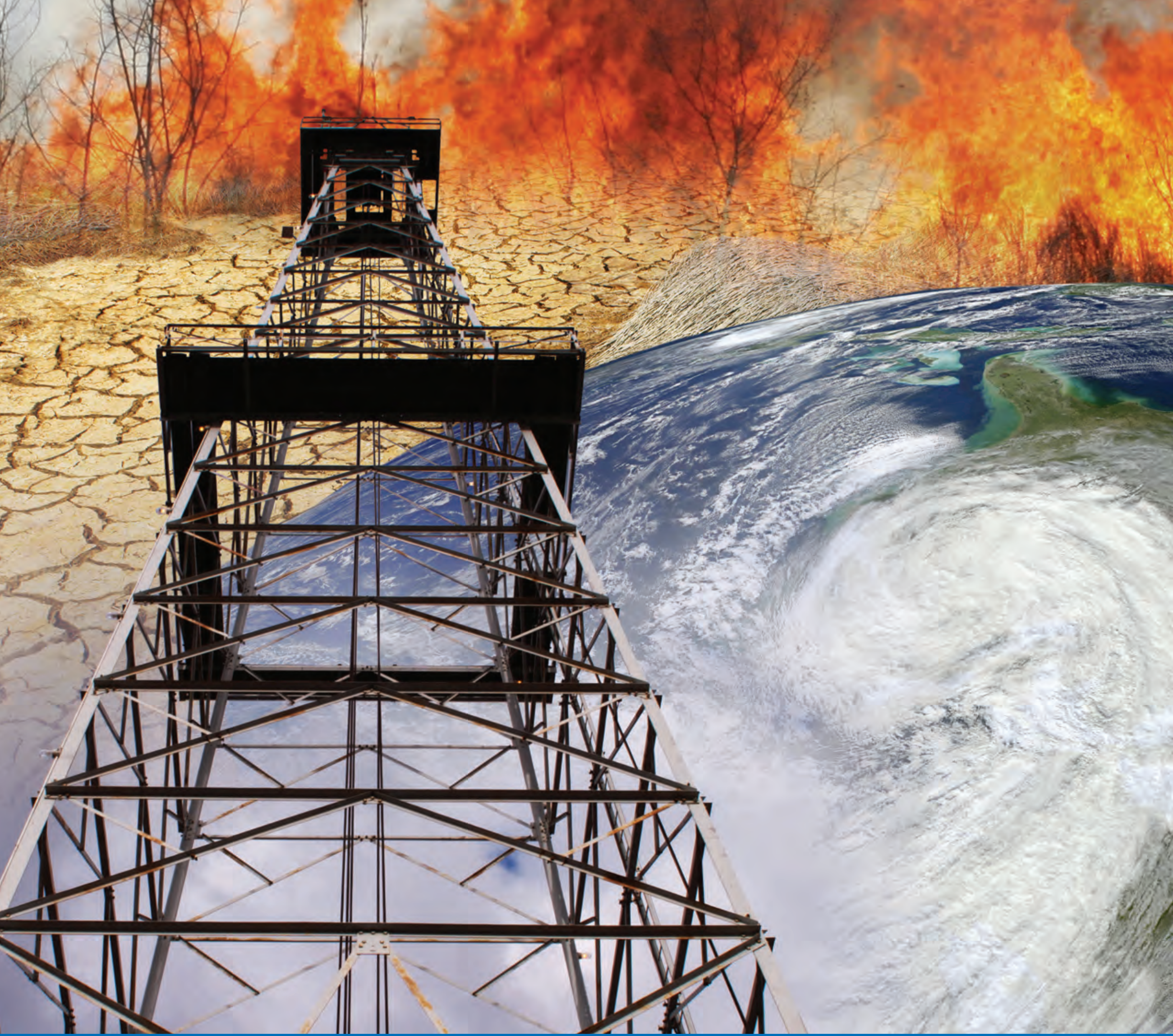

# Fracking's Bridge to Climate Chaos

## Exposing the Fossil Fuel Industry's Deadly Spin

FOOD & WATER WATCH

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Food & Water Watch mobilizes regular people to build political power to move bold and uncompromised solutions to the most pressing food, water, and climate problems of our time. We work to protect people's health, communities, and democracy from the growing destructive power of the most powerful economic interests.

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# Fracking's Bridge to Climate Chaos

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# Executive Summary

While communities across the globe experience the impacts of catastrophic climate change, proponents of shale gas development push for continued drilling and hydraulic fracturing ("fracking"). They misleadingly claim that fracked gas is a "bridge fuel" to move us from traditional fossil fuels like oil and coal to renewable energy like wind and solar. But this bridge has led only to more fossil fuel dependence, locking us in to decades of worsening climate chaos.

Communities plagued by fracking experience well documented and severe environmental impacts.[1] These harms fall disproportionately on frontline communities that are more likely to be rural, lower income and/or communities of color.[2] In addition to known environmental and public health consequences, fracked gas production is associated with significant leaks of methane.

With help from their trade associations and industry-supported "green" groups, fracking proponents have claimed that natural gas production was necessary to shift the country from coal and to provide back-up for intermittent renewables. Now, decades after the term "bridge fuel" was first coined, gas production continues to climb and greenhouse gas emissions fail to budge; the myth that fracked gas plays any positive role in a climate transition has been exhausted. From fracking-related methane leaks to natural gas' role in displacing the deployment of renewable energy, the shale boom has been an engine of climate chaos. Our new research demonstrates that no regulatory half measures or voluntary initiatives can or will make fracking safe for the climate.

Only a dramatic economic reorientation to 100 percent renewable energy can stave off climate catastrophe.[3] The 2018 Intergovernmental Panel on Climate Change (IPCC) report warns that rapid warming would bring increasing droughts, wildfires, food shortages, coral reef die-offs and other ecological and humanitarian crises by 2040 — far earlier than previously expected.[4] But greenhouse gas emissions will be drastically reduced by implementing a strategic shift away from fossil fuels and relying on renewable power for energy generation, accompanied by increased use of energy efficiency technologies in buildings.[5] Only a nationwide ban on fracking and all fossil fuel use, accompanied by a rapid, fair and just transition to 100 percent renewable energy will allow us to avert climate chaos.



**Key findings:**

- **Natural gas leaks are inevitable and occur in every stage of the sprawling natural gas network — from wells to pipelines to compressor stations to power plants:** While no single national estimate reveals how much methane is leaked throughout the natural gas supply chain, science shows that even low leak rates (as low as 2.4 percent) similar to levels identified in some industry-friendly studies erase gas' purported "climate benefits."[6]
- **Small declines in greenhouse gas emissions from the fossil fuel power sector are not enough:** Over the past decade, the combined emissions from coal and gas power plants declined only 10.4 percent (see Figure 3 on page 9).[7] If emissions continued to decline at this slow pace, then greenhouse emissions would not reach zero by 2100.
- **Increasing natural gas production simply continues a never-ending "bridge," displaces clean, renewable energy, and locks in dirty fossil fuel infrastructure for decades:** As coal plants close slightly earlier than planned, they are replaced with gas plants that typically have lifespans of 40 to 50 years.[8] Even without methane leaks, the best natural gas plants still produce about 65 percent of the warming as the most efficient coal plant.[9] Significant carbon reductions are impossible if even 11 percent of the grid is powered by natural gas.[10]
- **Gas-fired electricity will not reduce fossil fuel emissions:** If all coal plants are decommissioned by 2030 and the electricity they produced were replaced solely by gas-powered electricity, greenhouse gas emissions would still continue to rise (see Figure 5 on page 11).[11] If natural gas remains the dominant energy source through 2050, as projected by the Energy Information Administration, annual greenhouse gas emissions from the power sector will be higher in the coming decades than they are today (see Figure 4 on page 10).[12]

- **The "bridge fuel" theory proselytized by fossil fuel fanatics does not actually pave the way to renewable energy solutions:** The only way to stave off the worst effects of climate change is through bold, systemic change, which involves investment in a New Deal-scale green energy public works program that fosters a rapid, fair and just transition to 100 percent clean, renewable energy by 2030.

# The Corporate Case for Fracking in the Face of Climate Chaos

The myth of natural gas as a "bridge fuel" to a post-carbon future was created by polluters desperate to create the appearance that they were addressing climate change. The "bridge fuel" narrative imagines that a short-term switch to natural gas will reduce carbon emissions until large-scale deployment of truly clean energy is technologically feasible.[13]

But calling natural gas a bridge fuel, "transition fuel" or "climate solution" is deeply misleading and risks legitimizing dangerous shale gas development.[14] All natural gas production emits methane into the atmosphere, but development of shale gas is particularly leaky.[15] Even industry studies show that shale development is associated with higher emissions than conventional gas.[16] For example, the authors of an International Energy Agency (IEA) report predicted that fracking could produce a "golden age of gas" with production levels that guarantee more than 3.5 degrees Celsius (°C) of warming in the long term.[17] Scientists have found that exceeding even the 1.5°C warming threshold could cause irreversibly destructive climate change.[18] The authors of the IEA report clarified, "We are not saying that it will be a golden age for humanity — we are saying it will be a golden age for gas."[19]

The bridge fuel sales pitch was invented by the American Gas Association in 1988 and has had a lasting impact on the gas narrative.[20] Enron's founder Kenneth Lay was an early adopter of the clean natural gas narrative, writing in a letter to then President George H. W. Bush, "Natural gas is our cleanest fossil fuel and through its increased use in electric power generation could play a major role in reducing carbon dioxide ($CO_2$) emissions."[21] Now other giant fossil fuel corporations like ExxonMobil pitch fracking as a climate solution.[22]

Bridge fuelers misleadingly argue that increased natural gas production directly replaces coal.[23] While natural gas-fired power plants can replace coal plants (responsible for roughly 93 percent of coal consumption), only about 35 percent of natural gas is used to generate electricity.[24] This narrow focus on electricity ignores the substantial climate consequences of the remaining 65 percent of natural gas consumption.[25] For example, fracked gas also powers plastic production and was responsible for 4 percent of global emissions in 2015.[26] Additionally, the use of natural gas for heating in buildings is responsible for higher emissions compared to readily available electric alternatives.[27]

Gas corporations have a significant financial stake in the continued use of greenhouse gas-intensive fossil fuels. Globally, fossil fuel corporations anticipate $30 trillion in profits from fossil fuels by 2100.[28] Exxon alone has assets (mostly fossil fueled) worth nearly $350 billion that produce $279 billion in revenue and $20 billion in profit annually.[29] Exxon worries that real climate regulations and shrinking of the oil, gas or petrochemical industries would significantly impact its earnings.[30] In fact, Exxon's strategy is based on the underlying assumption that renewables will still produce a minority of energy by 2040.[31] ConocoPhillips (Conoco) also promotes gas as a bridge fuel while acknowledging that climate regulation is a threat to its bottom line.[32] Outside of its bridge fuel production, Conoco does not always consider climate change; in fact, the company produces from one of the dirtiest oilfields in the world.[33]

The growing momentum to take real action on climate in the United States has shown that when renewable energy is on the table, natural gas corporations abandon their climate façade. For example, when California sought to enact sensible electrification standards that would reduce emissions from buildings, a major natural gas company fought back.[34] Likewise, when shareholders pushed Exxon to develop a plan to comply with the Paris climate accord, Exxon, with the support of the Securities and Exchange Commission, suppressed a vote.[35] And faced with increasing competition from wind electricity, fracking billionaire Harold Hamm bankrolled an anti-wind energy group that has fought subsidies to help renewables break into fossil-dominated markets.[36] Frackers do not want their bridge to end.

## Trade associations: Mouthpieces for fossil fuel corporations

The oil and gas industry's trade associations also champion dirty energy and work tirelessly against zero-emission clean energy. Even though modern storage and transmission technologies are capable of supporting a 100 percent renewable grid at low cost, trade associations still claim that renewable energy cannot exist without the aid of natural gas to provide on-demand power when the wind is not blowing or the sun is not shining.[37] The American Petroleum Institute (API) blusters that the United States is in "good shape" thanks to natural gas.[38] "Let's not get unreasonably concerned about [methane], because the industry has been addressing it," reassures an API executive.[39]

As its name would imply, the Northwest Gas Association holds natural gas in the same esteem as truly renewable and zero-emission energy like solar and wind. It claims that "the U.S. leads the world in absolute reductions in $CO_2$ emissions" in large part because of natural gas.[40] Likewise, the Independent Petroleum Association of America says climate regulation is not necessary because natural gas is helping the United States meet Paris Agreement goals.[41] This pitch has allowed trade associations to help themselves to unearned climate bona fides while pumping out dirty fossil fuels and putting up roadblocks to renewable energy. Fossil fuel trade associations have also directly funded studies to promote their self-serving positions.[42]

## Frackers collude to spin the narrative

Not all groups that call themselves "green" are stewards of the environment. Some large, national environmental organizations are powered by money from natural gas corporations and/or canoodle with the industry.[43] In tandem, their messaging has helped pave the way for shale gas development by portraying it as a favorable alternative to coal.[44] They advance the industry narrative that the imagined flexibility of natural gas generation makes it a necessary partner for renewable energy.[45]

Even if green groups do not contemplate their funding sources as they formulate their position on fracking, money from pro-gas interests has amplified the voices of environmental groups that have weak stances on natural gas.[46] These organizations acknowledge the ongoing extreme dangers associated with gas development, but they insist that these problems should be fixed through regulatory half measures, not bans.[47] In reality, regulation cannot protect people or the environment from the impacts of fracking. Regulated fracking still results in public health impacts, accidental spills of toxic waste, air pollution, earthquakes, drinking water contamination and unavoidable methane leaks that fuel climate change.[48]

In 2012, while the people of New York State were mobilizing to oppose opening their state to fracking, former New York City mayor Michael Bloomberg and fracking tycoon George Mitchell co-authored an op-ed championing regulation as an alternative to outright bans.[49] A day later, Bloomberg announced a $6 million grant as part of its support for big green groups and their weak fracking policies.[50] This kind of collaboration between environmental groups and the profit-driven fracking industry means ongoing rhetorical cover for, and questionable research that supports, bridge fuelers. These lucrative interlocks have bought big greens a megaphone to dominate the narrative on fracking.

# Fracking Is Responsible for Catastrophic Methane Emissions

The only reason that anyone has ever thought that natural gas could be a climate solution is because the industry and its shills control the dialogue. But the science and the facts are clear: fracking harms people and the environment, and methane emissions and leaks are a major threat to the climate.

Natural gas mostly comprises methane, an extremely potent greenhouse gas with a climate footprint worse than coal and oil because it traps more heat in the atmosphere.[51] When this burnable hydrocarbon is released to the atmosphere, it is 86 times as potent as $CO_2$ over 20 years and 34 times as potent over 100 years.[52] In fact, methane is responsible for a third of the total warming since the industrial revolution.[53] Atmospheric methane levels were steady for about a decade until 2007, after which they started to rise.[54]

This trend reversal closely corresponds to the fracking boom. Satellite analysis found that U.S. methane emissions increased 30 percent between 2002 and 2014.[55] At the same time, U.S. oil and gas production increased 20 percent on the back of a nine-fold increase in shale gas production.[56] Multiple analyses have also associated the 2007 to 2014 methane reversal with similar changes in atmospheric levels of ethane, a pollutant largely emitted by oil and gas production.[57]

Even small leaks erase gas' supposed climate benefit: a loss rate of 2.3 percent of methane emissions from the supply chain produces the same amount of warming as the $CO_2$ emitted from combustion.[58] Methane leaks in the 2.4 to 3.2 percent range are likely to completely neutralize any purported climate benefits of natural gas used in place of coal for electricity generation.[59]

In addition to driving perilous increases in global temperatures, methane also accelerates the formation of the hazardous pollutant ozone.[60] At fracking sites, volatile organic compounds, including methane, benzene and toluene, can mix with nitrogen oxide emissions from diesel-fueled vehicles and stationary equipment to form ground-level ozone.[61] A single megaton of methane emitted into the atmosphere can create enough ozone to cause $132 million in damages to forestry, agriculture and public health, as well as hundreds of premature deaths annually.[62] Prolonged contact with ground-level ozone is linked to asthma and chronic obstructive pulmonary disease. When mixed with particulate matter, which has been linked to various cancers, smog can form.[63] In addition to asthma, long-term exposure to smog has been connected to premature deaths in adults and to low birthweight in babies.[64]

## Leaks occur throughout the natural gas supply chain

Natural gas is leaking from every stage of the sprawling natural gas network — from wells to pipelines to compressor stations to power plants (see Figure 1 on page 6). A study analyzing 15,000 measurements of natural gas leakage concluded that imperfections in manmade systems make "some loss of product" inevitable.[65] Electricity grids commonly lose at least 5 percent of transmitted power, and the natural gas system is similarly complex.[66] However, because of the different methodological approaches used to quantify gas leaks, there is no single national estimate. Instead, a wide range of estimates have been produced over the past decade. These estimates are usually expressed as a percentage of gas lost, also known as the "leak rate" (see Appendix on page 13 for a comprehensive list of methane leak studies).

Methodologies used to calculate leak rates are typically either "top-down" or "bottom-up" studies. The top-down approach uses data from flyovers, satellites and towers to track total methane emitted to the atmosphere above gas-producing regions and infrastructure.[67] The bottom-up method records leaks using handheld or vehicle-mounted scanners and aggregates to create a leak rate estimate.[68] Some scientists incorporate data from both sources or use models to extrapolate information to unmeasured facilities, but official inventories used by the U.S. Environmental Protection Agency (EPA) are typically based on bottom-up data (see sidebar at right for detailed explanations of top-down vs. bottom-up methodologies).[69]

## Methods Used to Estimate Methane Leaks

**Use of bottom-up evidence has led to the chronic underestimation of methane leaks due to flaws in the bottom-up approach. For example, planes that do flyovers to procure data will estimate all methane emitted in the area examined, but bottom-up estimates are prone to omission because they can miss both the biggest emitters and catastrophic blow-outs.[77] Because of the sheer number of locations that bottom-up investigations need to examine to get their data, scientists often rely on combining numbers of facilities with "emissions factors," which are modeled leak rates for types of facility rather than direct measurements of actual methane emissions.[78] These emission factors are frequently drawn from a flawed EPA study performed in the 1990s, and are shown to be unrealistically low compared to top-down data.[79] Even direct measurements find factors 10 to 40 times greater than some emission factors used in bottom-up studies.[80]**

**Direct measurement issues have bedeviled bottom-up approaches. Many bottom-up studies have measured methane with a scanner that has been shown to systematically underestimate emissions.[81] Even after these flaws were conclusively demonstrated, some scientists still choose to include the bad data in their models.[82] Some methane sources are not measured because components are inaccessible or because companies do not cooperate (often the biggest emitters).[83] At production sites, it is challenging to measure ground-migrating methane, a proven side effect of fracking.[84]**

**While aerial and satellite studies are better (although imperfect), top-down critics claim that other sources such as wetlands and farms could be mistakenly included in estimates, although these sources have different chemical and isotopic signatures.[85] Another suggested (but unlikely) explanation for the discrepancy between bottom-up and top-down results is that emissions are higher during the daytime.[86]**

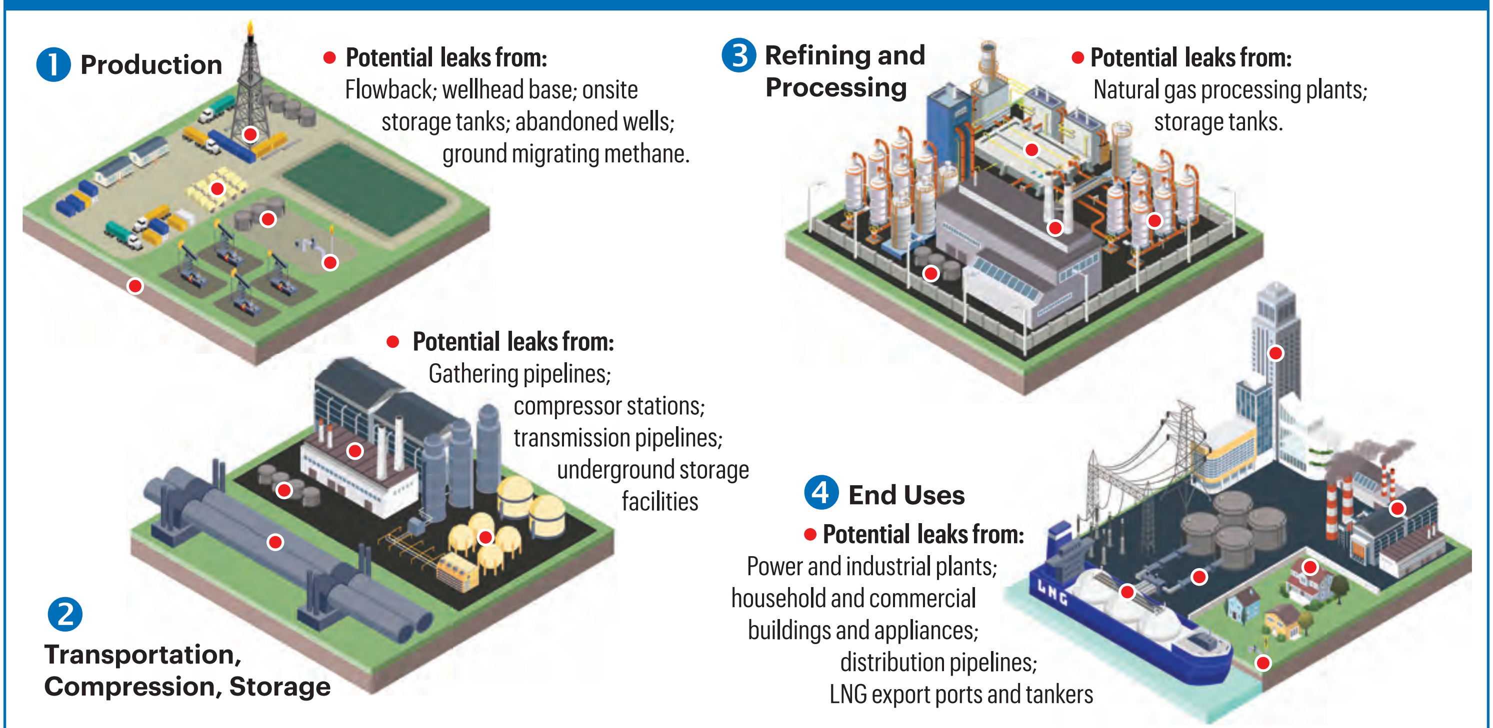
In 2014, researchers summarized top-down research results for the entire natural gas supply chain. They described the range of leak rate estimates as between 2.3 and 11.7 percent of total natural gas produced.[70] This estimate took into account the amount of gas leaked during production and processing (0.6 percent to 7.7 percent) as well as transportation and storage (0.007 to 10 percent).[71] Based on their review, about 7 percent of gas is likely lost between drilling and combustion.[72] Contrarily, in 2018, a 16-part joint study by the oil and gas industry and the Environmental Defense Fund (EDF) found much lower leak rates of 2.3 percent.[73] EDF's summary compared the study's results against top-down measurements conducted in 2015 and earlier, producing a low average.[74] Meanwhile, research from Cornell University employed a methodology based on carbon signatures[a]. The research found a 3.5 percent leak rate for shale gas production (consistent with the low-end range of top-down studies).[75] Adjusting for the well-documented emissions disparity between fracking and conventional production techniques yields a 4.0 percent leak rate for shale gas and a 2.67 percent leak rate for other gas.[76]

## Step 1: Production emissions from fracking

Methane leaks occur throughout the natural gas chain, starting with the production phase. In fact, fugitive methane emissions in U.S. oil and gas fields are among the highest worldwide.[87] Substantial emissions occur when producers drill through small gas deposits.[88] Broken, corroded and leaky well casings can provide pathways for methane to leak directly into the atmosphere.[89] Recent studies found that gas leaks through fractures and to the surface through old wells.[90] Even after production stops, methane can escape from faulty equipment, such as loose fittings on aging joints, rusted piping at the wellhead base, malfunctioning pressure regulators and condensate on produced water tank batteries.[91]

Before extracting natural gas from a frack well, injected chemicals, water and sand are brought back to the surface during a period known as flowback.[92] This wastewater brings, in addition to various chemicals and toxins, methane and ethane to the surface where they may be released into the atmosphere.[93] Additionally, shale reserves are often surrounded by previously developed oil, coal and natural gas fields.[94] Drilling through these layers of previously developed natural resources can create new pathways for gas leakage.[95] High pressure from fracking can crack or degrade well plugs and casings already weakened by naturally occurring $CO_2$.[96] Real-world evidence of these unique risks is abundant. For example, in Pennsylvania, unconventional wells experienced casing impairments 1.57 times more often than

**FIG. 1: Natural Gas Leaks Throughout the Supply Chain**




SOME VECTOR COMPONENTS COURTESY OF MACROVECTOR AND RAWPIXEL.COM

a Carbon molecules in methane samples correspond to particular histories. This allows researchers to determine the proportions of atmospheric methane arising from different sources.

conventional wells, creating a significant risk of increased methane leakage.[97]

## Step 2: Transportation, compression and storage

Once gas is produced, it must be transported or stored for later use. The transportation, compression and storage sector includes 2,000 compressor stations that pressurize natural gas to transport it through 300,000 miles of pipelines, storage wells and associated equipment.[98] While one of the few studies performed on high-pressure transmission and storage only found a 0.35 percent leak rate, actual leakage could be much higher.[99]

Leaks are underregulated and likely underreported. Pipelines rely on a complex combination of computer and human oversight that leaves numerous opportunities for accidents.[100] Natural events such as erosion from rain, landslides and sinkholes can also break pipelines.[101] Transmission pipelines self-report significant or serious accidents (reporting only covers a limited portion of events) once per 3,000 miles annually.[102]

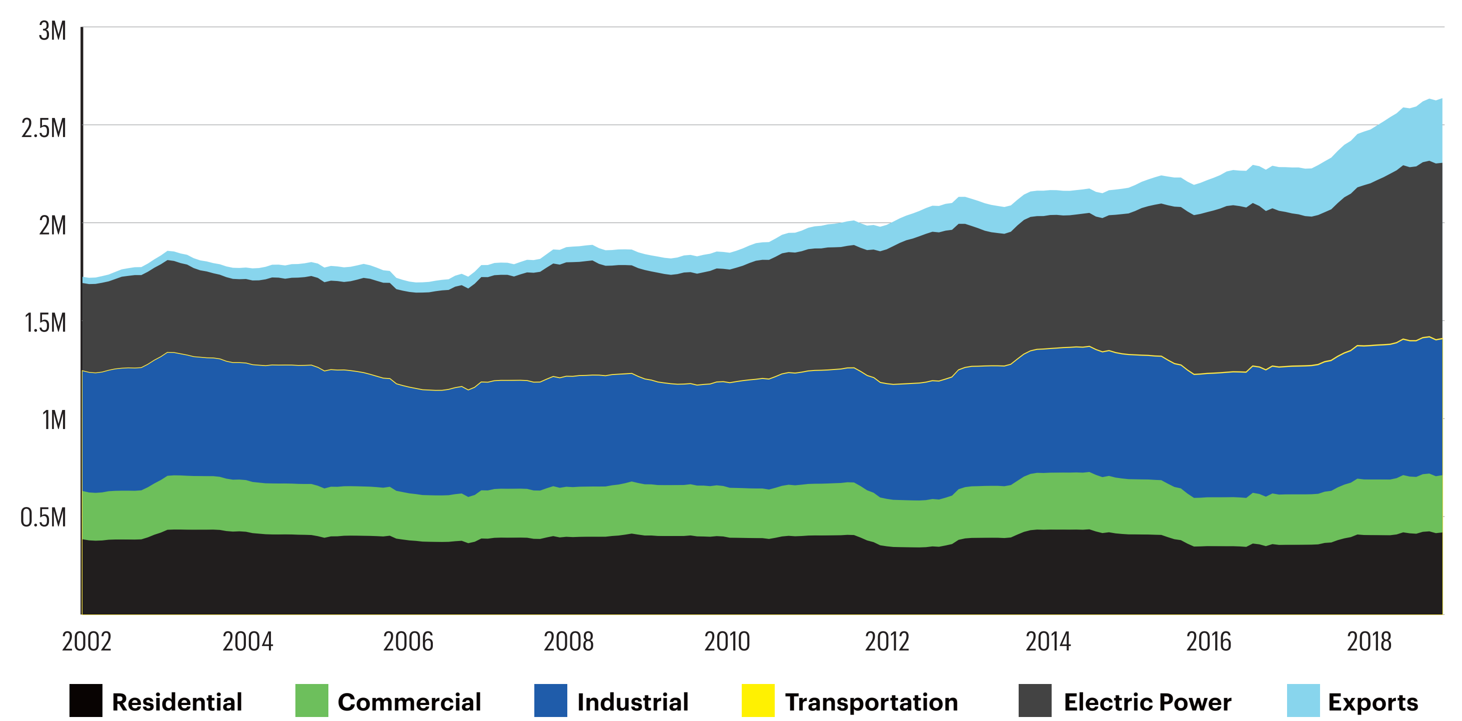
Along the pathway from well to customer, 13 percent of processed natural gas is injected into underground storage.[103] Storage wells pose high risk of accidents as they are often not designed for gas storage.[104] For example, in 2016 the Aliso Canyon storage facility in California leaked methane for months.[105] Gas production wells that have been repurposed to be storage wells are often ancient (median age of 74 years), are likely to exhibit design-related deficiencies and rarely incorporate protective measures to enhance their structural integrity.[106]

## Step 3: Refining and processing

Typically, natural gas is delivered to processing plants that separate dry natural gas (methane) from natural gas liquids (like ethane) and impurities.[107] The complex system of compressors, dehydrators and pneumatics at these facilities offers numerous points for methane to escape. Storage tanks at these facilities are particularly leaky and prone to off-gassing.[108] Of the three published investigations that quantified leakage rates in this sector, two were affiliated with EDF and all three were funded in part by gas companies[109] — suggesting that estimates woefully underestimate the fugitive methane releases.

Studies of this sector have also relied on cooperation with the industry for site access and have been unable to measure facilities of uncooperative companies.[110] Subsequently, these biased studies found that between 0.47 and less than 1 percent of produced gas escapes from gathering, compressing and processing facilities.[111] It is likely that the leak rate is significantly greater, but even these biased studies undermine the bridge fuel claim.

**FIG. 2: Natural Gas Consumption by End Use (Million Cubic Feet 12-Month Rolling Average)**




**Source:** EIA. U.S. Natural Gas Consumption by End Use. July 2019; EIA. U.S. Natural Gas Exports. July 2019.

## Step 4: End uses and other emissions

Once gas has gone through the first three steps of the natural gas chain, processed gas finds its way to "end users," a variety of which are served by different portions of the natural gas extraction and delivery system (see Figure 2 on page 7).[112] Typically, commercial and residential consumers use the leaky low-pressure distribution system, while the electric power and industrial users receive gas directly from the high-pressure transmission system.[113] Investigations like the large 2018 EDF study typically do not examine leakage from local distribution and focus on the use of gas for electricity.[114]

Accounting for the climate implications of non-electric power uses of natural gas is critical.[115] Only about a third of produced natural gas is actually used to generate electricity and could potentially offset coal.[116] Fracking also powers the production of plastic, which contributed 1.8 gigatons of $CO_2$-equivalent, or nearly 4 percent of global emissions in 2015.[117] Plastic also releases methane as it breaks into smaller pieces.[118]

When buildings heat water and air by burning natural gas instead of using electric equivalents, overall emissions increase, even considering the fossil fuels burned to produce electricity at power plants.[119] The final uses of the gas (such as in liquefied natural gas (LNG) facilities, petrochemical refineries, power plants and buildings) are also associated with substantial leakage (see page Fig. 1 on page 4 for further discussion).[120]

### *Buildings*

Natural gas use in buildings is associated with substantial leakage. Local distribution pipes in large metro areas leak between 0.7 and 6 percent of the gas they carry.[121] In 2011, local distributors reported that an average of 1.6 percent of gas delivered was "lost-and-unaccounted-for."[122] Even the best-designed pipes are prone to leaks when added supply increases operating pressure on local distribution lines.[123] Once delivered, leaks from appliances and valves inside buildings release methane and pose safety risks.[124]

Natural gas use is responsible for the majority of combustion emissions in commercial and residential settings.[125] Buildings primarily use natural gas for tasks like heating and cooking that could be easily electrified.[126] According to the National Renewable Energy Laboratory, electrification can decrease fossil fuel-related carbon emissions by 41 percent (from 2005 levels).[127] These immediate emissions reductions grow as renewables replace fossil fuels in electric generation.[128] Additionally, long-term climate goals cannot be reached without electrification.[129]

### *Power plants*

Like all gas infrastructure, industrial users like power plants are prone to escaping methane emissions. A study of three gas power plants found that the leak rate was between 0.1 percent and 0.42 percent, which was 21 to 120 times more methane than the facilities estimated.[130] When gas plants have to be restarted, some vent remaining methane into the atmosphere for safety purposes.[131]

But a switch to gas power in the United States pushes domestic coal overseas, where international consumers burn it.[132] Every 10 percent drop in U.S. natural gas prices is associated with a 3.3 percent increase in coal exports.[133] As fracking boomed from 2007 to 2013, U.S. coal exports doubled, despite a recession.[134] This dynamic helps eliminate the supposed advantage of natural gas over coal.[135]

**Every 10 percent drop in U.S. natural gas prices is associated with a 3.3 percent increase in coal exports. As fracking boomed from 2007 to 2013, U.S. coal exports doubled, despite a recession. This dynamic helps eliminate the supposed advantage of natural gas over coal.**

### *LNG and CNG*

Efforts to find new outlets for surplus gas supply push methane into leaky end uses. When LNG is stored in tanks, the vastly different air and storage temperatures lead to pressure buildup and require venting to release or "boil-off" gas.[136] At some facilities, super-cold LNG is stored in tanks with only a single inner shell capable of withstanding the extreme temperature of the gas.[137] Observed leak rates are as high as 10 percent, which more than offsets any climate advantage relative to coal combustion.[138]

Fueling vehicles with compressed natural gas (CNG) creates many opportunities for seepage. In addition to the direct act of releasing methane into the atmosphere through pressure venting, the nozzles, plumbing and engines can leak methane.[139] Car engines vent methane directly into the atmosphere in the form of uncombusted exhaust.[140] Leakage rates of 1.3 percent have been found solely from the filling station through car use.[141]

## Natural Gas Isn't Closing Coal: Evidence Doesn't Support the Bridge Fuel Hypothesis

Even excluding methane leaks, natural gas is detrimental for the climate.[142] Fracking can never deliver on its bridge promises. Between 2007 and 2013, U.S. $CO_2$ emissions fell by a modest 11 percent; but globally, emissions increased as $CO_2$-intensive production of U.S. consumer goods was offshored to countries like China.[143]

Attributing the U.S. decline in $CO_2$ purely to fracked gas ignores the effects of the 2008 recession, improvements in energy efficiency and the deployment of renewables.[144] Even optimistic models find that about half of the 2.1 percent decrease in $CO_2$ emissions between 2011 and 2013 can be attributed to natural gas.[145] As the economy recovered, $CO_2$ emissions began increasing.[146]

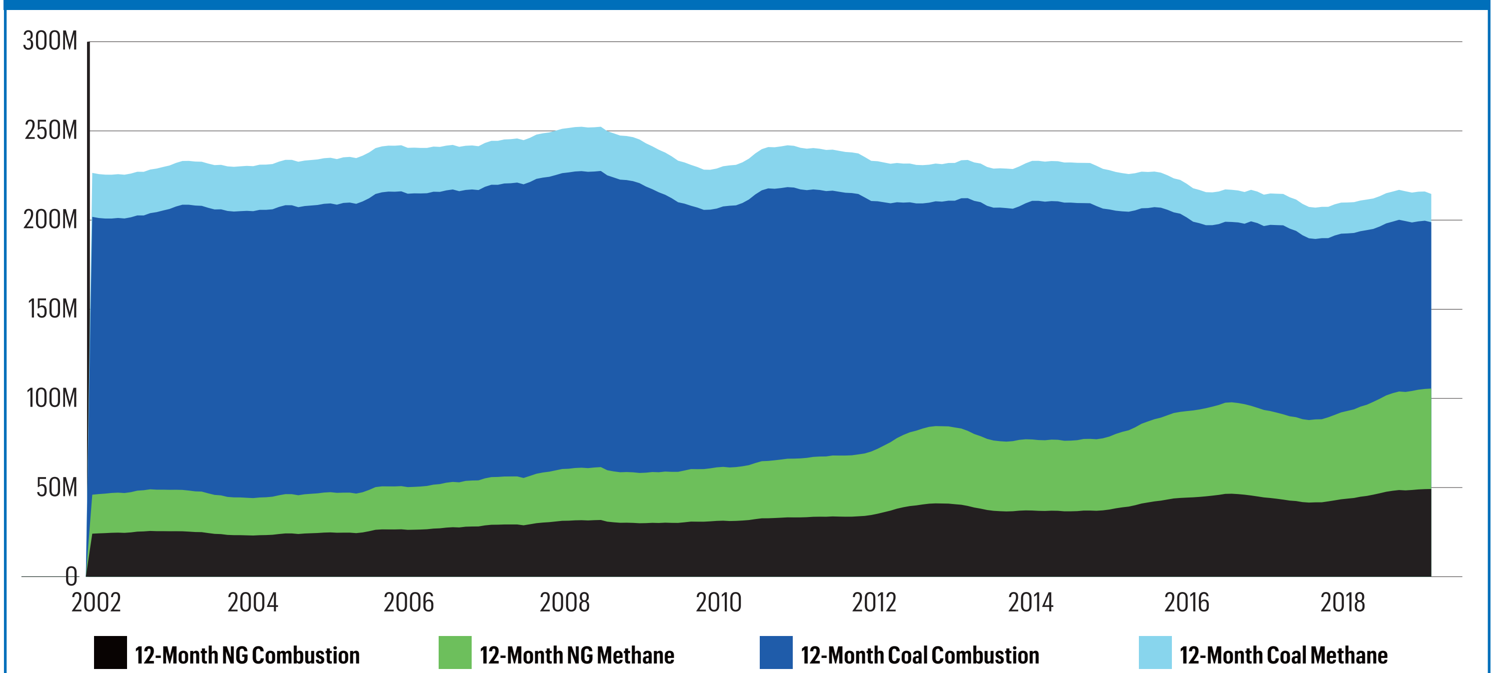
Going forward, natural gas will prove even more detrimental to climate progress. If we exceed the 1.5°C warming threshold, increased temperatures could cause irreversibly destructive climate change, potentially making parts of the planet uninhabitable this century.[147] Abundant gas breaks the carbon budget even for the insufficient Paris Agreement climate targets.[148] Long-term projections by the U.S. Energy Information Administration (EIA) find that even with continued fracking, coal's share of generation will stabilize in the 2020s.[149] As coal use stabilizes, large supplies of natural gas will continue to increase carbon emissions.[150]

### Lifecycle greenhouse gas emissions from electricity generation

Using data from the EIA, a peer-reviewed emissions inventory and a recent Cornell University study,[151] Food & Water Watch developed a model to evaluate the lifecycle emissions of electricity generation. The model included the methane emissions from coal and natural gas production, processing, transportation and end use. Our model found that, largely as a result of the fracking boom, the methane emissions from natural gas that was produced for gas-fired power plants have a greater climate impact than the $CO_2$ emitted at power plants.

Projections show that the combined emissions from natural gas and coal power plants, including leaks of methane, declined only 10.4 percent over the past decade (see Figure 3).[152] If emissions continued to decline at this rate, then greenhouse emissions would not reach zero by 2100.

**FIG. 3: Historical Electric Power Emissions (Million Metric Tons $CO_2$eq 12-Month Rolling Average)**




**Source:** See Methodology on page 18.

If natural gas remains a dominant energy source and an increasingly large share of electricity production, as the EIA has projected, then annual greenhouse gas emissions from the power sector will either remain stagnant (same as the present day) or rise by 2050 (see Figure 4).[153] And even if all coal plants were replaced with gas plants by 2030, greenhouse gas emissions would increase through 2050 (see Figure 5 on page 11).[154]

## Renewables have already crossed "the bridge"

Renewables alone can close coal. Technology exists to support a transition to 100 percent clean, renewable energy backed up by storage and transmission at prices lower than current energy costs.[155] While natural gas generation and some renewables are comparable in cost, new coal generation is substantially more expensive than both.[156] Levelized costs[b] of new coal generation are more than double the cost of natural gas.[157]

These price disadvantages were compounded by Obama-era EPA regulations that added legal hurdles to building new coal generation.[158] Since 2013, major coal capacity has not been added to the grid.[159] The EIA predicted that almost all capacity additions in 2019 would be powered by either wind, solar or natural gas with no new coal on the horizon through 2050.[160] Not only are costs of new renewables lower than those for new coal, but up to 74 percent of the current coal capacity could be closed immediately and replaced with renewables, all while saving money.[161]

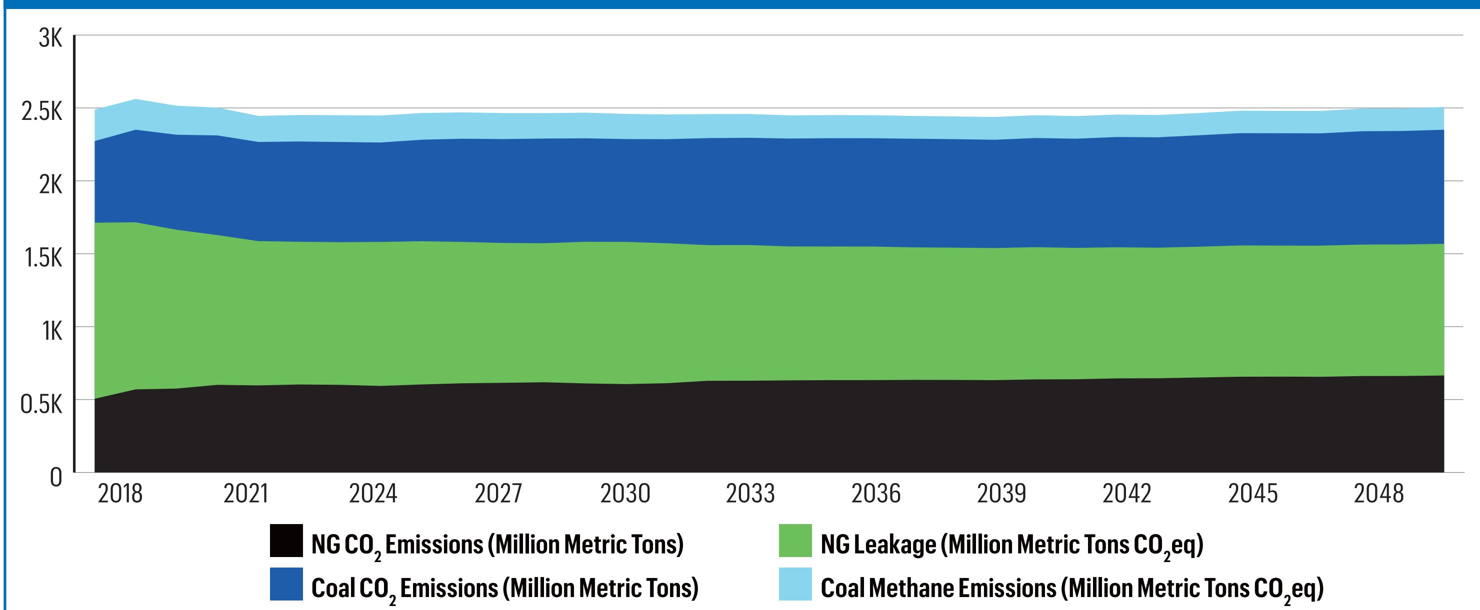
## Renewables, transmission and storage obviate need for gas

A common argument made in favor of fracking is that natural gas generation's supposed ability to rapidly respond to supply fluctuations makes it easier to integrate renewables into the grid.[162] But modern gas turbines (combined cycle) are not the rapid-start facilities touted by the gas industry, and peaker plants that are designed to respond quickly to peak energy demands are much more expensive and increasingly outmatched by batteries on cost alone.[163] (Even without storage for wind and solar, current renewable energy technologies balanced by transmission wires could reduce emissions to 80 percent of 1990 levels.[164])

A variety of energy storage technologies can provide cost-effective, reliable and long-term back-up for a 100 percent renewable energy system.[165] Battery storage, for example, can provide cheap energy storage with fast response times to account for changes in sun or wind.[166] Battery storage capacity is also experiencing sustained, exponential growth.[167]

The Arizona Public Service Company recently announced plans to install 850 megawatts of battery storage over the next six years because it was a cheaper option than natural gas.[168] In California, gas plants are calling for

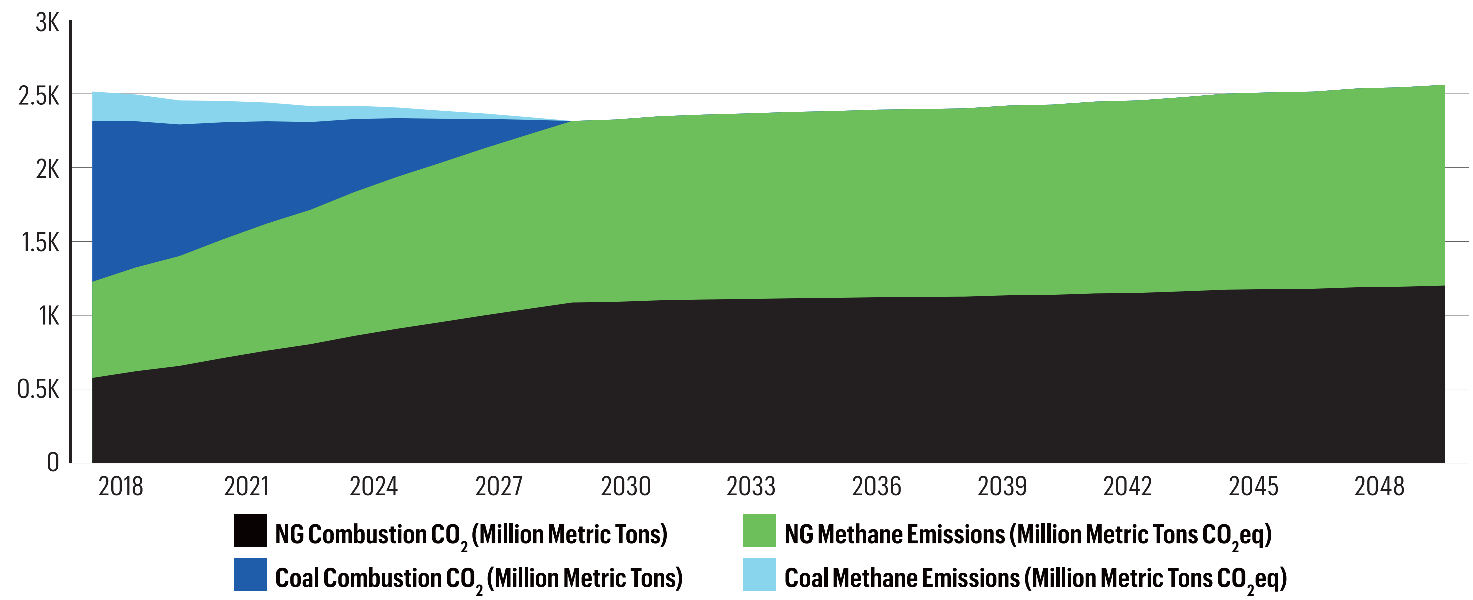
**FIG. 4: Annual Power Sector Greenhouse Gas Emissions 2018-2050, EIA Reference Scenario**




**Source:** See Methodology on page 18.

b Levelized cost of energy is the cost of producing energy from a facility across its lifetime. This means the cost to build a facility divided by the electricity it will produce during its years in operation plus the cost to operate, repair and fuel the facility. Renewables typically have large construction costs, but lower levelized costs because they do not need to buy fuel to operate.

**FIG. 5: Annual Power Sector Greenhouse Gas Emissions 2018-2050, Closing Coal Scenario**




**Source:** See Methodology on page 18.

subsidies because they are faced with competition from solar and storage alternatives for back-up.[169] In New England, a solar company won a competitive bid against fossil fuel companies to provide on-demand power capacity using storage systems.[170]

## Fracking delays adoption of real clean alternatives

Abundant gas has been shown to reduce investment in renewables.[171] Although renewables are a cheaper option than natural gas over their lifetime, investors tend to commit to natural gas in the short term because power plants have lower upfront costs.[172] High capital costs combined with abundant gas remain the key barriers to renewable energy development.[173]

Since fossil fuels and renewables compete to provide energy, gas supplies depress the production of renewable energy.[174] A 2017 study found that low natural gas prices shifted investment from wind power to gas turbines, which resulted in 6 percent higher average emissions, and solar power companies blame fracking for stifling domestic projects.[175]

Natural gas-fired power does not provide a one-to-one replacement of coal plants. Closed power plants use a diverse range of fuels, but tend to be among the oldest plants whose maintenance and operating costs are eroding profitability.[176] This means that some new gas plants simply close old gas plants.[177] Moreover, new renewable energy capacity is among the most cost-competitive sources of electricity and is capable of displacing older, less profitable generation capacity.[178]

## Gas plants built now will last for decades

As coal plants close slightly earlier than planned, they are replaced with gas plants that could last 40 to 50 years, cementing us into continued reliance on fossil fuels.[179] Even if methane leakage did not occur, the best natural gas plants still produce two-thirds the warming of the most efficient coal plants.[180] Significant carbon reductions are impossible if as much as 10 percent of the grid is powered by natural gas.[181]

If we do not ban fracking now, there is no guarantee that renewables can displace natural gas and finally end the purported “bridge.” Supporting infrastructure like refineries and pipelines creates a fossil-oriented inertia that delays climate action.[182] It also gives an unfair advantage to fossil fuels that are compatible with the existing energy systems.[183] Institutional interlocks between energy companies, bureaucracies and policy makers favor current technologies and throttle potential competitors.[184]

Building new gas plants means that one of two things will happen: (1) these gas plants could operate for their economic and technical lifetimes, pushing us over the brink of climate chaos; or, (2) the plants could be closed early, becoming stranded economic assets.[185] Weaning off gas later would actually be more expensive than doing it now.[186] Instead of doubling down on fracking and new fossil fuel facilities, the United States must massively invest in clean energy.

# Conclusions

Continued fracking puts the world on an unsustainable trajectory, producing vastly more gas and oil than is compatible with a safe climate. Industries benefiting from the fracking boom like plastic and LNG export facilities produce products of little value, and gas power plants prolong an outdated and dirty method of producing electricity that is neither economical nor safe.

Now, more than a decade after the inception of the fracking boom, leaks of methane from fracking, transportation and end use remain dangerously high. Voluntary initiatives, stakeholder engagement sessions and industry/"big green" collaboration are merely band-aid approaches designed to make the general public feel better about the status quo. They do not solve the intrinsic climate problems associated with fossil fuel production and fracking in particular.

Communities and advocates across the country have worked hard and won victories in the fight against fracking. Hundreds of local municipalities have passed regulations that protect their communities from fracking and disposal of wastewater where they live. States like New York and Maryland have proven that it is possible to stand up to fossil fuel interests and win by banning fracking outright. Federally, a movement is growing to support a large-scale effort that would move the United States away from fossil fuels by building renewable energy and electrifying infrastructure.

Instead of doubling down on more fossil fuels, we must close coal and natural gas plants and replace them with renewable energy. Technology for a large-scale transition to renewables has existed for over 20 years but is cheaply available now[187] — we need strong government policies backed by political will to see them through. Food & Water Watch recommends:

- Instituting a national ban on fracking and its associated activities, such as frack sand mining and waste disposal that support the practice;
- Shutting down dangerous infrastructure that props up the fracking and fossil fuel industries and stopping fossil fuel exports and the construction of infrastructure to support these exports;
- Restricting the sale of plastic products that prop up the oil and gas industry;
- Transitioning to 100 percent clean, renewable energy by 2030 through investment in a New Deal-scale green energy public works program that fosters a rapid transition to real, zero-emission clean energy like solar and wind, accompanied by widescale deployment of energy efficiency.

# Appendix: Methane Leak Studies

| Author(s) | Study Name | Section Covered | Year | Leak Percentage | Method | Location Covered | Relevant Pages | Notable Affiliations |
|---|---|---|---|---|---|---|---|---|
| Allen et al. | Measurements of methane emissions at natural gas production sites in the United States | Production | 2013 | 0.42% | Bottom Up | National | 7 and 8 | Funded by gas companies, EDF |
| Alvarez et al. | Assessment of methane emissions from the U.S. oil and gas supply chain | Life Cycle Assessment | 2018 | 2.30% | Synthesis | National | 1 to 3 | EDF |
| Balcombe et al. | Characterising the distribution of methane and carbon dioxide emissions from the natural gas supply chain | Life Cycle Assessment | 2018 | 1.6 to 5.5% | Synthesis | | 2019, 2020 and 2031 | Sustainable Gas Institute |
| Barkley et al. | Quantifying methane emissions from natural gas production in northeastern Pennsylvania | Production and Gathering | 2017 | 0.36% | Top Down | Northeastern Pennsylvania | 13941 | |
| Brandt et al. | Methane leaks from North American natural gas systems | Life Cycle Assessment | 2014 | 1.8 to 7.1% | Synthesis | National | 733 and S29 | |
| Brantley et al. | Assessment of methane emissions from oil and gas production pads using mobile measurements | Production | 2014 | 0.14 to 0.59% | Bottom Up | Barnett, Denver-Julesburg, Pinedale | 14508 and 14514 | EDF |
| Burnham et al. | Life-cycle greenhouse gas emissions of shale gas, natural gas, coal, and petroleum | Life Cycle Assessment | 2012 | 2.75% for Conventional, 2.01% for Shale | Bottom Up | National | 619 and 621 | |
| Caulton et al. | Toward a better understanding and quantification of methane emissions from shale gas development | Production | 2014 | 2.8 to 17.3% | Top Down | Southwestern Pennsylvania | 6237, 6238 and 6240 | |

## *Appendix: Methane Leak Studies continued*

| Author(s) | Study Name | Section Covered | Year | Leak Percentage | Method | Location Covered | Relevant Pages | Notable Affiliations |
|---|---|---|---|---|---|---|---|---|
| Caulton et al. | Importance of super-emitter natural gas well pads in the Marcellus Shale | Production | 2019 | 0.53% | Bottom Up | Marcellus (PA) | 2 | |
| Clark et al. | Pump-to-wheels methane emissions from the heavy-duty transportation sector | CNG and LNG | 2016 | 1.3% | Bottom Up | National | 974 and 968 | |
| Englander et al. | Aerial interyear comparison and quantification of methane emissions persistence in the Bakken formation of North Dakota, USA | Production | 2018 | Similar to Peischl et al. (2016) 4.2% to 8.4% | Top Down | Bakken (ND) | 8947, 8952 and 8953 | |
| Foster et al. | Quantifying methane emissions in the Uintah Basin during wintertime stagnation episodes | Production | 2019 | Similar to Kairon et al. (2013) 6.2% to 11.7% | Top Down | Uintah (UT) | 13 | |
| Howarth | A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas | Life Cycle Assessment | 2014 | 3.8% (Conventional) to 5.8% (Shale) | Synthesis | National | 47 and 49 | |
| Howarth | Is shale gas a major driver of recent increase in global atmospheric methane? | Life Cycle Assessment | 2019 | 3.5% (Both) 4.1% (Shale specific) | Top Down | National | 3039 and 3040 | |
| Howarth et al. | Methane and the greenhouse-gas footprint of natural gas from shale formations | Life Cycle Assessment | 2011 | 3.6% to 7.9% (Shale), 1.7% to 6% (Conventional) | Synthesis | National | 679 and 683 | |
| Karion et al. | Methane emissions estimate from airborne measurements over a western United States natural gas field | Production | 2013 | 6.2% to 11.7% | Top Down | Uintah (UT) | 4393 | |

## *Appendix: Methane Leak Studies continued*

| Author(s) | Study Name | Section Covered | Year | Leak Percentage | Method | Location Covered | Relevant Pages | Notable Affiliations |
|---|---|---|---|---|---|---|---|---|
| Lamb et al. | Direct measurements show decreasing methane emissions from natural gas local distribution systems in the United States | Local Distribution Pipelines | 2015 | 0.1% to 0.22% | Bottom Up | National | 5161 and 5168 | American Gas Association; SoCal Gas; PG&E; EDF |
| Lavoie et al. | Assessing the methane emissions from natural gas-fired power plants and oil refineries | Power Plants | 2017 | 0.1% to 0.42% | Top Down | | 3373 and 3380 | EDF |
| Marchese et al. | Methane emissions from United States natural gas gathering and processing | Gathering and Processing | 2015 | 0.47% | Bottom Up | National | 10718 and 10725 | Funded by gas and pipeline companies; EDF |
| McKain et al. | Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts | Transmission, Distribution, End Use | 2015 | 2.7% | Synthesis | Boston | 1941 and 1946 | EDF |
| Mitchell et al. | Measurements of methane emissions from natural gas gathering facilities and processing plants: Measurement results | Gathering and Processing | 2015 | 0.1% to <1% | Bottom Up | National | 3219 and 3226 | Funded by gas and pipeline companies; EDF |
| Omara et al. | Methane emissions from conventional and unconventional natural gas production sites in the Marcellus shale basin | Production | 2016 | 0.13% to 11% | Top Down | Marcellus | 2099 and 2100 | |
| Omara et al. | Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate | Production | 2018 | 1.5% | Synthesis | National | 12921 and 12924 | EDF |

## *Appendix: Methane Leak Studies continued*

| Author(s) | Study Name | Section Covered | Year | Leak Percentage | Method | Location Covered | Relevant Pages | Notable Affiliations |
|---|---|---|---|---|---|---|---|---|
| Peischl et al. | Quantifying sources of methane using light alkanes in the Los Angeles basin, California | Production | 2013 | 17% | Top Down | South Coast Air Basin (CA) | 4988 and 4989 | |
| Peischl et al. | Quantifying atmospheric methane emissions from the Haynesville, Fayetteville, and northeastern Marcellus shale gas production regions | Production | 2015 | 0.18% to 2.8% | Top Down | Haynesville, Fayetteville, Marcellus | 2119 | |
| Peischl et al. | Quantifying atmospheric methane emissions from oil and natural gas production in the Bakken shale region of North Dakota | Production | 2016 | 4.2% to 8.4% | Top Down | Bakken (ND) | 6101 and 6110 | |
| Peischl et al. | Quantifying methane and ethane emissions to the atmosphere from central and western U.S. oil and natural gas production regions | Production | 2018 | 1% to 5.4% | Top Down | Central/ Western U.S. | 7725 and 7738 | |
| Pétron et al. | Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study | Production Through Processing | 2012 | 1.68% to 7.7% | Top Down and Bottom Up | Weld County (CO) | 15 | |
| Pétron et al. | A new look at methane and nonmethane hydrocarbon emissions from oil and natural gas operations in the Colorado Denver-Julesburg Basin | Production | 2014 | 4.10% | Top Down | Denver-Julesburg Basin (CO) | 6836, 6850 and 6851 | EDF |
| Ren et al. | Methane emissions from the Baltimore-Washington area based on airborne observations: Comparison to emissions inventories | Urban Natural Gas Systems | 2018 | 1.1% to 2.1% | Top Down | Baltimore-Washington | 10 | |

## Appendix: Methane Leak Studies continued

| Author(s) | Study Name | Section Covered | Year | Leak Percentage | Method | Location Covered | Relevant Pages | Notable Affiliations |
|---|---|---|---|---|---|---|---|---|
| Riddick et al. | Measuring methane emissions from abandoned and active oil and gas wells in West Virginia | Wells | 2019 | 8.8% | Bottom Up | West Virginia | 1855 | |
| Robertson et al. | Variation in methane emission rates from well pads in four oil and gas basins with contrasting production volumes and compositions | Production | 2017 | 0.09% to 2.8% | Bottom Up | Upper Green River, Denver-Julesburg, Uintah, Fayetteville | 8832 and 8839 | Funded by oil and gas companies |
| Schneising et al. | Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations | Production | 2014 | 9.1% to 10.1% | Top Down | Eagle Ford and Bakken | 548 and 556 | |
| Schwietzke et al. | Natural gas fugitive emissions rates constrained by global atmospheric methane and ethane | Life Cycle Assessment | 2014 | 2% to 5% | Top Down | | 2, 3 and 22 | |
| Wennberg et al. | On the sources of methane to the Los Angeles atmosphere | Local Distribution Pipelines | 2012 | 2.5% to 6% | Top Down | Los Angeles | 9282 | |
| Zaimes et al. | Characterizing regional methane emissions from natural gas liquid unloading | Production Phase Liquid Unloading | 2019 | 0.0093% to 0.38% | Bottom Up | | A and I | One author works for Cheniere; EDF |
| Zavala-Araiza et al. | Reconciling divergent estimates of oil and gas methane emissions | Life Cycle Assessment | 2015 | 1.5% | Synthesis | Barnett Shale | 15597, 15598 and 15600 | EDF |
| Zimmerle et al. | Methane emissions from the natural gas transmission and storage system in the United States | Transmission and Storage | 2015 | 0.35% | Bottom Up | National | 9374, 9378 and 9382 | Funded by gas and pipeline companies; EDF |

# Methodology for Lifecycle Emissions of Electricity Generation

## Analysis

Food & Water Watch evaluated overall greenhouse gas emissions from coal and gas-fired power plants, which included $CO_2$ from combustion as well as methane emissions and leaks. To achieve this, we ascribed methane emissions from coal and natural gas production to their use in electric power generation and looked at three different scenarios. The first looked at historical greenhouse gas emissions from these sectors between 2002 and 2019 to evaluate the climate impact of the fracking boom (by plotting on a graph the emissions from before and during the boom). This scenario determined that we will be unable to get to zero greenhouse gas emissions by 2100 if we continue on the same trajectory. In scenario two, we projected greenhouse gas emissions out to 2050 based on an EIA reference scenario. This assumes little to no change in the current electricity sector trends. For the third scenario, we tested the bridge fuel hypothesis, which showed that replacing all current coal-fired electricity with natural gas-fired electricity by 2030 results in an upward trend of greenhouse gas emissions.

Methane emission estimates were converted to $CO_2$ equivalent emissions based on the 20-year global warming potential (86 times that of $CO_2$) due to the immediacy and urgency of the climate crisis and the potential for a lock-in of dangerous climate tipping points and feedback loops.

This model assumes that all power plants use the same proportion of unconventional (shale) and conventional fuel for natural gas; for coal it assumes that all power plants use the same proportion of surface-mined and underground-mined coal.

Scenario three created a projection of electricity production (kilowatt-hours), in which gas plants displace current and future coal plant electricity generation. The projection assumed a linear change from 2019 to 2030. Greenhouse gas emissions for this scenario were evaluated by multiplying methane and $CO_2$ emissions rates (per kilowatt-hour, 2019 rates) for coal and gas by projected electricity generation. The scenario used emission rates from 2019 instead of projecting emission rate changes because emission rates are sensitive to the changes in consumption that our scenario projected. For example, more gas consumption would likely result in a higher proportion of overall gas production from fracking. In the electricity sector, slower retirement rates would change the proportions of gas generation (e.g., combined cycle, combustion turbine).

## Data Sources

***Natural gas methane leak data:*** U.S. gas leak estimates (4 percent for shale gas, 2.67 percent for non-shale gas) were based on Howarth, Robert W. "Is shale gas a major driver of recent increase in global atmospheric methane?" *Biogeosciences*. Vol. 16, Iss. 15. August 14, 2019 at 3040.

***Coalbed methane leak data:*** U.S. leak rates for surface and underground mined were based on Schwietzke, Stefan et al. "Global bottom-up fossil fuel fugitive methane and ethane emissions inventory for atmospheric modeling." *ACS Sustainable Chemistry & Engineering*. Vol. 2. 2014 at 1996.

***Energy Information Administration data:*** Historical $CO_2$ emissions, coal production, natural gas production and electricity generation were obtained (projected where not available) from publicly available EIA data; Dry Shale Gas Production Estimates by Play. Released August 15, 2019. Available at www.eia.gov. Accessed August 2019; Natural Gas Consumption by End Use. U.S. Natural Gas Deliveries to Electric Power Consumers. Released July 31, 2019. Available at www.eia.gov. Accessed August 2019; July 2019 Monthly Energy Review. Table 11.6 Carbon Dioxide Emissions from Energy Consumption: Electric Power Sector. Table 6.2 Coal Consumption by Sector. Released July 29, 2019. Available at www.eia.gov. Accessed August 2019; U.S. Natural Gas Gross Withdrawals. Released July 31, 2019. Available at www.eia.gov. Accessed August 2019; Annual Coal Report 2017. Table ES 1. Released November 2, 2018. Available at www.eia.gov. Accessed August 2019; Coal Data Browser. United States: Electric power short tons. Available at www.eia.gov/coal/data/browser. Accessed August 2019; Annual Energy Outlook 2019. Table 8 Electricity Supply, Disposition, Prices, and Emissions. Table 14 Oil and Gas Supply. Table 15 Coal Supply, Disposition, and Prices. Table 18 Energy-Related Carbon Dioxide Emissions by Sector and Source. Table 63 Natural Gas Consumption by End-Use Sector and Census Division. Table 67 Coal Production by Region and Type. Released January 2019. Available at www.eia.gov. Accessed August 2019.

# Endnotes


1 Gorski, Irena and Brain S. Schwartz. "Environmental health concerns from unconventional natural gas development." *Oxford Research Encyclopedia Global Public Health*. February 2019 at 11 and 39.

2 Castelli, Matthew. "Fracking and the rural poor: Negative externalities, failing remedies, and federal legislation." *Indiana Journal of Law and Social Equality*. Vol. 3, Iss. 2. May 2015 at 281 and 285 to 287; Zwickl, Klara. "The demographics of fracking: A spatial analysis for four U.S. states." *Ecological Economics*. Vol. 161. July 2019 at 202.

3 Davenport, Coral. "Major climate report describes a strong risk of crisis as early as 2040." *New York Times*. October 7, 2018.

4 *Ibid*.

5 Hansen, Kenneth et al. "Status and perspectives on 100% renewable energy systems." *Energy*. Vol. 175. May 2019 at 2 and 6; Intergovernmental Panel on Climate Change (IPCC). "Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty." October 2018 at 142.

6 Alvarez, Ramón A. et al. "Assessment of methane emissions from the U.S. oil and gas supply chain." *Science*. Vol. 361, Iss. 6398. July 2018 at 186; Howarth, Robert W. "A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas." *Energy Science & Engineering*. Vol. 2, Iss. 2. June 2014 at 56.

7 Food & Water Watch calculations from historical model. See Methodology for more details.

8 Food & Water Watch analysis of U.S. Energy Information Administration (EIA) data from Form EIA-860, 2016. The average age of U.S. gas-fired power plants is 24 years, but 643 (12 percent) began operating before 1968, 50 years ago, and the oldest gas plant went online in 1915.

9 Zhang, Xiaochun et al. "Key factors for assessing climate benefits of natural gas versus coal electricity generation." *Environmental Research Letters*. Vol. 9, No. 11. November 2014 at 6.

10 Kis, Zoltán et al. "Electricity generation technologies: Comparison of materials use, energy return on investment, jobs creation and $CO_2$ emissions reduction." *Energy Policy*. Vol. 120. September 2018 at 156.

11 Food & Water Watch calculations from AEO Replace Coal model. See Methodology for more details.

12 Food & Water Watch calculations from AEO model. See Methodology for more details.

13 "Methane leaks — A dirty little secret." *Economist*. July 23, 2016.

14 Stephenson, Eleanor et al. "Greenwashing gas: Might a 'transition fuel' label legitimize carbon-intensive natural gas development?" *Energy Policy*. Vol. 46. July 2012 at 452.

15 Howarth (2014).

16 Stephenson et al. (2012) at 454.

17 Broderick, John and Kevin Anderson. University of Manchester. Prepared for The Co-operative. "Has US Shale Gas Reduced $CO_2$ Emissions?" October 2012 at 4; International Energy Agency. "Golden Rules for a Golden Age of Gas." November 2012 at 91.

18 IPCC (2018) at 61 and 64.

19 Harrabin, Roger. "Campaigners' anger over agency's shale gas report." *BBC*. May 29, 2012.

20 Ladd, Anthony E. "Meet the new boss, same as the old boss: The continuing hegemony of fossil fuels and hydraulic fracking in the third carbon era." *Humanity & Society*. Vol. 41, Iss. 1. February 2017 at 24.

21 Lay, Kenneth. Enron. Letter to George H. W. Bush. April 3, 1992.

22 ExxonMobil. "The Outlook for Energy: A View to 2040." 2016 at 5 and 50.

23 Grubert, Emily A. and Adam R. Brandt. "Three considerations for modeling natural gas system methane emissions in life cycle assessment." *Journal of Cleaner Production*. Vol. 222. June 2019 at 761 and 765.

24 EIA. "Power sector pushed domestic U.S. natural gas consumption to new record in 2018." March 25, 2019; EIA. "Monthly Energy Review August 2019." August 2019 at Table 6.2 at 114.

25 Howarth (2014) at 56.

26 Zheng, Jiajia and Sangwon Suh. "Strategies to reduce the global carbon footprint of plastics." *Nature Climate Change*. Vol. 9, Iss. 5. April 2019 at 374 and 375.

27 Steinberg, Daniel et al. National Renewable Energy Laboratory. "Electrification & Decarbonization: Exploring U.S. Energy Use and Greenhouse Gas Emissions in Scenarios With Widespread Electrification and Power Sector Decarbonization." NREL/TP-6A20-68214. July 2017 at vi, 12 and 13.

28 Bauer, Nico et al. "Global fossil energy markets and climate change mitigation — an analysis with REMIND." *Climatic Change*. Vol. 136, Iss. 1. May 2016 at 1 and 7.

29 ExxonMobil Corporation. U.S. Securities and Exchange Commission. Form 10-K. Fiscal year ending December 31, 2018 at 31.

30 *Ibid*. at 1 to 3.

31 *Ibid*. at 43.

32 ConocoPhillips. U.S. Securities and Exchange Commission. Form 10-K. Fiscal year ending December 31, 2018 at 23 and 24; Lowe, John E. ConocoPhillips. Testimony before the Select Committee on Energy Independence and Global Warming. U.S. House of Representatives. April 1, 2008 at 5.

33 ConocoPhillips (2018) at 8; Lattanzio, Richard K. Congressional Research Service (CRS). "Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions." R42537. March 10, 2014 at Summary.

34 Chediak, Mark. "Sempra is fighting back against Californians who want natural gas gone." *Bloomberg*. February 21, 2019.

35 Mandel, Jenny. "SEC lets Exxon ax shareholder vote." *E&E News*. April 3, 2019.

36 Price, Asher. "Fight over wind power ramps up in Texas." *Austin American-Statesman*. April 5, 2019.

37 Diesendorf, Mark and Ben Elliston. "The feasibility of 100% renewable electricity systems: A response to critics." *Renewable and Sustainable Energy Reviews*. Vol. 93. October 2018 at 318, 320 to 323; Brown, T. W. et al. "Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems.'" *Renewable and Sustainable Energy Reviews*. Vol. 92. September 2018 at 840 and 841; Iaconangelo, David. "Cheap batteries could soon replace gas plants — study." *E&E News*. March 26, 2019; Schmidt, Oliver et al. "Projecting the future levelized cost of electricity storage technologies." *Joule*. Vol. 3, Iss. 1. January 2019 at 85 and 86; Kirschner, Dan. "The power of natural gas in the war on carbon emissions." *Seattle Times*. August 3, 2017.

38 "Methane leaks — a dirty little secret." (2016).

39 *Ibid*.

40 Kirschner (2017).

41 Whitehead, Seth. Independent Petroleum Association of America. Energy in Depth. "EIA: U.S. carbon emissions fall again in 2017, 'mainly' because of natural gas." February 12, 2018.

42 Hausfather, Zeke. "Bounding the climate viability of natural gas as a bridge fuel to displace coal." *Energy Policy*. Vol. 86. November 2015 at 286 and 293; Lamb, Brian K. et al. Laboratory for Atmospheric Research. Department of Civil & Environmental Engineering. "Direct measurements show decreasing methane emissions from natural gas local distribution systems in the United States." *Environmental Science & Technology*. Vol. 49, No. 8. April 2015 at 5168.

43 Gillis, Justin. "Group earns oil income despite pledge on drilling." *New York Times*. August 4, 2014; Stephens, Joe. "Oil spill threatens to stain alliances; Environmental nonprofits face potential backlash

as supporters learn of ties to BP." *Washington Post*. May 24, 2010; Mishkin, Kate. "WVU official named to natural gas company board." *Charleston Gazette-Mail*. March 15, 2018; Ottaway, David B. and Joe Stephens. "Big Green; Is $3 billion Nature Conservancy working too closely with polluters?" *Washington Post*. May 11, 2003.

44 Natural Resources Defense Council (NRDC). "The role of natural gas in America's Energy Mix." June 2012 at 1; Brownstein, Mark. Environmental Defense Fund (EDF). "Why EDF is working on natural gas." September 10, 2012.

45 NRDC (2012) at 4; EDF (September 2012).

46 Applebome, Peter. "Drilling critics face a divide over the goal of their fight." *New York Times*. January 9, 2012.

47 Brownstein (2012).

48 Frazier, Reid. "Wolf's fracking-health record hammered by new industry opposition group." *StateImpact*. May 23, 2018; Patterson, Lauren A. et al. "Unconventional oil and gas spills: Risks, mitigation priorities, and state reporting requirements." *Environmental Science & Technology*. Vol. 51, Iss. 5. March 2017 at 2563 and 2566; Phillips, Susan. "Air pollutants from Pa. oil and gas sites continue to rise." *StateImpact*. August 17, 2016; Davis, Charles and Jonathan M. Fisk. "Mitigating risks from fracking-related earthquakes: Assessing state regulatory decisions." *Society & Natural Resources*. Vol. 30, Iss. 8. February 2017 at 2, 7, 8 and 12; Yudhowijoyo, Azis. "Subsurface methane leakage in unconventional shale gas reservoirs: A review of leakage pathways and current sealing techniques." *Journal of Natural Gas Science and Engineering*. Vol. 54. June 2018 at 309 and 318.

49 Bloomberg, Michael R. and George P. Mitchell. "Fracking is too important to foul up." *Washington Post*. August 23, 2012.

50 EDF. [Press release]. "Environmental Defense Fund announces key grant from Bloomberg Philanthropies." August 24, 2012.

51 Howarth (2014) at 1; Howarth, Robert W. et al. "Methane and the greenhouse-gas footprint of natural gas from shale formations." *Climatic Change*. April 2011 at 679, 687 and 688.

52 Myhre, Gunner et al. "Anthropogenic and Natural Radiative Forcing." In Stocker, T. F. et al. (Eds.). (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press at Table 8.7 at 714.

53 Rosen, Julia. "Methane in the atmosphere is surging, and that's got scientists worried." *Los Angeles Times*. March 1, 2019.

54 *Ibid*.

55 Turner, A. J. et al. "A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations." *Geophysical Research Letters*. Vol. 43, Iss. 5. March 2016 at 2218.

56 *Ibid*. at 2222.

57 Franco, B. et al. "Evaluating ethane and methane emissions associated with the development of oil and natural gas extraction in North America." *Environmental Research Letters*. Vol. 11, No. 4. April 2016 at 1 and 9; Hausmann, Petra et al. "Contribution of oil and natural gas production to renewed increase in atmospheric methane (2007-2014): Top–down estimate from ethane and methane column observations." *Atmospheric Chemistry and Physics*. Vol. 16, Iss. 5. March 2016 at 3228, 3230, 3231, 3235 and 3236; Miller, Scot M. and Anna M. Michalak. "Constraining sector-specific CO2 and CH4 emissions in the US." *Atmospheric Chemistry and Physics*. Vol. 17, Iss. 6. March 2017 at 3975.

58 Alvarez, Ramón A. et al. "Assessment of methane emissions from the U.S. oil and gas supply chain." *Science*. Vol. 361, Iss. 6398. July 2018 at 186.

59 Howarth (2014) at 56.

60 Avnery, Shiri et al. "Increasing global agricultural production by reducing ozone damages via methane emission controls and ozone-resistant cultivar selection." *Global Change Biology*. Vol. 19, Iss. 4. April 2013 at 1285 to 1286.

61 Colborn, Theo et al. "Natural gas operations from a public health perspective." *Human and Ecological Risk Assessment*. Vol. 17, Iss. 5. September 2011 at 1042.

62 Shindell, D. T. et al. "The social cost of methane: Theory and applications." *Faraday Discussions*. Vol. 200. August 2017 at 31.

63 Colborn et al. (2011) at 1042; Wong, Chit Ming et al. "Cancer mortality risks from long-term exposure to ambient fine particle." *Cancer Epidemiology, Biomarkers & Prevention*. May 2016 at 839.

64 Salam, Muhammad T. et al. "Birth outcomes and prenatal exposure to ozone, carbon monoxide, and particulate matter: Results from the Children's Health Study." *Environmental Health Perspectives*. Vol. 113, No. 11. November 2005 at 1638 and 1643; Bravender, Robin. "Study links smog exposure to premature death." *New York Times*. March 12, 2009.

65 Brandt, Adam R. "Methane leaks from natural gas systems follow extreme distributions." *Environmental Science & Technology*. Vol. 50, Iss. 22. November 2016 at 12512.

66 *Ibid*.

67 Cowern, Nick and Robin Russell-Jones. Newcastle University and Help Rescue the Planet. "Global Warming Impact of a Switch From Coal to Gas-fired Electricity Generation in the UK: Evidence Towards a Better Solution." Submitted to the UK Climate Change Committee. February 2016 at 9 and 10.

68 *Ibid*; Alvarez et al. (2018) at 186.

69 Cowern and Russell-Jones (2016) at 10.

70 Caulton, Dana R. et al. "Toward a better understanding and quantification of methane emissions from shale gas development." *Proceedings of the National Academy of Sciences*. Vol. 111, No. 17. April 2014 at 6237.

71 *Ibid*.

72 *Ibid*. at 6240.

73 Alvarez et al. (2018) at 186; Zimmerle, Daniel J. et al. "Methane emissions from the natural gas transmission and storage system in the United States." *Environmental Science & Technology*. Vol. 49. July 21, 2015 at 9382.

74 Alvarez et al. (2018) at Supplementary Information 9 and 36.

75 Howarth, Robert W. "Is shale gas a major driver of recent increase in global atmospheric methane?" *Biogeosciences*. Vol. 16, Iss. 15 August 14, 2019 at 3038 to 3040.

76 *Ibid*. at 3040.

77 Zavala-Araiza, Daniel et al. "Reconciling divergent estimates of oil and gas methane emissions." *Proceedings of the National Academy of Sciences*. Vol. 112, No. 51. December 22, 2015 at 15598; Cowern and Russell-Jones (2016) at 10 to 12; Zimmerle et al. (2015) at 9382.

78 Zavala-Araiza et al. (2015) at 15598; Brandt, A.R. et al. "Methane leaks from North American natural gas systems." *Science*. Vol. 343. February 2014 at 734.

79 Karion, Anna et al. "Methane emissions estimate from airborne measurements over a western United States natural gas field." *Geophysical Research Letters*. Vol. 40. August 2013 at 4393; Lavoie, Tegan N. et al. "Aircraft-based measurements of point source methane emissions in the Barnett Shale basin." *Environmental Science & Technology*. Vol. 49. July 2015 at 7904 and 7909.

80 Omara, Mark et al. "Methane emissions from conventional and unconventional natural gas production sites in the Marcellus shale basin." *Environmental Science & Technology*. Vol. 50. January 2016 at 2099.

81 Howard, Touché et al. "Sensor transition failure in the high flow sampler: Implications for methane emission inventories of natural gas infrastructure." *Journal of the Air & Waste Management Association*. Vol. 65, Iss. 7. June 2015 at 2 to 4.

82 Alvarez, Ramón A. et al. "Possible malfunction in widely used methane sampler deserves attention but poses limited implications for supply chain emission estimates." *Elementa: Science of the Anthropocene*. Vol. 4. December 2016 at 1, 6 and 7.

83 Roscioli, J. R. et al. "Measurements of methane emissions from natural gas gathering facilities and processing plants: Measurement methods." *Atmospheric Measurement Techniques*. Vol. 8. May 2015 at 2018 and 2019; Brandt et al. (2014) at 734.

84 Forde, O. N. et al. "Identification, spatial extent and distribution of fugitive gas migration on the well pad scale." *Science of the Total Environment*. Vol. 652. February 2019 at 357; Darrah, Thomas H. et al. "Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales." *Proceedings of the National Academy of Sciences*. Vol. 111, No. 39. September 2014 at 14076.

85 Brandt et al. (2014) at 733 and 734.

86 Alvarez et al. (2018) at 186.

87 Vaidyanathan, Gayathri. "Leaky methane makes natural gas bad for global warming." *E&E News*. June 26, 2014.

88 Caulton (2014) at 6237, 6239 and 6240.

89 Forde et al. (2019) at 357.

90 Darrah et al. (2014) at 14076.

91 Omara et al. (2016) at 2103 and 2100.

92 *Ibid*. at 2100.

93 *Ibid*.

94 Caulton et al. (2014) at 6239 and 6240. Howarth, Robert W. "Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: Implications for policy." *Energy and Emission Control Technologies*. Vol. 3. October 2015 at 46.

95 Howarth (2015) at 46.

96 Yudhowijoyo (2018) at 309 and 318.

97 Ingraffea, Anthony R. et al. "Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000-2012." *Proceedings of the National Academy of Sciences*. Vol. 111, No. 30. July 2014 at 10955.

98 Subramanian, R. 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*. Vol. 49. February 2015 at 3253; Penn State Extension. [Fact sheet]. "Understanding Natural Gas Compressor Stations." 2015 at 1.

99 Zimmerle et al. (2015) at 9375 and 9378.

100 Meshkati, Najmedin. "The human factor in pipeline accidents." *New York Times*. October 28, 2011.

101 Soraghan, Mike. "Pipeline blast in Ohio linked to earth movement." *E&E News*. April 3, 2019.

102 CRS. "DOT's Federal Pipeline Safety Program: Background and Key Issues for Congress." R44201. March 29, 2019 at 1 to 3; Food & Water Watch analysis of data from Pipeline and Hazardous Materials Safety Administration (PHMSA). Gas Transmission & Gathering Annual Data — 2010 to present. Updated April 17, 2019. Available at https://www.phmsa.dot.gov/. Accessed May 2019.

103 Michanowicz, Drew R. 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*. Vol. 12. May 2017 at 1.

104 *Ibid*.

105 Abram, Susan. "LA doctor sounds alarm over effects of Aliso Canyon gas leak." *Los Angeles Daily News*. February 5, 2017.

106 Michanowicz et al. (2017) at 1 to 2.

107 Mitchell, Austin L. et al. "Measurements of methane emissions from natural gas gathering facilities and processing plants: Measurement results." *Environmental Science & Technology*. Vol. 49. February 10, 2015 at 3221.

108 *Ibid*. at 3224.

109 See Appendix. Marchese, Anthony J. et al. "Methane emissions from United States natural gas gathering and processing." *Environmental Science & Technology*. Vol. 49. August 2015; Mitchell et al. (2015); Vaughn, Timothy L. et al. "Comparing facility-level methane emission rate estimates at natural gas gathering and boosting stations." *Elementa: Science of the Anthropocene*. Vol. 5, Art. 71. November 2017.

110 Mitchell et al. (2015) at 3221 and 3226.

111 Marchese et al. (2015) at 10718; Mitchell et al. (2015) at 3219.

112 Grubert and Brandt (2019) at 764 and 765.

113 *Ibid*.

114 Alvarez et al. (2018) at 186.

115 Howarth (2014) at 56.

116 EIA (March 2019).

117 Zheng and Suh (2019) at 374.

118 Royer, Sarah-Jeanne et al. "Production of methane and ethylene from plastic in the environment." *PLoS ONE*. Vol. 13, No. 8. August 2018 at 1 to 2.

119 Steinberg, Daniel et al. National Renewable Energy Laboratory. "Electrification & Decarbonization: Exploring U.S. Energy Use and Greenhouse Gas Emissions in Scenarios with Widespread Electrification and Power Sector Decarbonization." NREL/TP-6A20-68214. July 2017 at vi, 12 and 13.

120 *See:* Appendix on page 13.

121 Ren, Xinrong et al. "Methane emissions from the Baltimore-Washington area based on airborne observations: Comparison to emissions inventories." *Journal of Geophysical Research: Atmospheres*. Vol. 123. August 2018 at 8878; Wennberg, Paul O. et al. "On the sources of methane to the Los Angeles atmosphere." *Environmental Science & Technology*. Vol. 46. August 2012 at 9282.

122 Jackson, Robert B. et al. "Natural gas pipeline leaks across Washington, DC." *Environmental Science & Technology*. Vol. 48. January 2014 at 2056.

123 Hendrick, Margaret F. et al. "Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments." *Environmental Pollution*. Vol. 213. March 2016 at 714.

124 Fischer, Marc L. et al. "An estimate of natural gas methane emissions from California homes." *Environmental Science & Technology*. Vol. 52. 2018 at 10211.

125 Office of Energy Policy and Systems Analysis (EPASA). U.S. Department of Energy (DOE). "Environment Baseline, Volume 1: Greenhouse Gas Emissions From the U.S. Power Sector." June 2016 at 4.

126 Steinberg et al. (2017) at 12 and 13.

127 *Ibid*. at vi.

128 Renaldi, R. et al. "An optimisation framework for thermal energy storage integration in a residential heat pump heating system." *Applied Energy*. Vol. 186. February 2016 at 7 and 10.

129 Reyna, Janet L. and Mikhail V. Chester. "Energy efficiency to reduce residential electricity and natural gas use under climate change." *Nature Communications*. Vol. 8. May 2017 at 2.

130 Lavoie, Tegan N. et al. "Assessing the methane emissions from natural gas-fired power plants and oil refineries." *Environmental Science & Technology*. Vol. 51. February 2017 at 3373 and 3379.

131 Chamberlain, Samuel D. et al. "Sourcing methane and carbon dioxide emissions from a small city: Influence of natural gas leakage and combustion." *Environmental Pollution*. Vol. 218. August 2016 at 109.

132 Feng, Kuishuang et al. "Drivers of the US CO2 emissions 1997-2013." *Nature Communications*. Vol. 6. July 2015 at 5; Broderick and Anderson (2012) at 21 and 22.

133 Knittel, Christopher et al. "Are we fracked? The impact of falling gas prices and the implications for coal-to-gas switching and carbon emissions." *Oxford Review of Economic Policy*. Vol. 32, No. 2. April 2016 at 253.

134 Feng et al. (2015) at 4 and 5.

135 Knittel et al. (2016) at 241.

136 Clark, Nigel N. et al. "Pump-to-wheels methane emissions from the heavy-duty transportation sector." *Environmental Science & Technology*. Vol. 51. December 2017 at 969.

137 Corkhill, Mike. "Two Sabine Pass LNG tanks removed from service." *LNG World Shipping*. February 13, 2018.

138 Bousso, Ron. "LNG growth to propel oil and gas industry's carbon emissions — WoodMac." *Reuters*. September 20, 2017; Boersma, Tim and Sarah M. Jordaan "Whatever happened to the Golden Age of natural gas?" *Energy Transit*. Vol. 1, No. 5. August 2017 at 1 and 2.

139 Clark et al. (2017) at 969.

140 *Ibid*. at 968 to 969.

141 *Ibid*. at 969 and 974. Calculation: g/kg = 1 ($CH_4$ leak)/1000 ($CH_4$ use). $CH_4$ Leak/$CH_4$ Use = (5.2/.391)/1000 converted to percent.

142 Shearer, Christine et al. "The effect of natural gas supply on US renewable energy and CO2 emissions." *Environmental Research Letters*. Vol. 9. September 2014 at 1 and 2.

143 Feng et al. (2015) at 1 and 4.

144 Boersma and Jordaan (2017) at 2.

145 Feng (2015) at 4.

146 Plumer, Brad. "U.S. carbon emissions surged in 2018 even as coal plants closed." *New York Times*. January 9, 2019.

147 Schär, Christoph. "The worst heat waves to come." *Nature Climate Change*. Vol. 6. February 2016 at 128 to 129.

148 Healey, Stephen and Mark Jaccard. "Abundant low-cost natural gas and deep GHG emissions reductions for the United States." *Energy Policy*. Vol. 98. November 2016 at 241.

149 EIA. "Annual Energy Outlook 2019." January 24, 2019 at 91.

150 Hilaire, Jerome et al. Potsdam Institute for Climate Impact Research. "Achieving the 2°C target will not be facilitated by relying on a global abundance of natural gas." 2015 at 9.

151 Howarth (2019) at 3040.

152 Food & Water Watch calculations from historical model. See Methodology for more details.

153 Food & Water Watch calculations from AEO model. See Methodology for more details.

154 Food & Water Watch calculations from AEO Replace Coal model. See Methodology for more details.

155 Diesendorf, Mark and Ben Elliston. "The feasibility of 100% renewable electricity systems: A response to critics." *Renewable and Sustainable Energy Reviews*. Vol. 93. October 2018 at 318, 320 to 323; Brown et al. (2018) at 840 and 841; Iaconangelo (2019); Schmidt et al. (2019) at 85 and 86; Lazard. "Lazard's Levelized Cost of Energy Analysis — Version 12.0." November 2018 at 7.

156 Lazard (2018) at 7.

157 EIA. "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018." March 2018 at 5 and 6.

158 Farquharson, DeVynne et al. "Beyond global warming potential: A comparative application of climate impact metrics for the life cycle assessment of coal and natural gas based electricity." *Journal of Industrial Ecology*. Vol. 21, No. 4. August 2017 at 2.

159 Food & Water Watch analysis of EIA data from Form EIA-860, 2018. Available at https://www.eia.gov/electricity/data/eia860/. Accessed September 2019.

160 EIA. "New electric generating capacity in 2019 will come from renewables and natural gas." January 10, 2019; EIA. "EIA uses two simplified metrics to show future power plants' relative economics." March 29, 2018.

161 Gimon, Eric et al. Energy Innovation. Vibrant Clean Energy. "The Coal Cost Crossover: Economic Viability of Existing Coal Compared to New Local Wind and Solar Resources." March 2019 at 1 and 2.

162 ICF International. Prepared for The Natural Gas Council. "Finding the Facts on Methane Emissions: A Guide to the Literature." April 2016 at 1-3.

163 Stockman, Lorne. Oil Change International. "Burning the Gas 'Bridge Fuel' Myth: Why Gas Is Not Clean, Cheap or Necessary." May 2019 at 14 and 15; Diesendorf and Elliston (2018) at 318, 320 to 323; Brown et al. (2018) at 840 and 841; Iaconangelo (2019); Schmidt et al. (2019) at 85 and 86.

164 MacDonald, Alexander E. et al. "Future cost-competitive electricity systems and their impact on US CO2 emissions." *Nature Climate Change*. Vol. 6. January 2016 at 1.

165 Schmidt et al. (2019) at 85 and 86; Crampes, Claude and Jean-Michel Trochet. "Economics of stationary electricity storage with various charge and discharge durations." *Journal of Energy Storage*. Vol. 24. August 2019 at 100746; Botha, C. D. and M.J. Kamper. "Capability study of dry gravity energy storage." *Journal of Energy Storage*. Vol. 23. June 2019 at 160, 161 and 173.

166 Diesendorf and Elliston (2018) at 318 and 320 to 323; Brown et al. (2018) at 840 and 841; Iaconangelo (2019); Schmidt et al. (2019) at 85 and 86.

167 EIA. "U.S. Battery Storage Market Trends." May 2018 at 1.

168 Storrow, Benjamin. "Utility goes big on energy storage. But will it cut CO2?" *E&E News*. February 26, 2019.

169 Trabish, Herman K. "California strives to nix its natural gas habit without letting the lights go out." *Utility Dive*. October 15, 2018.

170 Burger, Andrew. "Sunrun's ISO New England home solar-plus-storage forward capacity award establishes a distributed, renewable energy landmark." *Solar Magazine*. February 21, 2019.

171 Hilaire et al. (2015) at 1.

172 Lazard (2018) at 7; Bistline, John E. "Electric sector capacity planning under uncertainty: Climate policy and natural gas in the US." *Energy Economics*. Vol. 51. July 2015 at 236, 241 and 244.

173 Steckel, Jan Christoph and Michael Jakob. "The role of financing cost and de-risking strategies for clean energy investment." *International Economics*. Vol. 17. October 2018 at Abstract; Hilaire et al. (2015) at 1.

174 Shah, Imran Hussain et al. "How do oil prices, macroeconomic factors and policies affect the market for renewable energy?" *Applied Energy*. Vol. 215. April 2018 at 87; Magill, Bobby. "Fracking pushes concentrating solar power growth overseas." *Bloomberg*. April 20, 2018.

175 Holladay, J. Scott and Jacob LaRiviere. "The impact of cheap natural gas on marginal emissions from electricity generation and implications for energy policy." *Journal of Environmental Economics and Management*. Vol. 85. September 2017 at 205 and 226; Magill (2018).

176 EIA. "Almost all power plants that retired in the past decade were powered by fossil fuels." January 9, 2018; Seto, Karen C. et al. "Carbon lock-in: Types, causes, and policy implications." *Annual Review of Environment and Resources*. Vol. 41. September 2016 at 428.

177 EIA (January 9, 2018).

178 Diesendorf and Elliston (2018) at 318, 320 to 323; Brown et al. (2018) at 840 and 841; Iaconangelo (2019); Schmidt et al. (2019) at 85 and 86; Lazard (2018) at 7.

179 Pfeiffer, Alexander et al. "The '2°C capital stock' for electricity generation: Committed cumulative carbon emissions from the electricity generation sector and the transition to a green economy." *Applied Energy*. Vol. 179. October 2016 at 1406; Food & Water Watch analysis of EIA data from EIA-860 2016. The average age of U.S. gas-fired power plants is 24 years, but 643 (12 percent) began operating before 1968, 50 years ago, and the oldest gas plant went online in 1915.

180 Zhang et al. (2014) at 6.

181 Kis et al. (2018) at 156.

182 Seto et al. (2016) at 428.

183 *Ibid*.

184 *Ibid*. at 434.

185 Pfeiffer et al. (2016) at 1395 and 1396.

186 Healey and Jaccard (2016) at 253.

187 Unruh, Gregory C. and Javier Carrillo-Hermosilla. "Globalizing carbon lock-in." *Energy Policy*. Vol. 34. July 2006 at 1186; Brown et al. (2018) at 834 and 842.

## The Fracking Endgame

### Locked Into Plastics, Pollution and Climate Chaos

As a 10-year fracking boom has evolved, and as our planet hangs on the precipice of climate catastrophe, fossil fuel corporations and their elected enablers are seeking to turn up the pace of new fracking projects once again. Our latest research shows that their endgame is a world locked into plastics, pollution and climate chaos. In addition to the buildout of a growing pipeline network, we've discovered that more than 700 new facilities have been built or proposed to capitalize off of a glut of cheap fracked gas.

foodandwaterwatch.org/insight/fracking-endgame-locked-plastics-pollution-and-climate-chaos

## Building Climate Justice

### Investing in Energy Efficiency for a Fair and Just Transition

Buildings are the biggest energy hogs in the United States. They use nearly 40 percent of U.S. energy demand — more power than the entire industrial and transportation sectors use, respectively. Food & Water Watch has estimated the energy, financial and climate savings that a $500 billion investment in upgrading the energy efficiency of buildings could have over 15 years. This investment would reap dramatic economic benefits, create good jobs, reduce energy use and save money — all while reducing climate emissions.

foodandwaterwatch.org/insight/building-climate-justice-investing-energy-efficiency-fair-and-just-transition

## Cleanwashing

### How States Count Polluting Energy Sources as Renewable

Twenty-nine states and the District of Columbia have mandatory programs to encourage renewable electricity generation. These Renewable Portfolio Standard (RPS) programs set renewable electricity goals and determine which energy sources qualify as renewable. Food & Water Watch graded each of the state RPS programs based on a number of key metrics. Unfortunately, most RPS programs have not been robust enough to foster a rapid transition to clean, renewable energy. California received a grade of "D," among the worst in the nation.

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