18, 2019).

- November 18, 2019 – A Carnegie Mellon, Stanford, and Princeton University study examined both the human health and climate impacts of fracking in Appalachia and was the first to put dollar values on some of the external and cumulative costs. The team found that premature deaths caused by the industry's pollution had an economic cost of $23 billion, while climate impacts cost an additional $34 billion, from 2004-2016. Their findings showed that one year of life is lost for every three job years created by the industry. These premature deaths extend beyond the communities where the gas wells—and attendant employment benefits—are located, with almost half occurring downwind of the fracking areas in urban regions of the Northeast. While these health harms from air pollution effects follow the boom-and-bust cycles of the industry, the climate harms will persist for generations well beyond the end of fracking. The study's lead author, Erin Mayfield, a postdoctoral research associate at the Princeton Environmental Institute, said, "Private firms across the supply chain have not faced the full costs of natural gas development… and the public has effectively subsidized greenhouse gas and air pollution emissions that result in climate change and health impacts."[2281, 2282] See also the companion study above (December 8, 2019).

- October 9, 2019 – In a nationwide study, an Ohio State team examined social changes linked to fracking from 2009 to 2014. They anticipated that oil and gas employment growth during the shale boom would increase marriage rates. However, they found just

[2280] Erin N. Mayfield et al., "Quantifying the Social Equity State of an Energy System: Environmental and Labor Market Equity of the Shale Gas Boom in Appalachia," *Environmental Research Letters* 14, no. 12 (2019): 124072, https://doi.org/10.1088/1748-9326/ab59cd.
[2281] Erin N. Mayfield et al., "Cumulative Environmental and Employment Impacts of the Shale Gas Boom," *Nature Sustainability* 2, no. 12 (December 2019): 1122–31, https://doi.org/10.1038/s41893-019-0420-1.
[2282] "Is Shale Development Worth the Costs? A CMU Study Says No.," *Pittsburgh Post-Gazette*, August 2019, https://www.post-gazette.com/news/health/2019/12/08/shale-development-natural-gas-drilling-fracking-costs-health-study-pennsylvania-cmu/stories/201912060038.

the opposite. Marriage rates decreased and divorce rates increased. Specifically, fracking was linked to a decline in the share of the population who were married, an increase in the proportion of divorced people, and had little effect on those who never married or cohabited.[2283] Authors discuss the range of potential negative and positive consequences of this demographic restructuring in rural communities along with the possible role that inevitable fracking busts may play in altering marriage behaviors as compared to boom-phase fracking.

- October 1, 2019 – Fracking booms can bring gains in income, employment, and salaries, and increases in housing prices and rent. An economic analysis of nine U.S. shale regions found that, despite improvements in certain economic indicators such as these, fracking was also linked to "deterioration in local amenities, which may include increases in crime, noise, and traffic and declines in health.[2284] The researchers developed a measure called "willingness to pay" for allowing fracking, which was about $2,500 per household annually. They emphasized that they found "evidence of important heterogeneity in the local net benefits," and understanding these differences "is a first-order question for researchers and policymakers interested in assessing the impacts of allowing fracking in their community."

- August 29, 2019 – Economists found reduced student test scores and reduced student attendance in Texas school shale oil districts, compared to non-shale districts.[2285] Despite tripling of the local tax base in these districts in the study period from 2001 to 2014, schools did not spend money on teacher and other school staff wages. "As the gap between teacher wages and private sector wages grew, so did teacher turnover and the percentage of inexperienced teachers, which helps explain the decline in student achievement." Researchers noted that per capita student spending did increase in other needed areas such as renovations and debt service, but this type of spending did not prevent the declines in student achievement. They noted that oil and gas revenue has entirely bypassed the education section in other fracking states.

- August 7, 2019 – The *Houston Chronicle* reported on data from two research firms that compared differences between mid-2018 and mid-2019 in numbers of wells fracked and numbers of workers in the Permian Basin. The data showed that the wells were being fracked and completed at record numbers, but with the number of crews down almost 20 percent. The article stated, "the work is being done with far fewer people as energy

[2283] Michael Shepard, Michael Betz, and Anastasia Snyder, "The Shale Boom and Family Structure: Oil and Gas Employment Growth Relationship to Marriage, Divorce, and Cohabitation," *Rural Sociology* 85, no. 3 (2020): 623–57, https://doi.org/10.1111/ruso.12306.
[2284] Alexander W. Bartik et al., "The Local Economic and Welfare Consequences of Hydraulic Fracturing," *American Economic Journal: Applied Economics* 11, no. 4 (2019): 105–55, https://doi.org/10.1257/app.20170487.
[2285] Joseph Marchand and Jeremy G. Weber, "How Local Economic Conditions Affect School Finances, Teacher Quality, and Student Achievement: Evidence from the Texas Shale Boom," *Journal of Policy Analysis and Management* 39, no. 1 (2020): 36–63, https://doi.org/10.1002/pam.22171.

companies scale back costs to appease Wall Street investors concerned about overspending."[2286]

- July 6, 2019 – Substantial evidence shows that that vulnerable women face increased violence in boomtowns full of transient laborers building big resource projects, according to a report by the Canadian National Inquiry into Missing and Murdered Indigenous Women and Girls. Pertinent to the impending approval of the Trans Mountain pipeline, the report is based on the testimony of thousands of survivors and family members of murdered and missing women, and it links "man camps" with higher rates of violence against Indigenous women. The report also raises concern about vulnerable women entering the sex trade near activity such as pipeline projects. "Women are made vulnerable by the combination of exclusion from high-paying resource jobs and having to make ends meet in a town where the cost of living is rising," according to Indigenous advocate Connie Greyeyes.[2287]

- July 5, 2019 – A statewide survey of 2,240 Pennsylvanians found that 23.4 percent of respondents had encountered fracking-related activities, including well sites, related truck traffic, pipelines, or fracking workers, during outdoor recreation. Over 12 percent reported being substantially impacted by fracking activities in their recreation, and almost 14 percent changed their plans, avoided a certain area, or no longer traveled to the Pennsylvania for outdoor activities due to these encounters. Outdoor recreation impacts were highest in the North Central and Southwest Pennsylvania, where fracking is most prominent.[2288] As noted in coverage of the study by *Consumer Affairs,* "outdoor activities provide a huge influx of income to the U.S. government, and interfering with such activities will start to interfere with those profits."[2289]

- March 16, 2019 – University of Rochester environmental and health economists found that the public announcement of the proposed Constitution pipeline led to a led to a 9.29 percent (about $12,000) decrease in sale price for New York State homes located within three kilometers of its main route, compared to houses between 3-20 kilometers away.[2290] "Our results suggest that homebuyer expectations of the environmental externalities of natural gas pipeline construction and operations are large and negative." (The

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[2286] Jordan Blum, "Permian Fracking Activity Sets New Records with Fewer People," *Houston Chronicle*, August 7, 2019, https://www.chron.com/business/energy/article/Permian-fracking-activity-breaks-new-records-with-14286709.php.
[2287] Lori Culbert, "Indigenous Women Vulnerable to 'Man Camps': MMIWG Report. So, What's at Stake with the Pipeline Approval?," *Vancouver Sun*, July 6, 2019, https://vancouversun.com/business/energy/mmiwg-report-says-indigenous-women-vulnerable-in-resource-towns-whats-at-stake-with-the-pipeline-approval.
[2288] Michael D. Ferguson et al., "The Impacts of Shale Natural Gas Energy Development on Outdoor Recreation: A Statewide Assessment of Pennsylvanians," *Journal of Outdoor Recreation and Tourism* 27 (2019): 100230, https://doi.org/10.1016/j.jort.2019.100230.
[2289] Kristen Dalli, "Shale Natural Gas Development Hampers Consumer Outdoor Activities, Study Finds," *Consumer Affairs*, August 1, 2019, https://web.archive.org/web/20210302210635/https://www.consumeraffairs.com/news/shale-natural-gas-development-hampers-consumer-outdoor-activities-study-finds-080119.html.
[2290] Andrew Boslett and Elaine Hill, "Shale Gas Transmission and Housing Prices," *Resource and Energy Economics* 57 (2019): 36–50, https://doi.org/10.1016/j.reseneeco.2019.02.001.

Constitution pipeline was canceled in February 2020 after years of public opposition and failure to obtain a state water permit.)

- 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."[2291]

- 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."[2292]

[2291] Chris G. Buse et al., "Locating Community Impacts of Unconventional Natural Gas across the Supply Chain: A Scoping Review," *The Extractive Industries and Society* 6, no. 2 (2019): 620–29, https://doi.org/10.1016/j.exis.2019.03.002.
[2292] Brian Alexander Chalfant and Caitlin C. Corrigan, "Governing Unconventional Oil and Gas Extraction: The Case of Pennsylvania," *Review of Policy Research*, 2018, e0001, https://doi.org/10.1111/ropr.12319.

- 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."[2293]

- 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.[2294] The results of the study, conducted by a team of economists, aligned with 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.[2295]

- 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

[2293] Rebecca Rasch, Matt Reeves, and Colin Sorenson, "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 (2018): 45–51, https://doi.org/10.1016/j.jort.2018.11.001.
[2294] Na Zuo, Jack Schieffer, and Steven Buck, "The Effect of the Oil and Gas Boom on Schooling Decisions in the U.S," *Resource and Energy Economics* 55 (2019): 1–23, https://doi.org/10.1016/j.reseneeco.2018.10.002.
[2295] Mike Lee and Pamela King, "These Places Rode out the Boom and Bust. Now What?," *E&E News*, September 24, 2018, https://web.archive.org/web/20180924163148/https://www.eenews.net/stories/1060099341.

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.[2296]

- 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 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.[2297]

- May 21, 2018 – Public administration scholars at Binghamton University interviewed 43 local government officials in 26 municipalities in high-density drilling areas of the Marcellus Shale regions of Pennsylvania.[2298] They considered these officials to be "on the frontlines" of social equity issues linked to the geographic distribution of environmental costs versus economic benefits of fracking. They found that most municipal officials "explicitly recognized that there were distributional benefits-sharing problems associated with shale gas drilling," while most also believed shale gas drilling was a net positive for their communities. Still, "there were mixed feelings regarding whether the financial gains of drilling compensated for the environmental impacts," with some expressing "incredulity" at the idea that money compensated for impact. Researchers demonstrate that local officials are aware of equity issues, with some taking

[2296] Jeffrey B. Jacquet et al., "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, no. 4 (2018): 596–609, https://doi.org/10.1016/j.exis.2018.06.006.
[2297] Gene L. Theodori, "Shale Energy Development in the Southern United States: A Review of Perceived and Objective Social Impacts," *The Extractive Industries and Society* 5, no. 4 (2018): 610–18, https://doi.org/10.1016/j.exis.2018.05.006.
[2298] Pamela A. Mischen and Stephanie Swim, "Social Equity and 'Fracking': Local Awareness and Responses," *Administration & Society* 52, no. 1 (2020): 138–65, https://doi.org/10.1177/0095399718774032.

action to reduce inequities, but that action in their communities often conflicts with convictions about property rights.

- 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.[2299]

- 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."[2300]

- 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 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

[2299] Richard G. Newell and Daniel Raimi, "The Fiscal Impacts of Increased U.S. Oil and Gas Development on Local Governments," *Energy Policy* 117 (2018): 14–24, https://doi.org/10.1016/j.enpol.2018.02.042.
[2300] Ron Cheung, Daniel Wetherell, and Stephan Whitaker, "Induced Earthquakes and Housing Markets: Evidence from Oklahoma," *Regional Science and Urban Economics* 69 (2018): 153–66, https://doi.org/10.1016/j.regsciurbeco.2018.01.004.

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."[2301]

- 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."[2302]

- 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.[2303]

- 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 related to extraction… but the peer-reviewed literature suggests mixed or modest effects."[2304]

- 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

[2301] Timothy M. Komarek, "Crime and Natural Resource Booms: Evidence from Unconventional Natural Gas Production," *The Annals of Regional Science* 61, no. 1 (2018): 113–37, https://doi.org/10.1007/s00168-018-0861-x.
[2302] Mike Lee and Mike Soraghan, "Rig Wreckage Probed for Cause of Deadly Okla. Blast," *E&E News*, January 24, 2018, https://web.archive.org/web/20180124201230/https://www.eenews.net/stories/1060071777.
[2303] Thomasine Heitkamp, "Sex Trafficking in the Bakken Oil Fields" (Society for Social Work and Research, Washington, DC, 2018), https://sswr.confex.com/sswr/2018/webprogram/Paper32717.html.
[2304] Adam Mayer, Shawn K. Olson-Hazboun, and Stephanie Malin, "Fracking Fortunes: Economic Well-Being and Oil and Gas Development along the Urban-Rural Continuum: Fracking Fortunes," *Rural Sociology* 83, no. 3 (2018): 532–67, https://doi.org/10.1111/ruso.12198.

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."[2305]

- 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."[2306] 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."[2307]

- 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 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

[2305] Dan Murtaugh, "Life in the Oil Ghost Towns of Texas," *Bloomberg*, September 26, 2017, https://www.bloomberg.com/news/features/2017-09-26/the-oil-ghost-towns-of-texas.
[2306] Nathan Ratledge and Laura Zachary, "Impacts of Unconventional Oil and Gas Booms on Public Education: A Mixed-Methods Analysis of Six Producing States" (Resources for the Future, 2017), https://www.rff.org/publications/reports/impacts-of-unconventional-oil-and-gas-booms-on-public-education-a-mixed-methods-analysis-of-six-producing-states/.
[2307] Eric Englert, "Fracking Brings Challenges to Local School Systems," *US News & World Report*, August 10, 2017, //www.usnews.com/news/national-news/articles/2017-08-10/fracking-brings-challenges-to-local-school-systems.

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.[2308]

- 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.[2309]

- 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 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

[2308] The Academy of Medicine, Engineering and Science of Texas, *Environmental and Community Impacts of Shale Development in Texas* (TAMEST, 2017), https://doi.org/10.25238/TAMESTstf.6.2017.
[2309] Kyle A. Hoy, Timothy W. Kelsey, and Martin Shields, "An Economic Impact Report of Shale Gas Extraction in Pennsylvania with Stricter Assumptions," *Ecological Economics* 138 (2017): 178–85, https://doi.org/10.1016/j.ecolecon.2017.03.037.

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."[2310]

- 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."[2311]

- 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.[2312]

- 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:

> 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.

[2310] John Loomis and Michelle Haefele, "Quantifying Market and Non-Market Benefits and Costs of Hydraulic Fracturing in the United States: A Summary of the Literature," *Ecological Economics* 138 (2017): 160–67, https://doi.org/10.1016/j.ecolecon.2017.03.036.
[2311] Clifford Krauss, "Texas Oil Fields Rebound From Price Lull, but Jobs Are Left Behind," *The New York Times*, February 19, 2017, sec. Business, https://www.nytimes.com/2017/02/19/business/energy-environment/oil-jobs-technology.html.
[2312] Robert B. Jackson, Jessica Owley, and James Salzman, "Mineral Estate Conservation Easements: A New Policy Instrument to Address Hydraulic Fracturing and Resource Extraction," *The Environmental Law Reporter*, January 31, 2017, https://elr.info/news-analysis/47/10112/mineral-estate-conservation-easements-new-policy-instrument-address-hydraulic-fracturing-and-resource-ext.

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.[2313]

- 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.[2314]

- 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."[2315]

- 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 drilling activity and marred broadly positive trends for late debt payments by American consumers."[2316]

- 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

[2313] Tsvetana Paraskova, "Robots Over Roughnecks: Next Drilling Boom Might Not Add Many Jobs," *OilPrice.Com*, January 26, 2017, https://oilprice.com/Energy/Energy-General/Robots-Over-Roughnecks-Next-Drilling-Boom-Might-Not-Add-Many-Jobs.html.
[2314] Bartik et al., "The Local Economic and Welfare Consequences of Hydraulic Fracturing."
[2315] Alexander James and Brock Smith, "There Will Be Blood: Crime Rates in Shale-Rich U.S. Counties," *Journal of Environmental Economics and Management* 84 (2017): 125–52, https://doi.org/10.1016/j.jeem.2016.12.004.
[2316] Sam Fleming, "US Fracking Bust Sparks Surge in Car Debt," *Financial Times*, May 24, 2016, https://www.ft.com/content/a4cb1270-21c2-11e6-aa98-db1e01fabc0c.

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.[2317]

- 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.[2318]

- 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."[2319]

- 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.[2320]

- 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 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

[2317] Eric Lindquist, "Silent Sandbox: Once Booming Frac Sand Industry Continues Major Downturn," *Leader-Telegram*, May 8, 2016, https://www.leadertelegram.com/news/front-page/silent-sandbox-once-booming-frac-sand-industry-continues-major-downturn/article_b6c1877b-3586-588f-a2b6-5cb2fe9b49ce.html.
[2318] Concetta Callahan, "Fracking Fall-off Leaves South Texas Roads a Mess," *KSAT*, March 8, 2016, sec. News, https://www.ksat.com/news/2016/03/08/fracking-fall-off-leaves-south-texas-roads-a-mess/.
[2319] Dan Boyce, "Wage Theft Claims Surge As Oil Prices Fall," *Inside Energy*, February 22, 2016, http://insideenergy.org/2016/02/22/wage-theft-claims-surge-as-oil-prices-fall/.
[2320] K. Querry and Lorne Fultonberg, "Firefighters Extinguish Damaging Grady Co. Fracking Fire," *KFOR.Com Oklahoma City*, January 13, 2016, https://kfor.com/news/all-lanes-of-traffic-shut-down-due-to-large-oil-rig-fire/.

significantly affect property values. Researchers found "strong evidence of localized costs borne particularly by groundwater-dependent homes."[2321]

- 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.[2322]

- 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.[2323]

- 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.[2324] 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."[2325] 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 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

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[2321] Lucija Muehlenbachs, Elisheba Spiller, and Christopher Timmins, "The Housing Market Impacts of Shale Gas Development," *American Economic Review* 105, no. 12 (2015): 3633–59, https://doi.org/10.1257/aer.20140079.
[2322] Marie Cusick, "Despite Drilling Slowdown, Rents Still High in Fracking Boomtowns," *State Impact Pennsylvania*, December 8, 2015, https://stateimpact.npr.org/pennsylvania/2015/12/08/despite-drilling-slowdown-rents-still-high-in-fracking-boomtowns/.
[2323] Edward McAllister, "America's Biggest Gas Field Finally Succumbs to Downturn," *Reuters*, December 2, 2015, https://www.reuters.com/article/us-usa-marcellus-decline-insight-idUSKBN0TL0CY20151202#W0DRBI8eM4MKscSV.97.
[2324] Cesar Quiroga and Ioannis Tsapakis, "Oil and Gas Energy Developments and Changes in Crash Trends in Texas," Final Report (Transportation Policy Research Center, October 2015), http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/PRC-15-35-F.pdf.
[2325] Jim Malewitz, "Report: Traffic Crashes Related to Energy Boom Cost Billions," *The Texas Tribune*, October 7, 2015, https://www.texastribune.org/2015/10/07/report-shows-huge-toll-energy-boom-traffic-crashes/.

human trafficking and organized crime in western North Dakota … as increased oil production resulted in growing populations."[2326]

- 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.[2327]

- 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.[2328] Referencing the report, *McClatchy DC* 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.[2329]

- 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.[2330]

- 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

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[2326] Nick Smith, "North Dakota to Hire 9 More Criminal Investigation Agents," *Billings Gazette*, September 30, 2015, https://billingsgazette.com/news/state-and-regional/montana/north-dakota-to-hire-9-more-criminal-investigation-agents/article_a4192344-c9b0-51cc-9693-5a4335f5be05.html.
[2327] Ben Lane, "Is Fracking about to Bust Housing in North Dakota?," *HousingWire*, September 29, 2015, sec. Mortgage, Real Estate, https://www.housingwire.com/articles/35196-is-fracking-about-to-bust-housing-in-north-dakota/.
[2328] Richard Newell and Daniel Raimi, "Shale Public Finance: Local Government Revenues and Costs Associated with Oil and Gas Development" (Cambridge, MA: National Bureau of Economic Research, September 2015), https://doi.org/10.3386/w21542.
[2329] Sean Cockerham, "Oil Boom a Loser for North Dakota Cities, Counties, Study Finds," *McClatchy Washington Bureau*, September 9, 2015, https://www.mcclatchydc.com/news/nation-world/national/economy/article34552824.html.
[2330] Tim Kellison et al., "Fracking & Parkland – Research Report," Research Report, 2015, http://plaza.ufl.edu/tkellison/_/Fracking.html.

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.[2331]

- 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."[2332, 2333]

- 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.[2334]

- 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.[2335] The dynamics of the oil boom, with an influx of out-of-state and primarily male workers far from their families, created an increase in demand for prostitution.[2336]

[2331] Adam Vaughan and Rowena Mason, "Fracking Could Hurt House Prices, Health and Environment, Official Report Says," *The Guardian*, July 1, 2015, sec. Environment, https://www.theguardian.com/environment/2015/jul/01/fracking-could-hurt-house-prices-health-and-environment-official-report-says.
[2332] Elizabeth U. Cascio and Ayushi Narayan, "Who Needs a Fracking Education? The Educational Response to Low-Skill Biased Technological Change," Working Paper, Working Paper Series (National Bureau of Economic Research, July 2015), https://doi.org/10.3386/w21359.
[2333] Sho Chandra, "Fracking Jobs Encouraged American Teens to Become High School Dropouts," *Bloomberg*, July 14, 2015, https://www.bloomberg.com/news/articles/2015-07-14/fracking-jobs-encouraged-american-teens-to-become-high-school-dropouts.
[2334] Rich Newberg, "Meth Use Tied to Fracking Workers in Pennsylvania," *News 4 Buffalo*, March 20, 2015, https://www.wivb.com/news/crime/meth-use-tied-to-fracking-workers-in-pennsylvania/.
[2335] Amy Dalrymple and Katherine Lymn, "Trafficked: Sex for Sale in the Bakken," *Human Trafficking Search*, January 4, 2015, https://humantraffickingsearch.org/resource/trafficked-sex-sale-bakken/.
[2336] Jason Gaines, "The Oil Boom in North Dakota Now Has a Serious Sex-Trafficking Problem," *Business Insider*, March 9, 2015, https://www.businessinsider.com/north-dakota-sex-trafficking-prostitution-oil-boom-police-raid-2015-3.

- 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.[2337]

- 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.[2338]

- 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.[2339] 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 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.[2340]

- 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

[2337] Deborah Sontag and Brent McDonald, "In North Dakota, a Tale of Oil, Corruption and Death," *The New York Times*, December 29, 2014, sec. U.S., https://www.nytimes.com/2014/12/29/us/in-north-dakota-where-oil-corruption-and-bodies-surface.html.
[2338] John Finnerty, "Fracking's Biggest Safety Threat Is on Rural Roads," *Star Beacon*, December 26, 2014, https://www.starbeacon.com/news/fracking-s-biggest-safety-threat-is-on-rural-roads/article_bc48687a-8caf-11e4-b4d9-6382c924a6f9.html.
[2339] Mark Price et al., "The Shale Tipping Point - Multi-State Shale Research Collaborative" (Multi-State Shale Research Collaborative, December 2014), http://www.multistateshale.org/shale-tipping-point.
[2340] Wallace McKelvey, "Fracking Brought Spikes in Crime, Road Deaths and STDs to Pa.: Report," *Pennlive*, December 18, 2014, https://www.pennlive.com/midstate/2014/12/fracking_brought_spikes_in_vio.html.

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."[2341]

- 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."[2342]

- 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."[2343]

- 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 ended. Six years prior, there were 13,000 more jobs in the Youngstown metro area than there were in summer 2014.[2344]

- 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

[2341] Sean McCarthy, "Fracking Dealt Another Setback by Quebec Report," *The Globe and Mail*, December 15, 2014, https://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/bape-says-shale-gas-production-not-advantageous-for-quebec/article22096203/.
[2342] Aman Batheja, "A County Resents Oil Drilling, Despite the Money It Brings In," *The New York Times*, October 30, 2014, sec. U.S., https://www.nytimes.com/2014/10/31/us/a-county-resents-oil-drilling-despite-the-money-it-brings-in.html.
[2343] Sarah Horwitz, "Dark Side of the Boom," *The Washington Post*, September 28, 2014, http://www.washingtonpost.com/sf/national/2014/09/28/dark-side-of-the-boom/.
[2344] Jim Tankersley, "Fracking Hasn't Restored the Rust Belt's Lost Jobs," *The Washington Post*, September 11, 2014, https://www.washingtonpost.com/news/storyline/wp/2014/09/11/fracking-hasnt-restored-the-rust-belts-lost-jobs/.

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.[2345]

- 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."[2346]

- 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."[2347]

- 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.[2348] Rationale documented by tribal leaders, law enforcement, and the FBI included, "rapid 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."[2349]

- 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

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[2345] Tara Opsal and Tara O'Connor Shelley, "Energy Crime, Harm, and Problematic State Response in Colorado: A Case of the Fox Guarding the Hen House?," *Critical Criminology* 22, no. 4 (2014): 561–77, https://doi.org/10.1007/s10612-014-9255-2.
[2346] Tyler Bell Williston, "Modernized Slavery," *Williston Herald*, September 6, 2014, https://www.willistonherald.com/news/modernized-slavery/article_84e257d8-3615-11e4-a4f8-001a4bcf887a.html.
[2347] Frank Shafroth, "Fracking's Financial Losers: Local Governments," *Governing: The States and Localities*, August 25, 2014, sec. Archive, https://www.governing.com/archive/gov-frackings-financial-losers.html.
[2348] U.S. Department of Justice, "Associate Attorney General West Announces $3 Million in Grants to Address Violence Against Women in Rural and Tribal Communities in the Bakken Region," Press Release (U.S. Department of Justice, August 28, 2014), https://www.justice.gov/opa/pr/associate-attorney-general-west-announces-3-million-grants-address-violence-against-women.
[2349] U.S. Department of Justice, "OVW Fiscal Year 2014 Violence Against Women Bakken Region Initiative: Enhanced Response to Victims Application Guidelines," 2014.

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."[2350]

- 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.[2351]

- 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.[2352]

- 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. Unemployment rose after one county's boom ended; in another county, unemployment stayed above the state average throughout.[2353]

- 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

[2350] Asjylyn Loder, "Shakeout Threatens Shale Patch as Frackers Go for Broke," *Bloomberg*, May 27, 2014, https://www.bloomberg.com/news/articles/2014-05-26/shakeout-threatens-shale-patch-as-frackers-go-for-broke.
[2351] Jonathan Fahey, "AP IMPACT: Deadly Side Effect to Fracking Boom," *Associated Press*, May 5, 2014, sec. Archive, https://apnews.com/article/ac54bee4225241729f360adbbcf394dd.
[2352] Elisabeth N. Radow, "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, no. 2 (2014): 673–704.
[2353] Multi-State Shale Research Collaborative, "Assessing the Impacts of Shale Drilling County Case Studies," April 10, 2014, https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxtdWx0aXN0YXRlc2hhbGV8Z3g6NGU4MjIyNWU5ZjFhZjM4Yg.

estimated for New York by the New York State Department of Environmental Conservation (NYS DEC).[2354, 2355]

- 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.[2356]

- February 14, 2014 – Pennsylvania landowners with fracking leases rallied in Bradford County against gas companies for precipitous drops in royalty payments.[2357]

- 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.[2358]

- 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.[2359]

- 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."[2360]

- 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

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[2354] Marie Cusick, "Report Finds Each Marcellus Gas Well Costs Thousands in Road Damage," *State Impact Pennsylvania*, March 27, 2014, https://stateimpact.npr.org/pennsylvania/2014/03/27/report-finds-each-marcellus-gas-well-costs-thousands-in-road-damage/.
[2355] Shmuel Abramzon et al., "Estimating the Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways," *Journal of Infrastructure Systems* 20, no. 3 (2014): 06014001, https://doi.org/10.1061/(ASCE)IS.1943-555X.0000203.
[2356] Molly Hennessy-Fiske, "Fracking Brings Oil Boom to South Texas Town, for a Price," *Los Angeles Times*, February 15, 2014, sec. World & Nation, https://www.latimes.com/nation/la-na-texas-oil-boom-20140216-story.html.
[2357] J. Marshall, "Landowners Rally for Royalties from Gas Companies," *WBNG*, February 14, 2014, http://www.wbng.com/news/local/Landowners-rally-for-245596511.html.
[2358] Daily Real Estate News, "'Fracking' Sparks Concern over Nearby Home Values," December 20, 2013, https://web.archive.org/web/20201105141321/https://magazine.realtor/daily-news/2013/12/20/fracking-sparks-concern-over-nearby-home-values.
[2359] Michelle Conlin, "Gas Drilling Is Killing Property Values For Some Americans," *Business Insider*, December 12, 2013, https://www.businessinsider.com/drilling-can-make-some-properties-unsellable-2013-12.
[2360] J. Loewenstein, "Shrinking Royalty Checks," *The Daily Review*, December 10, 2013, http://thedailyreview.com/news/shrinking-royalty-checks-1.1598195.

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."[2361]

- 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."[2362]

- 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.[2363]

- 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 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.[2364]

- 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.[2365]

[2361] Jack Healy, "As Oil Floods Plains Towns, Crime Pours In," *The New York Times*, November 30, 2013, https://www.nytimes.com/2013/12/01/us/as-oil-floods-plains-towns-crime-pours-in.html?smid=tw-share&_r=0.
[2362] Jon Campbell, "Report: Industry-Backed Studies Exaggerate Fracking Job Estimates," *Democrat and Chronicle*, November 21, 2013, https://www.democratandchronicle.com/story/news/local/2013/11/21/report-industry-backed-studies-exaggerate-fracking-job-estimates/3671199/.
[2363] Andy Peters, "Fracking Boom Gives Banks Mortgage Headaches," *American Banker*, November 12, 2013, https://www.americanbanker.com/news/fracking-boom-gives-banks-mortgage-headaches.
[2364] Brendan S. Gibbons, "Environmental Groups Calculate Social Cost of Natural Gas Boom," *The Times-Tribune*, September 25, 2013, https://www.thetimes-tribune.com/archive/environmental-groups-calculate-social-cost-of-natural-gas-boom/article_a6f11ae0-77d7-5fe1-ac25-a4ec8dd6cd06.html.
[2365] Will Bunch, "Pa. Fracking Boom Goes Bust," *The Philadelphia Inquirer*, November 12, 2013, https://www.inquirer.com/philly/hp/news_update/20130911_Pa__fracking_boom_goes_bust.html.

- 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.[2366]

- 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.[2367, 2368]

- 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.[2369]

- 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.[2370]

- 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 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.[2371]

- 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.[2372]

[2366] Bob Downing, "Survey Says Home Values Hurt by Fracking at Drill Sites," *Akron Beacon Journal*, April 22, 2013, https://web.archive.org/web/20140326041052/http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/survey-says-home-values-hurt-by-fracking-at-drill-sites-1.422838.
[2367] Roger Drouin, "How the Fracking Boom Could Lead to a Housing Bust," *CityLab*, August 19, 2013, https://www.bloomberg.com/news/articles/2013-08-19/how-the-fracking-boom-could-lead-to-a-housing-bust.
[2368] Jason Notte, "Fracking Leaves Property Values Tapped Out," *Concerned Burlington Neighbors* (blog), August 21, 2013, http://concernedburlingtonneighbors.blogspot.com/2013/08/.
[2369] Abrahm Lustgarten, "Unfair Share: How Oil and Gas Drillers Avoid Paying Royalties," *ProPublica*, August 13, 2013, https://www.propublica.org/article/unfair-share-how-oil-and-gas-drillers-avoid-paying-royalties.
[2370] Alan R. Collins and Kofi Nkansah, "Divided Rights, Expanded Conflict: The Impact of Split Estates in Natural Gas Production," Scholarly Project (Natural Resource Economics, West Virginia University, August 4, 2013), https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.734.6591&rep=rep1&type=pdf.
[2371] PR News Wire, "Increased Gas Drilling Activities Bringing New Challenges to Local Governments in Pennsylvania," *PR Newswire*, May 24, 2010, https://www.prnewswire.com/news-releases/increased-gas-drilling-activities-bringing-new-challenges-to-local-governments-in-pennsylvania-94774764.html.
[2372] Rachel Morgan, "Beaver County Times: What Boom? Industry Pundits Claim Thousands of Jobs Will Be Created, but Numbers Don't Quite Add up," *Keystone Research Center*, May 4, 2013, https://web.archive.org/web/20131010021511/http://keystoneresearch.org/media-center/media-coverage/beaver-county-times-what-boom-industry-pundits-claim-thousands-jobs-will.

- 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.[2373]

- 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."[2374]

- 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.[2375]

- November 16, 2012 – A Duke University study showed a drop in home values near fracking for properties that rely on groundwater.[2376]

- 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.[2377]

- 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.[2378]

[2373] Nelson D. Schwartz, "Rumors of a Cheap-Energy Jobs Boom Remain Just That," *The New York Times*, April 1, 2013, sec. Business, https://www.nytimes.com/2013/04/02/business/economy/rumors-of-a-cheap-energy-jobs-boom-remain-just-that.html.
[2374] James R. Hagerty, "Shale-Gas Boom Alone Won't Propel U.S. Industry," *Wall Street Journal*, March 19, 2013, sec. Business, https://online.wsj.com/article/SB10001424127887324392804578362781776519720.html.
[2375] Jannette M. Barth, "The Economic Impact of Shale Gas Development on State and Local Economies: Benefits, Costs, and Uncertainties," *New Solutions* 23, no. 1 (2013): 85–101, https://doi.org/10.2190/NS.23.1.f.
[2376] Danielle Muoio, "Duke Researchers Show Dip in Home Value Caused by Nearby Fracking," *The Chronicle*, November 16, 2012, https://www.dukechronicle.com/article/2012/11/duke-researchers-show-dip-home-value-caused-nearby-fracking.
[2377] Mireya Navarro, "Gas Drilling Jitters Unsettle Catskills Sales," *The New York Times*, September 27, 2012, sec. Real Estate, https://www.nytimes.com/2012/09/30/realestate/fracking-fears-hurt-second-home-sales-in-catskills.html.
[2378] "Impact of Population Growth on Law Enforcement in the Williston Basin Region" (Montana All Threat Intelligence Center & North Dakota State and Local Intelligence enter, August 17, 2012).

- October 30, 2011 – A comprehensive article in the *New York State Bar Association Journal* concluded that the risks inherent with fracking threaten mortgages.[2379]

- 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."[2380]

- October 20, 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."[2381]

- 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.[2382]

- 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.[2383]

- 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.[2384]

- 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

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[2379] Elisabeth N. Radow, "Homeowners and Gas Drilling Leases: Boon or Bust?," *New York State Bar Association* 83, no. 9 (2011), https://planetwaves.net/pdf/fracking.pdf.
[2380] Mark Levy, "Towns See Crime, Carousing Surge amid Gas Boom," *The San Diego Union-Tribune*, October 26, 2011, https://www.sandiegouniontribune.com/sdut-towns-see-crime-carousing-surge-amid-gas-boom-2011oct26-story.html.
[2381] Ian Urbina, "Rush to Drill for Natural Gas Creates Conflicts With Mortgages," *The New York Times*, October 20, 2011, sec. U.S., https://www.nytimes.com/2011/10/20/us/rush-to-drill-for-gas-creates-mortgage-conflicts.html.
[2382] New York State Department of Environmental Conservation, "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," 2011.
[2383] Zack Needles, "Must Crime Follow Pennsylvania's Gas Drilling Boom?," *Pittsburgh Post-Gazette*, August 15, 2011, https://www.post-gazette.com/business/legal/2011/08/15/Must-crime-follow-Pennsylvania-s-gas-drilling-boom/stories/201108150204.
[2384] S. Reilly, "Document Estimates Fracking's Toll on N.Y. Roads," *Pressconnects.Com*, July 26, 2011, http://www.pressconnects.com/article/20110726/NEWS01/107260384/Document-estimates-fracking-s-toll-N-Y-roads.

Pennsylvania is a far cry from the actual number of only 5,669 jobs—many of which were out-of-state hires.[2385]

- 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.[2386]

- 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.[2387]

- 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.[2388]

[2385] Stephen Herzenberg, "Drilling Deeper into Job Claims" (Keystone Research Center, 2011), http://keystoneresearch.org/sites/keystoneresearch.org/files/Drilling-Deeper-into-Jobs-Claims-6-20-2011_0.pdf.
[2386] Susan Christopherson and Ned Rightor, "How Shale Gas Extraction Affects Drilling Localities: Lessons for Regional and City Policy Makers," *Journal of Town & City Management* 2, no. 4 (2012), http://greenchoices.cornell.edu/resources/publications/drilling/Effects_on_Drilling_Localities.pdf.
[2387] Peggy Heinkel-Wolfe, "Drilling Can Dig into Land Value," *Dallas News*, September 18, 2010, https://web.archive.org/web/20120323152358/http://www.dallasnews.com/incoming/20100918-Drilling-can-dig-into-land-value-9345.ece.
[2388] Brandon Evans, "Rising Volume: 'Fracking' Has Bolstered Economies, but Noise Still Echoes around Drilling," *WC Messenger*, November 28, 2010, https://web.archive.org/web/20110603152315/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, profitability problems, and risk disclosure to investors

Industry projections of shale-based oil and gas reserves have proven undependable and unable to forecast how much oil or gas can be extracted from a given basin based on the production of existing wells. Further, unlike conventional wells, which can provide steady yields for decades, fracked wells typically deplete 70-90 percent within three years, requiring more drilling and continuous capital investment. Low yields and heavy extraction costs have 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 fracking boom, the industry as a whole has spent more money drilling wells than selling oil and gas and remained dependent on cheap credit and low interest rates. Fracking has never been consistently profitable, despite being heavily subsidized through tax incentives that have functioned to encourage continuing investments even when gas and oil prices are low.

In 2014, a fall in oil and gas prices led to a two-year downturn in fracking operations and a wave of bankruptcies. 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. Bonding requirements proved—and still are—notoriously inadequate.

A modest upswing in prices in 2017 brought renewed industry enthusiasm for fracking. However, because of the rapid depletion of individual shale wells and the falling output of major shale basins, operators invested in drilling new wells at an increasingly rapid pace to maintain the same level of extraction. More than half of all U.S. oil was extracted from wells that were two years old or younger, and they pumped less oil than forecast. Despite rising oil prices, fracking-focused companies continued to lose cash. By 2018, the need to stabilize economic fundamentals by increasing production and lowering costs contributed to the shift toward mega-fracking—with ever-longer laterals and higher volumes of water, sand, and chemicals per well—and also toward the practice of clustering many secondary wells near a productive parent well. The act of fracking these so-called child wells, however, often permanently damages the primary wells they surround, undermining production in the whole area.

In 2020, oil and gas prices collapsed under suddenly constricted demand during the COVID-19 pandemic, oversupply in the global markets, and a price war between Russia and Saudi Arabia. By April 2020, oil futures had fallen to levels below the break-even point for fracking operations, triggering a wave of bankruptcies. Decisions by major investors to divest from fossil fuel projects followed. By 2021, under investor pressure to turn profits and slash carbon emissions, oil and gas majors began selling off fracking assets to smaller, independent companies. As a group, however, these companies are among the biggest methane emitters in the industry. By 2023, pressure from investors to increase dividends had suppressed capital expenditures and productivity. A shift to higher prices and a solution to the ongoing labor crisis within the oil and gas industry would be required for fracking companies to expand aggressively.

- June 1, 2023 – Over objections that the oil and gas industry should fund its own fracking activities, North Dakota legislature passed a bill, signed by the governor, that incentivizes fracking by reducing the oil extraction tax on wells that are re-stimulated. The law went into effect on July 1, 2023.[2389]

- January 12, 2023 – An investigation by the Ohio River Valley Institute into Diversified Energy's financial practices revealed that the company has likely not set aside sufficient funds for decommissioning its inventory of more than 72,000 wells in Appalachia. Eschewing industry standards in accounting for its obligations to pay for plugging its wells once they are no longer productive, Diversified assumes in its financial statements that it can plug wells at an average cost of $21,000, a fraction of industry norms, and also assumes that its wells will remain productive for the next 73 years. Diversified's estimates of its own costs to decommission wells are also questionable because they are only a fraction of what the company charges states when it is hired to plug orphaned wells using federal funds. "For example, the company has been awarded a contract to plug and abandon 100 wells in West Virginia, at an average cost per well of $126,000. Yet it claims in its financial filings that it can plug and abandon its own wells for roughly one sixth the cost it will be paid with federal dollars."[2390]

- August 17, 2022 – The U.S. fracking boom allowed crude oil production per active well to more than double from 2011 to 2019, while gas production per well jumped 50 percent over the same time period. However, economic profits declined over this same period, with persistent losses setting in after 2014. This disconnect between productivity and profits in U.S. oil and gas extraction created pressure from investors to increase dividends and pay down debt at the expense of capital expansion. Going forward, a shift to higher prices would be required for fracking companies to expand production aggressively, according to an analysis by the Federal Reserve Bank of New York.[2391]

- June 23, 2021 – A study from the Stockholm Environment Institute, a nonprofit research center, examined how U.S. federal policy in the form of powerful tax incentives has created an indirect subsidy to the fracking industry throughout the past two decades. These tax breaks reduce the risks of investing and amplify the expected financial returns of investing in fracking operations, thereby aiding and sustaining the U.S. shale boom. The expensing of intangible drilling costs and percentage depletion provisions, for example, work to reduce tax payments and increase the expected value of new oil and gas wells by up to $20 billion in a single year. Among other specific findings: between 2007 and 2014, when oil prices were high (above $60/barrel), subsidies had relatively little

[2389] North Dakota Office of Tax Commissioner, "2023 Legislative Recap," North Dakota Wholesale & Oil Taxes Newsletter, June 2023, https://www.tax.nd.gov/sites/www/files/documents/newsletters/2023-wholesale-and-oil-taxes-newsletter.pdf.
[2390] Ted Boettner and Kathy Hipple, "Diversified Energy's Questionable Financial Practices Continue in 2022" (Ohio River Valley Institute, January 12, 2023), https://ohiorivervalleyinstitute.org/diversified-energys-questionable-financial-practices-continue-in-2022/.
[2391] Matthew Higgins and Thomas Klitgaard, "The Disconnect between Productivity and Profits in U.S. Oil and Gas Extraction," Liberty Street Economics (Federal Reserve Bank of New York, August 17, 2022), https://libertystreeteconomics.newyorkfed.org/2022/08/the-disconnect-between-productivity-and-profits-in-u-s-oil-and-gas-extraction/.

effect on decisions to drill. But in low-price years, "subsidies increased expected returns enough to push more than 30 percent of new oil projects into profitability, greenlighting their investment decisions." Further, subsidies likely played a substantial role in abetting the fracking boom in Appalachia, "making new gas projects viable, beginning in 2010, when more than 30 percent of new gas projects may have been subsidy-dependent." This study illustrates that tax code is a powerful policy tool, able to influence what energy projects get developed.[2392]

- June 14, 2021 – Small, independent drilling and fracking companies backed by private equity are disproportionately represented among the highest emitters of methane, according to a report based on industry data submitted to the U.S. Environmental Protection Agency. These 195 small producers together account for 9 percent of production but contribute 22 percent of total reported emissions. "The study also reinforces concerns that oil firms 'greening up' by selling assets does little to help the climate when the emissions are just transferred to another operator that may be less environmentally minded."[2393]

- May 26, 2021 – A group of investors, backed by three large pension funds, installed new board members at ExxonMobil over the objection of the company's management. The new investors want ExxonMobil to pledge to reduce its emissions to net zero by 2050, warning that an emissions reduction strategy was a fundamental investor issue given the immense risk to ExxonMobil's current business model and flagging financial performance. "Investors are no longer standing on the sidelines."[2394]

- May 26, 2021 – The Hague District Court ordered Royal Dutch Shell to cut carbon emissions by 45 percent by 2030, in line with United Nations guidance for member states to limit global warming to 1.5° Celsius above pre-industrial levels. This is the first ruling in the Netherlands of a non-State entity being ordered to reduce carbon dioxide emissions, a ruling which can potentially pave the way for further litigation against other emitters in and outside of the Netherlands.[2395]

- May 18, 2021 – The International Energy Agency, an intergovernmental energy policy advisor to 30 different member nations and other emerging economies, called in a major report for no new investments in fossil fuels as part of a plan to achieve to net-zero

[2392] Peter Erickson and Ploy Achakulwisut, "How Subsidies Aided the US Shale Oil and Gas Boom" (Stockholm Environment Institute, June 23, 2021), https://www.sei.org/publications/subsidies-shale-oil-and-gas/.
[2393] Stephen Cunningham, "Private Equity-Backed Drillers Under Emissions Scrutiny," Argus, June 14, 2021, https://www.argusmedia.com/en/news/2224429-private-equitybacked-drillers-under-emissions-scrutiny?backToResults=true.
[2394] Stephen Cunningham, "Exxon Humbled by Shareholder Revolt: Update," Argus, May 26, 2021, https://www.argusmedia.com/en/news/2218876-exxon-humbled-by-shareholder-revolt-update.
[2395] "Climate Change Litigation Bombshell: Dutch Lower Court Orders Royal Dutch Shell to Reduce CO2 Emissions," Jonesday.com, May 26, 2021, https://www.jonesday.com/en/insights/2021/06/climate-change-litigation-bombshell-dutch-lower-court-orders-royal-dutch-shell-to-reduce-co2-emissions.

emissions by 2050. The plan also calls for retiring coal plants by 2030 and banning sales of new internal combustion engine cars by 2035.[2396]

- April 30, 2021 – The first study to fully assess the inadequacies of New Mexico's oil and gas bonding requirements on both state and private lands found a $8.18 billion gap between the bonds posted for in the state ($201.42 million) and the projected costs of cleaning up the sites should companies declare bankruptcy ($8.38 billion). The study also found that no bonding requirements exist for many of the ancillary pieces of drilling-related infrastructure, including compressor station sites, fracking waste pits, storage facilities, and warehouses.[2397] This study was based on publicly available data as well as data provided to researchers by the New Mexico State Land Office. However, the authors emphasize that their analysis was limited by lack of transparency. "For instance, we did not have access to a full report on the financial assurance carried by operators permitted by the New Mexico Oil Conservation Division, and therefore we had to use sampling techniques to build a reasonable estimate."[2398]

- March 9, 2021 – A joint analysis by the Stockholm Environment Institute and the Ohio River Valley Institute looked at the major drivers of demand for natural gas and found financial risks for expanding natural gas extraction in Appalachia, including for new gas wells, pipelines, and export terminals. Analysts predicted that decreased global demand and robust competition from renewables will ultimately render new fracking operations in the region, which includes Ohio, West Virginia, and Pennsylvania, unprofitable.[2399]

- February 9, 2021 – Chesapeake Energy, once the United States' second-largest natural gas producer, emerged from bankruptcy with a business plan that signals a shift back to fracking for natural gas—with a focus on Louisiana and Appalachia—and away from oil extraction. Chesapeake filed for court protection in June 2020 and won approval, six months later, for a plan that allowed it to shed about $7.7 billion in debt. Chesapeake was unable to turn a profit while simultaneously paying down $9 billion in debt. To complete its exit from bankruptcy, Chesapeake took on $1 billion in new debt and dismissed 15 percent of its workforce. "We were never able to invest in our assets to the benefit of our shareholders," said Chief Executive Doug Lawler in an interview with Reuters.[2400]

[2396] International Energy Agency, "Net Zero by 2050: A Roadmap for the Global Energy Sector, 3rd Revision," May 2021, https://www.iea.org/reports/net-zero-by-2050.
[2397] The Center for Applied Research, Inc., "An Analysis of the Adequacy of Financial Assurance Requirements for Oil and Gas Infrastructure Located on State Trust and Private Lands In New Mexico" (The Center for Applied Research, Inc., April 30, 2021), https://www.nmstatelands.org/wp-content/uploads/2021/05/NM-Assurance-Assessment-May-FINAL.pdf.
[2398] Hannah Grover, "Analysis Finds $8.1 Billion Gap in New Mexico Bonding Requirements, Clean Up Costs for Oil and Gas," *NM Political Report*, May 20, 2021, https://nmpoliticalreport.com/2021/05/20/analysis-finds-8-1-billion-gap-in-new-mexico-bonding-requirements-clean-up-costs-for-oil-and-gas/.
[2399] Peter Erickson and Ploy Achakulwisut, "Risks for New Natural Gas Developments in Appalachia" (Stockholm Environment Institute U.S. and Ohio River Valley Institute, March 2021), https://cdn.sei.org/wp-content/uploads/2021/03/risks-of-new-natural-gas-developments-in-appalachia-march-2021-final-3.9.21.pdf.
[2400] Jennifer Hiller, "Chesapeake Energy Emerges from Bankruptcy and Shifts Back to Natural Gas," February 2, 2021, https://www.reuters.com/article/us-chesapeake-energy-bankruptcy/chesapeake-energy-emerges-from-bankruptcy-and-shifts-back-to-natural-gas-

- February 1, 2021 – S&P Global Ratings downgraded the credit ratings of Exxon Mobil Corp, Chevron Corp and ConocoPhillips, citing poor financial performance and pressure to act on climate change. Weeks earlier, the agency had warned it was considering downgrades for 13 of the world's largest oil companies due to rising risk from energy transition and price volatility.[2401]

- January 21, 2021 – The president of the European Investment Bank, Werner Hoyer, announced that the bank is phasing out funding for fossil fuel projects and intends to pursue a decarbonization policy that aligns with the goals of the Paris Climate Agreement. "To put it mildly, gas is over. This is a serious departure from the past, but without the end to the use of unabated fossil fuels, we will not be able to reach the climate targets."[2402]

- January, 2021 – Providing 38.2 percent of Europe's electricity, renewable energy surpassed fossil fuels in the European power sector in 2020, jumping by four percent over its 2019 contribution. The use of fossil fuels for power generation declined in the years 2010-2020 from 49 percent to 37 percent, with coal falling fastest.[2403]

- October 2, 2020 – Credit rating agency Moody's announced that long-term credit risks for natural gas infrastructure projects are rising, as the increasing public focus on decarbonization threatens to reduce demand for natural gas. Moody's cited obstacles to pipeline permitting and construction, rising capital costs, and climate goals, in addition to methane emissions and rising safety concerns.[2404]

- July 22, 2020 – An analysis of energy return on investment showed that the fracking industry has consumed an ever-larger portion of the energy it extracts as the shale basins become exhausted and the energy infrastructure is forced to expand and absorb more GDP. Further, because fracked wells typically deplete 70-90 percent within three years, fracking incurs heavy extraction costs and continuous capital investment. The advent of the fracking boom itself, which corresponds to the economic downturn in 2008, was made possible by historically low interest rates and continues to depend on cheap credit. Driven by fracking, the fossil fuel economy suffers from an inability to sustain economic

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[2401] Reuters Staff, "S&P Downgrades Exxon and Chevron on Climate Risk, Dour Earnings," Reuters, February 12, 2021, https://www.reuters.com/article/us-usa-oil-credit/sp-downgrades-exxon-and-chevron-on-climate-risk-dour-earnings-idUSKBN2AC29C.

[2402] "'Gas Is over', EU Bank Chief Says," *Euractiv*, January 21, 2021, https://www.euractiv.com/section/energy-environment/news/gas-is-over-eu-bank-chief-says//.

[2403] Agora Energiewende and Ember, "The European Power Sector in 2020: Up-to-Date Analysis on the Electricity Transition," January 2021, https://ember-climate.org/wp-content/uploads/2021/01/Report-European-Power-Sector-in-2020.pdf.

[2404] Tom DiChristopher, "Moody's: Long-Term Credit Risks Are Rising for Natural Gas Infrastructure Projects," IEEFA.org, October 2, 2020, https://ieefa.org/moodys-long-term-credit-risks-are-rising-for-natural-gas-infrastructure-projects/.

growth as the energy return on investment is lower with fracking than it was for conventional fossil fuels. This article concludes that the United States' increasing reliance on fracking to obtain energy is not sustainable. "On the one hand, this will lead to 'energy sprawl'—the growth of the energy sector, as this sector consumes a much larger portion of the energy it extracts—leaving less energy surplus for other sectors. On the other hand, we will see an unsustainable imbalance between the fuel prices that fossil-fuel companies will need to meet their costs and the fuel prices that the larger economy can afford to pay."[2405]

- July 7, 2020 – The energy media outlet *Energy Review* reported that the collapse in the global gas market has jeopardized the future of capital-intense LNG export projects, which were driven by the U.S. fracking boom. Even as spending on new gas terminals to ship LNG abroad has doubled since 2019, these projects are at risk of being abandoned because of a global glut of fossil fuels. At least two dozen such projects are already canceled or facing serious financial difficulties. These problems have been made worse by the pandemic but are not expected to resolve when the pandemic ends due to other underlying trends. Other nations have adopted renewable energy technology sooner than expected, and some large investors, including the European Investment Bank, have stopped funding fossil fuel projects altogether as it becomes clear that any new gas infrastructure places the goals of the Paris Climate Accord out of reach.[2406]

- June 28, 2020 – Fracking giant Chesapeake Energy said that it had filed for bankruptcy protection. Once the nation's second-largest gas producer, Chesapeake was beset by debt and deeply harmed by the downturn in oil and gas prices in the wake of the coronavirus pandemic. Owing $9 billion to lenders, Chesapeake entered an agreement to cut $7 billion of its debt.[2407, 2408]

- June 17, 2020 – Goldman Sachs Group reports that investment in renewable energy is expected to overtake oil and gas investment in 2021, representing a $16 trillion investment opportunity in the coming decade. This trend is driven in part by a diverging cost of capital, as borrowing rates have risen as high as 20 percent for hydrocarbon projects compared with as little as 3 percent for clean energy.[2409]

[2405] Bart Hawkins Kreps, "The Rising Costs of Fossil-Fuel Extraction: An Energy Crisis That Will Not Go Away," *American Journal of Economics and Sociology* 79, no. 3 (2020): 695–717, https://doi.org/10.1111/ajes.12336.
[2406] "Gas Projects in Jeopardy as Global Market Collapses," *Energy Review*, July 7, 2020, https://energyreviewmena.com/index.php/article/oil-gas/item/813-gas-projects-in-jeopardy-as-global-market-collapses.
[2407] Cathy Bussewitz and Tali Arbel, "Fracking Pioneer Chesapeake Energy Files for Bankruptcy Protection," *USA Today*, June 28, 2020, https://www.usatoday.com/story/money/2020/06/28/plunging-oil-prices-send-chesapeake-into-bankruptcy/3275712001/.
[2408] Clifford Krauss, "Chesapeake Energy, a Fracking Pioneer, Is Reeling," *The New York Times*, June 9, 2020, sec. Business, https://www.nytimes.com/2020/06/09/business/energy-environment/chesapeake-energy-bankruptcy-protection.html.
[2409] Dan Murtaugh, "Goldman Sachs Sees $16 Trillion Investment Opportunity in Renewable Energy Through 2030," IEEFA.org, June 17, 2020, https://ieefa.org/goldman-sachs-sees-16-trillion-investment-opportunity-in-renewable-energy-through-2030/.

- April 24, 2020 – The largest oil producer in North Dakota, Continental Resources, stopped all drilling in the state and shut in most of its wells as another major player the Bakken Shale, Whiting Petroleum, filed for bankruptcy.[2410]

- April 19, 2020 – U.S. oil prices fell into negative numbers as demand for crude oil plummeted and created a supply glut that filled storage facilities, including tanker vessels anchored at sea. U.S. crude futures fell to levels well below the break-even costs for fracking operations, leading to a wave of drilling halts. Fracking service company Halliburton reported a $1 billion loss during its first quarter.[2411]

- April 10, 2020 – In a financial analysis of U.S. fracking operations, journalist Bethany McLean argued that the willingness of investors to continue buying debt at super-low interest rates has served as a financial lifeline to the fracking industry for the past decade. "They have subprimed the American energy ecosystem." As debt markets grew more cautious, fracking was propped up by private equity investors. "In the Haynesville and the Utica Shales, two major natural gas plays, over half of the drilling is being done by private equity-backed companies; in the oil-rich Permian Basin, it's about a quarter of the drilling. From 2015 through 2019, private equity firms raised almost $80 billion in funds focused mostly on shale production…. Energy independence was a fever dream, fed by cheap debt and frothy capital markets."[2412]

- April 1, 2020 – U.S. fracking company Whiting Petroleum announced it had filed for bankruptcy protection.[2413]

- March 11, 2020 – U.S. fracking company Occidental Petroleum announced it had cut dividends to investors for the first time in 30 years due to a sharp decline in prices.[2414]

- December 23, 2019 – Banks that have helped fund the fracking boom have begun to tighten revolving lines of credit as they revise estimates on the value of shale reserves held as collateral.[2415]

- December 11, 2019 – Chevron announced that it would write down at least $10 billion in assets, mostly shale gas holdings in the Marcellus Shale and a planned LNG export

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[2410] Devika Krishna Kumar and Liz Hampton, "U.S. Oil Firm Continental Resources Halts Shale Output, Seeks to Cancel Sales," *Reuters*, April 24, 2020, sec. Commodities, https://www.reuters.com/article/us-continental-resources-shale-north-dak-idUSKCN2260PX.
[2411] Stephanie Kelly, "Oil Price Crashes into Negative Territory for the First Time in History amid Pandemic," *Reuters*, April 19, 2020, sec. Commodities, https://www.reuters.com/article/us-global-oil-idUSKBN2210V9.
[2412] Bethany McLean, "Opinion | Coronavirus May Kill Our Fracking Fever Dream," *The New York Times*, April 10, 2020, sec. Opinion, https://www.nytimes.com/2020/04/10/opinion/sunday/coronavirus-texas-fracking-layoffs.html.
[2413] Collin Eaton and Andrew Scurria, "Whiting Petroleum Becomes First Major Shale Bankruptcy as Oil Prices Drop," *Wall Street Journal*, April 1, 2020, sec. Business, https://www.wsj.com/articles/u-s-shale-driller-whiting-petroleum-to-file-for-bankruptcy-11585746800.
[2414] "US Fracking Giant Feels Pain of Price Crash," *Energy Reporters*, March 11, 2020, https://www.energy-reporters.com/production/us-fracking-giant-feels-pain-of-price-crash/.
[2415] Christopher M. Matthews, Bradley Olson, and Allison Prang, "Banks Get Tough on Shale Loans as Fracking Forecasts Flop," *Wall Street Journal*, December 23, 2019, sec. Business, https://www.wsj.com/articles/banks-get-tough-on-shale-loans-as-fracking-forecasts-founder-11577010600.

facility in Canada, while EQT, also a major player in the Marcellus Shale, cut a quarter of its work force.[2416]

- August 20, 2019 – Using new methods involving water pyrolysis, a team of researchers at University of Nottingham estimated the amount of gas inside the Bowland Shale in the United Kingdom. Their findings showed dramatically less gas available for extraction by fracking than previous supposed. According to their results, the amount of gas available is the equivalent of five to seven years of gas, based on current rates of consumption in the United Kingdom. Previous estimates by the British Geological Survey had pegged the likely amount of gas as a 50-year supply.[2417, 2418]

- 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."[2419]

- 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 of rising oil prices, fracking companies spent $3.9 billion more on drilling than they generated by selling oil and gas.[2420]

- September 20, 2018 – Confronted with falling prices and mounting debt, Southwest Energy sold off its assets in Arkansas' Fayetteville Shale, placing fracking on hold.[2421]

- 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

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[2416] Clifford Krauss, "Natural Gas Boom Fizzles as a U.S. Glut Sinks Profits," *The New York Times*, December 11, 2019, sec. Business, https://www.nytimes.com/2019/12/11/business/energy-environment/natural-gas-shale-chevron.html.
[2417] Patrick Whitelaw et al., "Shale Gas Reserve Evaluation by Laboratory Pyrolysis and Gas Holding Capacity Consistent with Field Data," *Nature Communications* 10, no. 1 (2019): 3659, https://doi.org/10.1038/s41467-019-11653-4.
[2418] Matt McGrath, "Fracking: UK Shale Reserves May Be Smaller than Previously Estimated - BBC News," *BBC News*, August 20, 2019, https://www.bbc.com/news/science-environment-49395658.
[2419] Bradley Olson, Rebecca Elliott, and Christopher M. Matthews, "Fracking's Secret Problem—Oil Wells Aren't Producing as Much as Forecast," *Wall Street Journal*, January 2, 2019, sec. Markets, https://www.wsj.com/articles/frackings-secret-problemoil-wells-arent-producing-as-much-as-forecast-11546450162.
[2420] 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
[2421] Daniel Breen, "Fayetteville Shale Assets Sold Off, Fracking Still On Hold," *Arkansas Public Media*, September 20, 2018, https://www.arkansaspublicmedia.org/post/fayetteville-shale-assets-sold-fracking-still-hold.

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."[2422]

- December 12, 2017 – Under pressure from investors, Exxon agreed 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.[2423]

- 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.[2424]

- 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.[2425]

- 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 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."[2426]

- 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

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[2422] J.-F. Mercure et al., "Macroeconomic Impact of Stranded Fossil Fuel Assets," *Nature Climate Change* 8, no. 7 (2018): 588–93, https://doi.org/10.1038/s41558-018-0182-1.
[2423] David Hasemyer and John H. Cushman Jr., "Exxon Agrees to Disclose Climate Risks Under Pressure from Investors," *Inside Climate News*, December 12, 2017, https://insideclimatenews.org/news/12122017/exxon- climate-risk-disclosure-sec-shareholder-investigation-pressure.
[2424] C. Carlson, "Pennsylvania Gas Drilling Fee Revenue Falls for Third Year," *WENY News*, June 16, 2017, https://www.weny.com/story/35680098/pennsylvania-gas-drilling-fee-revenue-falls-for-third-year.
[2425] S.A. Clancy et al., "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 (2018): 586–94, https://doi.org/10.1016/j.scitotenv.2017.02.160.
[2426] "America's Shale Firms Don't Give a Frack about Financial Returns," *The Economist*, March 25, 2017, https://www.economist.com/business/2017/03/25/americas-shale-firms-dont-give-a-frack-about-financial-returns.

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.[2427, 2428]

- March 2, 2017 – In 2016, Chevron became the first major oil company to warn investors in its Form 10-K, which oil and natural gas companies are required to file with the U.S. Securities and Exchange Commission, 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."[2429]

- 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.[2430]

- 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.[2431]

- 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

[2427] J.B. Montgomery and F.M. O'Sullivan, "Spatial Variability of Tight Oil Well Productivity and the Impact of Technology," *Applied Energy* 195 (2017): 344–55, https://doi.org/10.1016/j.apenergy.2017.03.038.
[2428] Christa Marshall, "Studies Attack Conventional Wisdom on Natural Gas," *E&E News*, October 6, 2017, https://web.archive.org/web/20171006225015/https://www.eenews.net/stories/1060062933.
[2429] Joe Romm, "Chevron Is First Oil Major to Warn Investors of Risks from Climate Change Lawsuits," *Think Progress*, March 2, 2017, https://thinkprogress.org/chevron-admits-climate-lawsuits-threaten-profits-33937dd562fd/#.56j1qq4h3.
[2430] Alison Sider, "Revving Up Oil Fields Won't Be So Easily Done," *Wall Street Journal*, July 7, 2016, sec. Business, https://www.wsj.com/articles/revving-up-oil-fields-wont-be-so-easily-done-1467883807.
[2431] Asjylyn Loder, "Why Billions in Proven Shale Oil Reserves Suddenly Became Unproven," *Bloomberg*, June 15, 2016, https://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.[2432]

- 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."[2433]

- 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."[2434]

- 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.[2435]

- 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.[2436]

- 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'

[2432] Matt Egan, "Oil Bankruptcies Mount despite Crude Rebound," *CNNMoney*, May 16, 2016, https://money.cnn.com/2016/05/16/investing/sandridge-energy-oil-bankruptcy/index.html.
[2433] Christopher Helman, "The 15 Biggest Oil Bankruptcies (So Far)," *Forbes*, May 9, 2016, sec. Energy, https://www.forbes.com/sites/christopherhelman/2016/05/09/the-15-biggest-oil-bankruptcies-so-far/.
[2434] Chico Harlan, "The Big Bust in the Oil Fields," *The Washington Post*, March 25, 2016, https://www.washingtonpost.com/news/wonk/wp/2016/03/25/the-big-bust-in-the-oil-fields/.
[2435] Swetha Gopinath and Amrutha Gayathri, "Forget Fracking. Choking and Lifting Are Latest Efforts to Stem U.S. Shale Bust," *Reuters*, March 9, 2016, sec. Commodities News, https://www.reuters.com/article/us-usa-shale-analysis-idUSKCN0WB1AI.
[2436] Mason Inman, "Can Fracking Power Europe?," *Nature* 531, no. 7592 (2016): 22–24, https://doi.org/10.1038/531022a.

debt rose to $235 billion at the end of the first quarter, a 16 percent increase over the year 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.[2437]

- 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."[2438]

- 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.[2439]

- 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.[2440] IEA Chief Economist Fatih Birol said, "A well-supplied oil market in the short-term should not disguise the challenges that lie ahead."[2441]

- 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."[2442]

[2437] Asjylyn Loder, "The Shale Industry Could Be Swallowed By Its Own Debt," *Bloomberg*, June 18, 2015, https://www.bloomberg.com/news/articles/2015-06-18/next-threat-to-u-s-shale-rising-interest-payments.
[2438] Moody's Investors Service, "Lower Oil Prices Cause Suppliers of Liquefied Natural Gas to Nix Projects," *Moodys.Com*, April 7, 2015, sec. Ratings & Assessments News, http://www.moodys.com:18000/research/Moodys-Liquefied-natural-gas-projects-nixed-amid-lower-oil-prices--PR_322439.
[2439] Nicole Sagener, "Fracking Costs Outweigh Benefits for Germany and Europe, Study Says," *EurActiv*, March 20, 2015, sec. Energy, https://www.euractiv.com/section/energy/news/fracking-costs-outweigh-benefits-for-germany-and-europe-study-says/.
[2440] International Energy Agency, "World Energy Outlook 2014 – Executive Summary," December 2014, https://iea.blob.core.windows.net/assets/e6f58562-203e-474c-97a3-486f409aa7ff/WEO2014.pdf.
[2441] Dennis Dimick, "How Long Can the U.S. Oil Boom Last?," *National Geographic*, December 19, 2014, sec. Science, https://www.nationalgeographic.com/science/article/141219-fracking-oil-supply-price-reserves-profits-environment.
[2442] Andrew Nikiforuk, "A Big Summer Story You Missed: Soaring Oil Debt," *The Tyee*, August 29, 2014, 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 . . ."[2443]

- 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.[2444]

- 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."[2445]

- 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.[2446]

- 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.

[2443] U.S. Energy Information Administration, "As Cash Flow Flattens, Major Energy Companies Increase Debt, Sell Assets," *Today in Energy*, July 29, 2014, https://www.eia.gov/todayinenergy/detail.php?id=17311.
[2444] Environmental Law Institute & Washington & Jefferson College, "Getting the Boom without the Bust: Guiding Southwestern Pennsylvania through Shale Gas Development," 2014, https://www.eli.org/sites/default/files/eli-pubs/getting-boom-final-paper-exec-summary-2014-07-28.pdf.
[2445] Deborah Lawrence Rogers, "Huge CAPEX = Free Cash Flow? Not in Shales," *Energy Policy Forum*, June 19, 2014, https://web.archive.org/web/20130630100230/http://energypolicyforum.org/2013/06/19/huge-capex-free-cash-flow-not-in-shales/.
[2446] Labyrinth Consulting Services, Inc., A. Berman, and L. Pittinger, "Resource Assessment of Potentially Producible Natural Gas Volumes From the Marcellus Shale, State of New York," https://www.slideshare.net/MarcellusDN/resource-assessment-of-potentially-producible-natural-gas-volumes-from-the-marcellus-shale-state-of-new-york.

shale oil and gas boom, noting that her agency's analysis predicts that production will soon flatten out and, by 2025, begin to decline.[2447]

- 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.[2448] 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."[2449]

- 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.[2450]

- 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.[2451]

- 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.[2452]

- 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

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[2447] D. J. Unger, "IEA Chief: Only a Decade Left in US Shale Oil Boom," *Christian Science Monitor*, February 28, 2014, https://www.csmonitor.com/Environment/Energy-Voices/2014/0228/IEA-chief-Only-a-decade-left-in-US-shale-oil-boom.
[2448] Tad W. Patzek, Frank Male, and Michael P. Marder, "Gas Production in the Barnett Shale Obeys a Simple Scaling Theory," *Proceedings of the National Academy of Sciences* 110, no. 49 (2013): 19731–36, https://doi.org/10.1073/pnas.1313380110.
[2449] Mose Buchele, "New Study Shows How Gas Production From 'Fracked' Wells Slows Over Time," *State Impact Texas*, December 18, 2013, https://stateimpact.npr.org/texas/2013/12/18/new-study-shows-how-gas-production-from-fracked-wells-slows-over-time/.
[2450] Matthew Monks, Rebecca Penty, and Gerrit de Vynck, "Shale Grab in U.S. Stalls as Falling Values Repel Buyers: Energy," *Bloomberg*, August 18, 2013, https://www.bloomberg.com/news/articles/2013-08-18/shale-grab-in-u-s-stalls-as-falling-values-repel-buyers.
[2451] Clifford Krauss and Eric Lipton, "After the Boom in Natural Gas," *The New York Times*, October 20, 2012, https://www.nytimes.com/2012/10/21/business/energy-environment/in-a-natural-gas-glut-big-winners-and-losers.html?pagewanted=all.
[2452] Matt Wirz, "Chesapeake Reserve Doubted," *Wall Street Journal*, July 13, 2012, sec. Business, https://online.wsj.com/article/SB10001424052702303644004577523411723501548.html.

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.[2453]

- 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.[2454, 2455, 2456] The *New York Times*' public editor criticized the stories, but offered no evidence that the major findings were wrong.[2457] The *New York Times*' news editors publicly defended both stories against the public editor's criticism.[2458, 2459]

[2453] U.S. Geological Survey, "USGS Releases New Assessment of Gas Resources in the Marcellus Shale, Appalachian Basin," August 23, 2011, https://www.usgs.gov/science-explorer-results?es=USGS+releases+new+assessment+of+gas+resources+in+the+Marcellus+shale%2C+Appalachian+Basin.
[2454] Ian Urbina, "Insiders Sound an Alarm Amid a Natural Gas Rush," *The New York Times*, June 26, 2011, sec. U.S., https://www.nytimes.com/2011/06/26/us/26gas.html.
[2455] U.S. Energy Information Administration, "U.S. Natural Gas Summary," May 30, 2014, https://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm.
[2456] Ian Urbina, "Geologists Sharply Cut Estimate of Shale Gas," *The New York Times*, August 25, 2011, sec. U.S., https://www.nytimes.com/2011/08/25/us/25gas.html.
[2457] Arthur S. Brisbane, "Opinion | Clashing Views on the Future of Natural Gas," *The New York Times*, July 16, 2011, sec. Opinion, https://www.nytimes.com/2011/07/17/opinion/sunday/17pubed.html.
[2458] Arthur S. Brisbane, "Times Editors Respond to My Shale Gas Column," *The New York Times*, July 17, 2011, sec. Opinion, https://publiceditor.blogs.nytimes.com/2011/07/17/times-editors-respond-to-my-shale-gas-column/.
[2459] Arthur S. Brisbane, "Times Editors Respond to Column on Redactions," *The New York Times*, July 30, 2011, http://publiceditor.blogs.nytimes.com/2011/07/30/times-editors-respond-to-column-on-redactions/.

Medical and scientific calls for more study, reviews confirming evidence of harm, and calls for increased transparency and science-based policy

As published reviews and international governmental reports underscore the mounting evidence of health risks—including developmental, neurological, carcinogenic, respiratory, reproductive, and psychological—medical professionals and scientists in the United States and around the world increasingly call for the suspension of fracking in order to prevent its adverse public health harms, including health threats from climate change. Organizations of medical professionals and scientists are also issuing calls for comprehensive, long-term study of the full range of potential health and ecosystem effects of fracking. These appeals underscore the accumulating evidence of harm, point to the knowledge gaps that remain, and decry the atmosphere of secrecy and intimidation that continues to impede the progress of scientific inquiry.

- June 6, 2023 – Forty-five medical professionals who work or have previously worked as pediatricians in the Northern Territory, Australia signed a letter calling on their government to re-evaluate the health costs of moving forward with fracking in the Beetaloo Basin, and to "embrace urgent climate action." According to one signer, "For these doctors to be doing this really, I think, reflects the extent of their concern and their worry about their patient populations." The letter references the direct health risks identified in the United States, noting that millions of people there live within two kilometers of a fracked oil or gas well.[2460]

- December 23, 2022 – On the occasion of releasing its newest report, "Communities in Flux. Fracking and Health Impacts: The Lived Experience," Canadian Association of Physicians for the Environment (CAPE), restated its call for a moratorium on fracking in British Columbia. Based on a survey of 53 people living within five kilometers of fracking sites in the province's Peace region, their report provides new data on the health symptoms, diagnoses, and adverse physical conditions (such as odors and noise) experienced by respondents. CAPE's nine recommendations include ending government subsidies for fracking and more action to protect community members and workers. "Community health studies, notably co-designed with Indigenous residents, should be undertaken to document any adverse health impacts, and plans for the treatment and prevention of illnesses should be developed. In particular, the impacts on oil and gas workers' physical and mental health in Northeastern B.C. is a significant gap in literature and understanding that should be addressed."[2461, 2462]

[2460] Samantha Dick, "Paediatricians Sign Joint Letter Urging NT Government to Withdraw Beetaloo Basin Fracking Support," *ABC News*, June 6, 2023, https://www.abc.net.au/news/2023-06-07/nt-paediatrians-sign-letter-warning-fracking-health-risks/102440510.
[2461] Stefan Labbé, "'People from the Sacrifice Zone': Doctors Call for Moratorium on B.C. Fracking," *BIV*, December 23, 2022, https://biv.com/article/2022/12/people-sacrifice-zone-doctors-call-moratorium-bc-fracking.
[2462] Canadian Association of Physicians for the Environment (CAPE), "Communities in Flux. Fracking and Health Impacts: The Lived Experience," May 2022, https://cape.ca/wp-content/uploads/2022/12/Communities-in-Flux-%E2%80%93-Fracking-and-Health-Impacts.pdf.

- July 12, 2022 – A new report and fact sheet from Physicians for Social Responsibility (PSR) examine chemical disclosure standards related to fracking in 16 states. PSR's five resulting public health-related demands include detailed disclosure laws and practices to address the significant existing gaps that are currently preventing "full identification of these chemicals and their associated health and environmental risks."[2463]

- February 15, 2022 – In an open letter to the UK prime minister, United Kingdom medical institutions, with a combined membership of more than 250,000 health care professionals, called for an immediate halt to new oil and gas exploration and an end to the country's dependency on fossil fuels. "As healthcare professionals, we know that any new fossil fuel projects and their contribution to climate change constitute a grave threat to our patients and the resilience of our healthcare system."[2464]

- June 26, 2021 – The president and CEO of Mental Health Colorado called for a systemic shift away from the "harmful and short-sighted cycle of boom and bust" energy policies, noting that the oil and gas industry's activities in the state have led to chronic stress, depression, and anxiety among Colorado residents. Impacts threatening mental health include light pollution, noise pollution, safety concerns, landscape changes, and feelings of powerless in local decision-making. "Coloradans who have called these communities home for generations find that they often have little to say about the transformation of their world by an invasion of powerful industry." The author also urged "true representation in the decision-making process."[2465]

- June 8, 2021 – A sweeping review of the research on the environmental, economic, and anthropogenic impacts of fracking called for greater focus on the inevitable bust periods that follow fracking booms, noting that most research findings have been solely based on investigations of boom-time activities. In their analysis on costs and benefits of fracking, this team of economists and public health scientists examined the literature on local air pollution, global air pollution, water pollution, noise, light, seismic activity, direct and indirect measures of health, migration, education, labor, income, agriculture, and environmental justice. Their analysis showed mixed results and revealed data gaps. The authors emphasized that an understanding of all these impacts is critical for policy makers, who now must also pay attention to changes affecting communities while the industry contracts due to factors such as the COVID pandemic.[2466]

- June 4, 2021 – Following the fourth "near-miss" in nine months at the Enbridge North Weymouth gas compressor (a release of over 11,000 cubic feet of highly pressurized gas,

[2463] Dusty Horwitt and Meilen Teklemichael, "Chemical Makers' Exemptions from Fracking Chemical Disclosure Rules" (Physicians for Social Responsibility, July 12, 2022), https://psr.org/new-from-psr-gaps-in-fracking-chemical-disclosure-rules-may-pose-threat-to-human-health/.
[2464] Adele Waters, "Medical Leaders Urge Ministers to End UK's Fossil Fuel Dependence," *BMJ*, 2022, o389, https://doi.org/10.1136/bmj.o389.
[2465] Vincent Atchity, "Opinion: Another Factor to Keep in Mind in Colorado's Oil and Gas Communities — Healthy Minds," *The Colorado Sun*, June 26, 2021, https://coloradosun.com/2021/06/26/mental-health-oil-gas-opinion/.
[2466] Katie Jo Black et al., "Economic, Environmental, and Health Impacts of the Fracking Boom," *Annual Review of Resource Economics* 13 (2021), https://doi.org/10.1146/annurev-resource-110320-092648.

following large leaks on September 11, September 30, and April 6), two prominent Boston-area physician-researchers appealed for the facility to be shut down. Dr. Caren Solomon, a deputy editor at the *New England Journal of Medicine,* an associate professor of medicine at Harvard Medical School, and a physician at the Brigham and Women's Hospital, and Dr. Philip J. Landrigan, Professor at Boston College (BC) and Director of BC's Program for Global Public Health and the Common Good, wrote, "Enbridge's cavalier reaction is typical of the arrogance, dishonesty, lack of regulatory oversight, and lack of concern for public safety that has characterized the North Weymouth compressor project from its beginning." They welcomed the retraction of the state's own flawed Health Impact Assessment but noted that state support of the project should have been withdrawn much sooner.[2467]

- May 17, 2021 – Fracking was named as an emerging concern by the American Pediatric Society in its statement on ambient air pollution harming children. The authors of "Policy Statement on Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of all Children" identified fracking wells, flare stacks, water storage pits, tanks, sand operations, and diesel-powered equipment and trucks as contributors of multiple air pollutants, including toxic vapors, and criteria air pollutants, such as nitrogen oxides and fine particles. They also noted that fracking pollutants are among those named that originate outdoors but that may enter buildings and vehicles through open doors and windows, ventilation systems, and cracks in structures. By these pathways, fracking can exacerbate the burden of indoor-derived air pollutants on children.[2468]

- April 26, 2021 – Three faculty members at the Columbia University Mailman School of Public Health called for a rapid phaseout of fracking. Noting exemptions from "an astonishing list" of key federal regulations, the authors outlined the many significant risks research has documented for pregnant people, including congenital heart defects, elevated maternal stress from noise and light pollution, and endocrine disruption. They also noted environmental injustices from disproportionate impacts on low-income communities. "For the millions of Americans directly affected by fracking, it's time to put their health, and the health of future generations health, first and stop these injustices."[2469]

- January 25, 2021 – Dr. Philip J. Landrigan, a leading pediatrician, epidemiologist, and public health physician, wrote to the Federal Energy Regulatory Commission to request reexamination of the agency's decision to permit the operation of a natural gas compressor station in North Weymouth, Massachusetts. Dr. Landrigan critiqued the limited scope of the state's Health Impact Assessment, citing deficiencies in its review of

[2467] Caren Solomon and Philip Landrigan, "Enough Is Enough. It's Time To Shut Down The Weymouth Compressor," WBUR, June 4, 2021, https://www.wbur.org/cognoscenti/2021/06/04/weymouth-compressor-leak-shutdown-caren-solomon-philip-landrigan.
[2468] Heather L. Brumberg and Catherine J. Karr, "Ambient Air Pollution: Health Hazards to Children," *Pediatrics* 147, no. 6 (2021), https://doi.org/10.1542/peds.2021-051484.
[2469] Chelsea Clinton, Terry McGovern, and Micaela Martinez, "End Fracking Exemptions, a Threat to Maternal and Public Health," *Stat*, April 26, 2021, https://www.statnews.com/2021/04/26/end-fracking-exemptions-a-threat-to-maternal-and-public-health/.

fire and explosion hazards, toxic emissions, existing chronic disease burden in the community, economic and racial justice concerns, and climate impacts.[2470]

- June 1, 2020 – Writing in the *Lancet*, biologist and endocrinologist Barbara A. Demeneix called for recognition of, and action on, the interlinked threats to life brought by fossil fuels, specifically highlighting fracking. She described a web of threats originating with fossil fuel extraction and highlighted the dangers of endocrine-disrupting chemicals, writing that, "Gas derived from fracking is rapidly driving the development of new petrochemical and plastics plants worldwide," and those stark increases harm health, biodiversity, and the climate. Urgent attention, political support, and investment in alternative energies will reduce these harms and help attain the United Nations sustainable development goals.[2471]

- May 9, 2020 – The Advisory Committee of the German Society of Toxicology, the largest scientific toxicological organization in Europe, published a "Critical evaluation of human health risks due to hydraulic fracturing in natural gas and petroleum production."[2472] Among their conclusions: strong evidence links fracking fluids to local environmental contamination; fracking fluids that contain known human carcinogens cannot be confirmed as safe; and the health risks from fracking can include long-lasting contamination of soil and water. Reviewers noted that the "… most critical part of risk assessment in this context is the exposure assessment which is hampered by the unavailability of data from qualified baseline monitoring" before the start of fracking operations.

- February 24, 2020 – An open letter signed by over 50 health care professionals cited health risks related to fracking and climate change in their expressed opposition to the continued construction of the Coastal GasLink fracked gas pipeline in in northern British Columbia.[2473] They wrote, "the health risks from fracking are well known, including release of carcinogenic toxins such as benzene. Pregnant women in northeastern B.C. have serum benzene levels three times the normal level and studies have shown this has an association with increased childhood leukemia rates. U.S. studies have shown increases in congenital heart disease, chronic pulmonary disorders and small birth-weight babies in populations living in proximity to fracking operations. And as we all know, every pipeline leaks." Their letter expressed solidarity with Indigenous rights of Wet'suwet'en, whose land is being annexed for this pipeline without their consent.

[2470] Philip J. Landrigan, "Re: Natural Gas Compressor Station in North Weymouth, Massachusetts," Letter to the Federal Energy Regulatory Commission, January 25, 2021.
[2471] Barbara A Demeneix, "How Fossil Fuel-Derived Pesticides and Plastics Harm Health, Biodiversity, and the Climate," *The Lancet Diabetes & Endocrinology* 8, no. 6 (2020): 462–64, https://doi.org/10.1016/S2213-8587(20)30116-9.
[2472] Klaus-Michael Wollin et al., "Critical Evaluation of Human Health Risks Due to Hydraulic Fracturing in Natural Gas and Petroleum Production," *Archives of Toxicology* 94, no. 4 (2020): 967–1016, https://doi.org/10.1007/s00204-020-02758-7.
[2473] Various Authors, "Health Professionals Call for a Moratorium on Coastal GasLink Construction Permits," *Ricochet*, February 24, 2020, https://ricochet.media/en/2952.

- January 29, 2020 – A new report outlining the serious health and environmental dangers of fracking by Canadian Association of Physicians for the Environment called for a moratorium on the development of new fracked natural gas wells in each province and territory across Canada; plans to phase out existing fracking wells to meet Canada's commitments under the Paris Agreement; Health and Equity Impact Assessments to prioritize wells for early closure; and "Just Transition" plans to help workers and their 14communities prepare for the new low-carbon economy.[2474] In a press release, Dr. Éric Notebaert, member of the Association and advisor to the report, outlined findings of urgent concern and strong evidence including low birth weight, "an indicator for a number of serious health impacts including developmental deficits in children and increased rates of cardiovascular disease in later life."[2475]

- January 9, 2020 – "Gas is associated with health and environmental hazards and reduced social welfare at every stage of its life cycle," wrote three medical doctors in the *New England Journal of Medicine.*[2476] The piece briefly highlighted those hazards from the well to transport and storage, from routine exposures to explosions, as well as providing an up-to-date summary of the threat to the climate by continued extraction and use of fracked gas. The authors stated, "As physicians deeply concerned about climate change and pollution and their consequences, we consider expansion of the natural-gas infrastructure to be a grave hazard to human health," calling for "courageous political leadership" to enact the appropriate policies.

- January 8, 2020 – An interdisciplinary team headed by Yale environmental health epidemiologist Nicole Deziel together with Israeli colleagues conducted a scoping review to assess what is known about the human health outcomes associated with fracking. Of the 29 studies that met their criteria for inclusion, 25 reported at least one statistically significant adverse health outcome linked to a fracking-related exposure. The authors concluded that a growing body of evidence shows health problems in communities near drilling and fracking sites. They also emphasized that many health outcomes may take years to emerge, partly because of latency periods for diseases such as cancer. They stated that while it is important that these data be replicated in other populations, "the need for more research need not be used as a barrier to implementing policies."[2477]

- November 19, 2019 – A letter signed by over 100 leading Israeli scientists, including Nobel laureate Robert Aumann, called for the reversal of the government's decision to

[2474] Ronald Macfarlane and Kim Perrotta, "Fractures in the Bridge: Unconventional (Fracked) Gas, Climate Change and Human Health" (Canadian Association of Physicians for the Environment, 2020), https://cape.ca/wp-content/uploads/2020/01/CAPE-Fracking-Report-EN.pdf.
[2475] Milissa Hughes, "Doctors Release New Report Calling for Moratorium on Fracking in Canada" (Canadian Association of Physicians for the Environment, January 29, 2020), https://cape.ca/wp-content/uploads/2020/01/Fracking-press-release-EN-Jan-29.pdf.
[2476] Philip J. Landrigan, Howard Frumkin, and Brita E. Lundberg, "The False Promise of Natural Gas," *New England Journal of Medicine* 382, no. 2 (2020): 104–7, https://doi.org/10.1056/NEJMp1913663.
[2477] Nicole C. Deziel et al., "Unconventional Oil and Gas Development and Health Outcomes: A Scoping Review of the Epidemiological Research," *Environmental Research* 182 (2020): 109124, https://doi.org/10.1016/j.envres.2020.109124.

build a new network of 16 gas-fired power plants.[2478] In their appeal to transition to renewable energy rather than to gas, they cite the powerful short-term climate warming impact of methane as well as carcinogenic emissions. "During the production, refining and delivery of the gas, much greater quantities of methane are released than were previously recognized. These emissions contain volatile organic compounds that are recognized as carcinogenic." The letter also warned of negative economic and social impacts of building out a gas infrastructure instead of investing in renewables.

- November 19, 2019 – Brian Schwartz, a professor of environmental health and engineering at Johns Hopkins Bloomberg School of Public Health, called for a ban on fracking while addressing a public health conference in Pittsburgh.[2479] "Schwartz, who has presented his research at the conference in the past, but had never before called for a ban on fracking, said he'd recently become convinced the time had come to make a public statement." Dr. Schwartz cited years of studies indicating that proximity to fracking increases the risk of asthma, premature birth, headaches, and maternal stress levels, concluding that "the evidence that fracking is bad for your health is clear enough."

- June 15, 2019 – A Colorado and Pennsylvania team of epidemiologists summarized the literature to date on the health effects of populations living near fracking operations, with a focus on methodological rigor. They adapted systematic review frameworks from the medical and environmental health field, analyzing 20 epidemiologic studies, with 32 different health outcomes, ranging from self-reported symptoms to confirmed disease diagnoses. The review's highest rated studies primarily focused on birth outcomes, and in general they found that study quality has improved over time. They found that studies of populations living near fracking operations provide "modest scientific findings" of "harmful health effects including asthma exacerbations and various self-reported symptoms."[2480] The review includes an important discussion of the limitations inherent to observational epidemiologic studies and the necessity of combining them with exposure and risk assessments to inform public health and policies. Differences in observational epidemiologic study types make comparing results across studies a difficult task. The authors recommend researchers "integrate community members and concepts of health equity and environmental justice into their research approaches."

- 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

[2478] Sue Surkes, "112 Top Scientists Call on Government to Abort Plan for Gas-Fired Power Stations," *The Times of Israel*, November 19, 2019, https://www.timesofisrael.com/leading-scientists-call-on-government-to-abort-plan-for-gas-fired-power-stations/.
[2479] Reid Frazier, "Johns Hopkins Researcher: Pa. Should Ban Fracking," *State Impact Pennsylvania*, November 20, 2019, https://stateimpact.npr.org/pennsylvania/2019/11/20/johns-hopkins-researcher-pa-should-ban-fracking/.
[2480] Alison M. Bamber et al., "A Systematic Review of the Epidemiologic Literature Assessing Health Outcomes in Populations Living near Oil and Natural Gas Operations: Study Quality and Future Recommendations," *International Journal of Environmental Research and Public Health* 16, no. 12 (2019): 2123, https://doi.org/10.3390/ijerph16122123.

adverse health findings.[2481] 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."[2482]

- 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.[2483] 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 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.[2484]

- 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

[2481] Melissa Haswell and David Shearman, "Expanding Gas Mining Threatens Our Climate, Water and Health," *The Conversation*, March 29, 2019, http://theconversation.com/expanding-gas-mining-threatens-our-climate-water-and-health-113047.
[2482] Melissa Haswell and David Shearman, "The Implications for Human Health and Wellbeing of Expanding Gas Mining in Australia: Onshore Oil and Gas Policy," Background Report (Doctors for the Environment Australia, 2019), https://apo.org.au/sites/default/files/resource-files/2019-03/apo-nid208281.pdf.
[2483] Irena Gorski and Brian S. Schwartz, "Environmental Health Concerns From Unconventional Natural Gas Development," in *Oxford Research Encyclopedia of Global Public Health*, by Irena Gorski and Brian S. Schwartz (Oxford University Press, 2019), https://doi.org/10.1093/acrefore/9780190632366.013.44.
[2484] Adam Law et al., "Medical Organisations Must Divest from Fossil Fuels," *BMJ*, 2018, k5163, https://doi.org/10.1136/bmj.k5163.

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.[2485]

- 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 drilling and fracking operations, the limited number of scientific studies available, and the potential for episodically recurrent periods of high exposures.[2486]

- 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*.[2487]

- 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

[2485] Jill E. Johnston, Esther Lim, and Hannah Roh, "Impact of Upstream Oil Extraction and Environmental Public Health: A Review of the Evidence," *Science of The Total Environment* 657 (2019): 187–99, https://doi.org/10.1016/j.scitotenv.2018.11.483.
[2486] Celia Lewis, Lydia H. Greiner, and David R. Brown, "Setback Distances for Unconventional Oil and Gas Development: Delphi Study Results," ed. Carla A. Ng, *PLOS ONE* 13, no. 8 (2018): e0202462, https://doi.org/10.1371/journal.pone.0202462.
[2487] David McCoy and Patrick Saunders, "Fracking and Health," *BMJ*, 2018, k2397, https://doi.org/10.1136/bmj.k2397.

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."[2488]

- 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.[2489] 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.

- 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.[2490] 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

[2488] Rosemary Wright and Richard D. Muma, "High-Volume Hydraulic Fracturing and Human Health Outcomes: A Scoping Review," *Journal of Occupational & Environmental Medicine* 60, no. 5 (2018): 424–29, https://doi.org/10.1097/JOM.0000000000001278.
[2489] Andrew Watterson and William Dinan, "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, no. 4 (2018): 675, https://doi.org/10.3390/ijerph15040675.
[2490] Katherine Butler et al., "Public Health and Safety Risks of Oil and Gas Facilities in Los Angeles County" (Los Angeles County Department of Public Health, 2018), http://publichealth.lacounty.gov/eh/docs/PH_OilGasFacilitiesPHSafetyRisks.pdf.

from residents of South Los Angeles, Wilmington and unincorporated county areas in the past several years."[2491]

- 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.[2492] 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."[2493] 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 silica dust. They voiced specific concerns about parkinsonism, neuropathy, and kidney disease, and called for prospective toxicity studies.[2494]

- 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."[2495] 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."[2496]

[2491] Steve Scauzillo, "Living near Oil Wells Can Cause Health Problems, LA County Believes It Has Solutions," *Los Angeles Daily News*, February 28, 2018, https://www.dailynews.com/2018/02/27/living-near-oil-wells-can-cause-health-problems-la-county-believes-it-has-solutions/.
[2492] Northern Territory of Australia, "Draft Final Report of the Scientific Inquiry Into Hydraulic Fracturing in the Northern Territory," Draft Final Report (Government of Australia, January 30, 2018), https://frackinginquiry.nt.gov.au/inquiry-reports?a=479268.
[2493] Reuters Staff, "Study Seen Needed before Lifting Fracking Ban in Remote Australia," *Reuters*, December 12, 2017, sec. Environment, https://www.reuters.com/article/us-australia-fracking-idUSKBN1E60TL.
[2494] Russell A. Wilke and Jerome W. Freeman, "Potential Health Implications Related to Fracking," *JAMA* 318, no. 17 (2017): 1645, https://doi.org/10.1001/jama.2017.14239.
[2495] Ellen Webb et al., "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* 33, no. 1 (2018): 3–29, https://doi.org/10.1515/reveh-2017-0008.
[2496] Nicola Davis, "Pollutants from Fracking Could Pose Health Risk to Children, Warn Researchers," *The Guardian*, October 25, 2017, sec. Environment, https://www.theguardian.com/environment/2017/oct/25/pollutants-from-fracking-could-pose-health-risk-to-children-warn-researchers.

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.[2497] "This analysis creates a priority list of carcinogens to target for future exposure and health studies."[2498]

- 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 "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."[2499]

- 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."[2500]

- 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

[2497] Elise G. Elliott et al., "Unconventional Oil and Gas Development and Risk of Childhood Leukemia: Assessing the Evidence," *Science of The Total Environment* 576 (2017): 138–47, https://doi.org/10.1016/j.scitotenv.2016.10.072.
[2498] Denise Meyer, "Fracking Linked to Cancer-Causing Chemicals, New YSPH Study Finds," *Yale News*, October 24, 2016, https://ysph.yale.edu/news-article/fracking-linked-to-cancer-causing-chemicals-new-ysph-study-finds/.
[2499] Jameson K. Hirsch et al., "Psychosocial Impact of Fracking: A Review of the Literature on the Mental Health Consequences of Hydraulic Fracturing," *International Journal of Mental Health and Addiction* 16, no. 1 (2018): 1–15, https://doi.org/10.1007/s11469-017-9792-5.
[2500] Don Hopey, "Registry Will Study Health Impact from Living near Shale Gas Wells," *Pittsburgh Post-Gazette*, May 1, 2017, https://www.post-gazette.com/business/powersource/2017/05/01/Registry-will-study-health-impact-from-living-near-shale-gas-wells/stories/201705010018.

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.[2501]

- 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, in order to prevent violence against women and other life changing negative effects linked to the industrial camps.[2502]

- 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."[2503]

- 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

[2501] Daniele Costa et al., "Extensive Review of Shale Gas Environmental Impacts from Scientific Literature (2010–2015)," *Environmental Science and Pollution Research* 24, no. 17 (2017): 14579–94, https://doi.org/10.1007/s11356-017-8970-0.
[2502] G. Gibson et al., "Indigenous Communities and Industrial Camps: Promoting Healthy Communities in Settings of Industrial Change" (The Firelight Group with Lake Babine Nation and Nak'azdli Whut'en, 2017), https://firelight.ca/wp-content/uploads/2016/03/Firelight-work-camps-Feb-8-2017_FINAL.pdf.
[2503] Brenda Gazzar and Susan Abram, "$1 Million Health Study 'Shortchanges' Porter Ranch Gas Leak Victims, Critics Say," *Daily News*, February 8, 2017, https://www.dailynews.com/business/20170208/1-million-health-study-shortchanges-porter-ranch-gas-leak-victims-critics-say.

contaminants and relevant health outcomes, particularly to explain associations seen with respiratory and birth outcomes," the author concluded."[2504]

- 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.[2505]

- 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.[2506]

- 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.[2507, 2508]

- 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.[2509] 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.[2510]

[2504] Shaina L. Stacy, "A Review of the Human Health Impacts of Unconventional Natural Gas Development," *Current Epidemiology Reports* 4, no. 1 (2017): 38–45, https://doi.org/10.1007/s40471-017-0097-9.
[2505] Patrick J. Saunders et al., "A Review of the Public Health Impacts of Unconventional Natural Gas Development," *Environmental Geochemistry and Health* 40, no. 1 (2018): 1–57, https://doi.org/10.1007/s10653-016-9898-x.
[2506] Health Protection Scotland, "A Health Impact Assessment of Unconventional Oil and Gas in Scotland: Volume 1 – Full Report," 2016, https://www.hps.scot.nhs.uk/web-resources-container/a-health-impact-assessment-of-unconventional-oil-and-gas-in-scotland-volume-1-full-report/.
[2507] Pennsylvania Medical Society, "Resolution 16-206: Pennsylvania Medical Society Support for a Moratorium on Fracking," October 23, 2016, https://www.pamedsoc.org/docs/librariesprovider2/pamed-documents/pamed-downloads/HODAEC/16-206.pdf.
[2508] Don Hopey, "Doctors Call for State Ban on Drilling and Fracking," *Pittsburgh Post-Gazette*, October 27, 2016, https://www.post-gazette.com/local/region/2016/10/27/Doctors-group-calls-for-moratorium-on-fracking-in-Pennsylvania/stories/201610270226.
[2509] Massachusetts Health Care Professionals Against Fracked Gas, "Call for a Moratorium on Natural Gas Projects Undergoing Construction or Review in the Commonwealth of Massachusetts," October 2016.
[2510] Massachusetts Health Care Professionals Against Fracked Gas, "The Role of Comprehensive Health Impact Assessment in Evaluating Natural Gas Infrastructure Proposals in Massachusetts," February 20, 2016.

- 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."[2511]

- 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-term effects might be. . . . Ignoring the body of evidence, to us, is not a viable option anymore."[2512]

- 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."[2513]

- 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

[2511] Victoria D. Balise et al., "Systematic Review of the Association between Oil and Natural Gas Extraction Processes and Human Reproduction," *Fertility and Sterility* 106, no. 4 (2016): 795–819, https://doi.org/10.1016/j.fertnstert.2016.07.1099.
[2512] Madelon L. Finkel and Adam Law, "The Rush to Drill for Natural Gas: A Five-Year Update," *American Journal of Public Health* 106, no. 10 (2016): 1728–30, https://doi.org/10.2105/AJPH.2016.303398.
[2513] David McCoy and Alice Munro, "Shale Gas Production in England - an Updated Public Health Assessment" (MedAct Health Professionals for a Safer, Fairer, & Better World, July 7, 2016), https://www.medact.org/2016/resources/reports/shale-gas-production-in-england/.

to plan this kind of operation…. There are a number of gaps and deficiencies that are significant."[2514]

- 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."[2515]

- 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 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."[2516]

- 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.[2517] 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."[2518]

[2514] Sue Bailey, "Too Many Gaps to Recommend Fracking in Newfoundland: Panel," *The Globe and Mail*, May 31, 2016, https://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/too-many-unknowns-to-recommend-fracking-in-western-newfoundland-panel/article30216746/.
[2515] Physicians for Social Responsibility, "PSR Position Statement on Hydraulic Fracturing," Physicians for Social Responsibility, May 13, 2016, https://www.psr.org/blog/resource/psr-position-statement-on-hydraulic-fracturing/.
[2516] Christopher D. Kassotis et al., "Endocrine-Disrupting Chemicals and Oil and Natural Gas Operations: Potential Environmental Contamination and Recommendations to Assess Complex Environmental Mixtures," *Environmental Health Perspectives* 124, no. 3 (2016): 256–64, https://doi.org/10.1289/ehp.1409535.
[2517] Lisa Song, "What Chemicals Are Used in Fracking? Industry Discloses Less and Less," *Inside Climate News*, November 24, 2015, https://insideclimatenews.org/news/24112015/fracking-natural-gas-drilling-chemicals-frac-focus-study/.
[2518] Katherine Konschnik and Archana Dayalu, "Hydraulic Fracturing Chemicals Reporting: Analysis of Available Data and Recommendations for Policymakers," *Energy Policy* 88 (2016): 504–14, https://doi.org/10.1016/j.enpol.2015.11.002.

- 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 years to present. The authors described several important studies that are currently underway that will add to the body of knowledge in the future.[2519]

- 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*.[2520] In an interview with *Michigan Radio*, Tuller noted that, because well development happens quickly, there was generally a lack of pre-drilling baseline studies.[2521]

- 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.[2522] 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.[2523]

[2519] Madelon L. Finkel and Jake Hays, "Environmental and Health Impacts of 'Fracking': Why Epidemiological Studies Are Necessary," *Journal of Epidemiology and Community Health* 70, no. 3 (2016): 221–22, https://doi.org/10.1136/jech-2015-205487.
[2520] David Tuller, "As Fracking Booms, Dearth Of Health Risk Data Remains," *Health Affairs (Project Hope)* 34, no. 6 (June 2015): 903–6, https://doi.org/10.1377/hlthaff.2015.0484.
[2521] Rebecca Williams, "Why There Are Gaps in Public Health Studies on Fracking," Michigan Radio, June 9, 2015, https://www.michiganradio.org/environment-science/2015-06-09/why-there-are-gaps-in-public-health-studies-on-fracking.
[2522] Ogneva-Himmelberger and Huang, "Spatial Distribution of Unconventional Gas Wells and Human Populations in the Marcellus Shale in the United States: Vulnerability Analysis."
[2523] Qingmin Meng, "Spatial Analysis of Environment and Population at Risk of Natural Gas Fracking in the State of Pennsylvania, USA," *The Science of the Total Environment* 515–516 (2015): 198–206, https://doi.org/10.1016/j.scitotenv.2015.02.030.

- 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.[2524] 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. There are clear grounds for adopting the precautionary principle and prohibiting fracking."[2525]

- 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."[2526]

- 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.[2527]

- 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.[2528]

[2524] David McCoy and Patrick Saunders, "Health & Fracking: The Impacts and Opportunity Costs" (MedAct Health Professionals for a Safer, Fairer, & Better World, 2015), https://www.medact.org/2015/resources/reports/health-and-fracking/.
[2525] Robin Stott et al., "Public Health England's Draft Report on Shale Gas Extraction," *BMJ* 348 (2014): g2728, https://doi.org/10.1136/bmj.g2728.
[2526] Lalita Bharadwaj and Bernard D. Goldstein, "Shale Gas Development in Canada: What Are the Potential Health Effects?," *CMAJ : Canadian Medical Association Journal* 187, no. 3 (2015): E99–100, https://doi.org/10.1503/cmaj.140599.
[2527] Paul Vecchiatto, "Chemicals Used in Fracking 'Could Cause Cancer'," *Business Day BDLive*, January 22, 2015, https://web.archive.org/web/20150124035808/http://www.bdlive.co.za/business/energy/2015/01/22/chemicals-used-in-fracking-could-cause-cancer.
[2528] Jake Hays et al., "Considerations for the Development of Shale Gas in the United Kingdom," *Science of The Total Environment* 512–513 (2015): 36–42, https://doi.org/10.1016/j.scitotenv.2015.01.004.

- 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."[2529]

- 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 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."[2530] 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?"[2531]

- 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.[2532]

[2529] Paul J. Lioy, "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 & Environmental Epidemiology* 25, no. 1 (2015): 1–3, https://doi.org/10.1038/jes.2014.59.

[2530] Ellen Webb et al., "Developmental and Reproductive Effects of Chemicals Associated with Unconventional Oil and Natural Gas Operations," *Reviews on Environmental Health* 29, no. 4 (2014), https://doi.org/10.1515/reveh-2014-0057.

[2531] Ian Sample, "Fracking Chemicals Could Pose Risks to Reproductive Health, Say Researchers," *The Guardian*, December 5, 2014, sec. Environment, https://www.theguardian.com/environment/2014/dec/05/fracking-chemicals-could-pose-risks-to-reproductive-health-say-researchers.

[2532] Angela K. Werner et al., "Environmental Health Impacts of Unconventional Natural Gas Development: A Review of the Current Strength of Evidence," *Science of The Total Environment* 505 (2015): 1127–41, https://doi.org/10.1016/j.scitotenv.2014.10.084.

- 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.[2533]

- 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."[2534]

- 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.[2535]

[2533] Katrina Smith Korfmacher, Kathleen M. Gray, and Erin Haynes, "Health Impacts of Unconventional Natural Gas Development: A Comparative Assessment of Community Information Needs in New York, North Carolina, and Ohio," Final Project Report, September 15, 2014.
[2534] Gwen Harrison and Stuart Parkinson, "Shale Gas and Fracking: Examining the Evidence" (Scientists for Global Responsibility & the Chartered Institute of Environmental Health, July 2014), https://www.sgr.org.uk/sites/sgr.org.uk/files/SGR-CIEH-Shale-gas-bfg.pdf.
[2535] Trevor M. Penning et al., "Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations," *Environmental Health Perspectives* 122, no. 11 (2014): 1155–59, https://doi.org/10.1289/ehp.1408207.

- 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?"[2536]

- 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, 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].[2537]

- 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."[2538]

- 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

[2536] Kevin Begos, "Expert: Pa. Didn't Address Fracking Health Impacts," *Observer-Reporter*, July 12, 2014, https://observer-reporter.com/news/regional/expert-pa-didn-t-address-fracking-health-impacts/article_88d539c7-cb17-56a5-95df-b19887246e60.html.
[2537] Jerome A. Paulson, "Letter to the Pennsylvania Department of Environmental Protection," June 30, 2014, https://concernedhealthny.org/2014/06/letter-from-dr-jerome-a-paulson-to-the-pennsylvania-department-of-environmental-protection/.
[2538] Michael Hill, "Shale Gas Regulation in the UK and Health Implications of Fracking," *The Lancet* 383, no. 9936 (2014): 2211–12, https://doi.org/10.1016/S0140-6736(14)60888-6.

understand associations between fracking, medical outcomes, and residents' ongoing concerns.[2539]

- 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 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.[2540] 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.[2541]

- 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."[2542, 2543]

- 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

[2539] Pouné Saberi et al., "Field Survey of Health Perception and Complaints of Pennsylvania Residents in the Marcellus Shale Region," *International Journal of Environmental Research and Public Health* 11, no. 6 (2014): 6517–27, https://doi.org/10.3390/ijerph110606517.
[2540] Frank Atherton et al., "Report of the Nova Scotia Independent Review Panel on Hydraulic Fracturing" (Cape Breton University, 2014).
[2541] Michael MacDonald, "N.S. Expert Calls for Go-Slow Approach for Fracking," *CTV News*, June 17, 2014, https://atlantic.ctvnews.ca/n-s-expert-calls-for-go-slow-approach-for-fracking-1.1872529.
[2542] Concerned Health Professionals of NY, "Letter to Governor Cuomo and Acting Health Commissioner Howard A. Zucker," Concerned Health Professionals of NY, May 29, 2014, https://concernedhealthny.org/letters-to-governor-cuomo/.
[2543] Kyle Hughes, "NY Fracking Opponents Call for Moratorium of 3 to 5 Years," *Daily Freeman*, May 29, 2014, https://www.dailyfreeman.com/news/ny-fracking-opponents-call-for-moratorium-of-3-to-5-years/article_f1383150-da0d-5291-973f-461498241056.html.

pollution particularly in the aggregate, and occupational exposures that pose a series of potential hazards to worker health.[2544, 2545]

- 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.[2546] The *Financial Post* reported that the panel of experts "found 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."[2547]

- 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."[2548]

- 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."[2549]

- 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."[2550]

[2544] Society of Toxicology, "Toxicologists Outline Key Health and Environmental Concerns Associated with Hydraulic Fracturing," *ScienceDaily*, May 9, 2014, https://www.sciencedaily.com/releases/2014/05/140509172545.htm.
[2545] Bernard D. Goldstein et al., "The Role of Toxicological Science in Meeting the Challenges and Opportunities of Hydraulic Fracturing," *Toxicological Sciences* 139, no. 2 (2014): 271–83, https://doi.org/10.1093/toxsci/kfu061.
[2546] Council of Canadian Academies, "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."
[2547] The Canadian Press, "Top Canadian Scientists Urge Cautious Approach to Fracking until More Known of Impact," *Financial Post*, May 1, 2014, https://financialpost.com/commodities/energy/top-canadian-scientists-urge-cautious-approach-to-fracking-until-more-known-of-impact.
[2548] Natasha Khan, "Health Impact of Gas Fracking Left in the Dark," *Pocono Record*, April 30, 2014, https://www.poconorecord.com/article/20140430/NEWS90/404300301.
[2549] Adam Law et al., "Public Health England's Draft Report on Shale Gas Extraction," *BMJ* 348, no. apr17 6 (2014): g2728–g2728, https://doi.org/10.1136/bmj.g2728.
[2550] Wendy Glauser, "New Legitimacy to Concerns about Fracking and Health," *Canadian Medical Association Journal* 186, no. 8 (2014): E245–46, https://doi.org/10.1503/cmaj.109-4725.

- 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 public attention, risks posed by wastewater, community disruption and the interaction between exposures are of also of concern.[2551]

- 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.[2552]

- 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."[2553]

- 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

[2551] Alicia Coram, Jeremy Moss, and Grant Blashki, "Harms Unknown: Health Uncertainties Cast Doubt on the Role of Unconventional Gas in Australia's Energy Future," *Medical Journal of Australia* 200, no. 4 (2014): 210–13, https://doi.org/10.5694/mja13.11023.
[2552] Sari Kovats et al., "The Health Implications of Fracking," *The Lancet* 383, no. 9919 (2014): 757–58, https://doi.org/10.1016/S0140-6736(13)62700-2.
[2553] Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development."

ability to address concerns raised by regulators at the federal and state levels, communities, and workers employed in the shale gas extraction industry."[2554]

- 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 long-term studies are not yet available, the authors point to emerging evidence for negative human and ecologic health effects of fracking. 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."[2555]

- 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)."[2556]

- 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.[2557]

[2554] Christine Coussens and Rose Marie Martinez, "Health Impact Assessment of Shale Gas Extraction: Workshop Summary," in *Roundtable on Environmental Health Sciences, Research, and Medicine* (Institute of Medicine and the Board on Population Health and Public Health Practice, Washington, D.C., 2013), https://www.ncbi.nlm.nih.gov/books/NBK201904/.
[2555] Ruth McDermott-Levy, Nina Kaktins, and Barbara Sattler, "Fracking, the Environment, and Health: New Energy Practices May Threaten Public Health," *American Journal of Nursing* 113, no. 6 (2013): 45–51, https://doi.org/10.1097/01.NAJ.0000431272.83277.f4.
[2556] Margaret A. Rafferty and Elena Limonik, "Is Shale Gas Drilling an Energy Solution or Public Health Crisis?," *Public Health Nursing* 30, no. 5 (2013): 454–62, https://doi.org/10.1111/phn.12036.
[2557] Madelon L. Finkel and Adam Law, "The Rush to Drill for Natural Gas: A Public Health Cautionary Tale," *American Journal of Public Health* 101, no. 5 (2011): 784–85, https://doi.org/10.2105/AJPH.2010.300089.