The Truth about Tight Oil

Methane from Unconventional Oil Extraction Poses Significant Climate Risks

Union of Concerned Scientists

Since 2010, "tight oil"—oil extracted from hard-to-access deposits using horizontal drilling and hydraulic fracturing (fracking)—has dramatically changed the US oil industry, reversing decades of declining domestic oil production and reducing US oil imports (EIA 2015a).

In 2015, tight oil comprised more than half of US oil production, bringing total production close to 10 million barrels per day—a peak not seen since the 1970s (see Figure 1). But this sudden expansion has also led to an increase of global warming emissions due, in large part, to methane—an extremely potent heat-trapping gas that is found in larger concentrations in tight oil regions.

Although most of the emissions associated with the consumption of oil are a result of burning the finished fuel (for example, in a car or truck), the emissions from extracting, transporting, and refining oil add, on average, 35 percent to a fuel's life cycle emissions. These "upstream" emissions cannot be overlooked when seeking to mitigate emissions from oil use overall. Recent scientific evidence highlights major gaps in our knowledge of these large and rising sources of global warming pollution (Caulton et al. 2014). Since oil and gas producers are responsible for the largest percentage of past and present industrial sources of global warming pollution (Frumhoff, Heede, and Oreskes 2015; Heede 2014), they must be held accountable to measure, report, and reduce heat-trapping emissions from their operations (Martin 2016).

What Is Tight Oil?

Tight oil is found in shale deposits called "plays"; domestic shale plays are located across the United States (see Figure 2, p. 4) (EIA 2016). Tight oil is both ultralight (comprised of somewhat smaller molecules) and sweet (low in sulfur content), and can have characteristics similar to oil from conventional wells. However, the unconventional methods used to extract it present unique risks and environmental harms (Gordon 2012).

The most common method for extracting tight oil is hydraulic fracturing (fracking), which refers to two processes. The initial process entails drilling downward for up to 10,000 feet to reach sedimentary rock and then sideways or horizontally for a mile or more. Next, a mixture of water, sand, and chemicals is pumped at high pressure into the wells to create fractures in the rocks, which frees the oil and gas

Photo courtesy of Jones Township, Pennsylvania

Horizontal drilling and hydraulic fracturing (fracking) has spurred the rapid growth of the US oil industry in the last decade. However, the ability and economic incentives to capture and transport natural gas (a byproduct of oil extraction) have not kept up with the demand for oil. As a result, many operators burn the gas on site, which wastes resources and generates global warming pollution.

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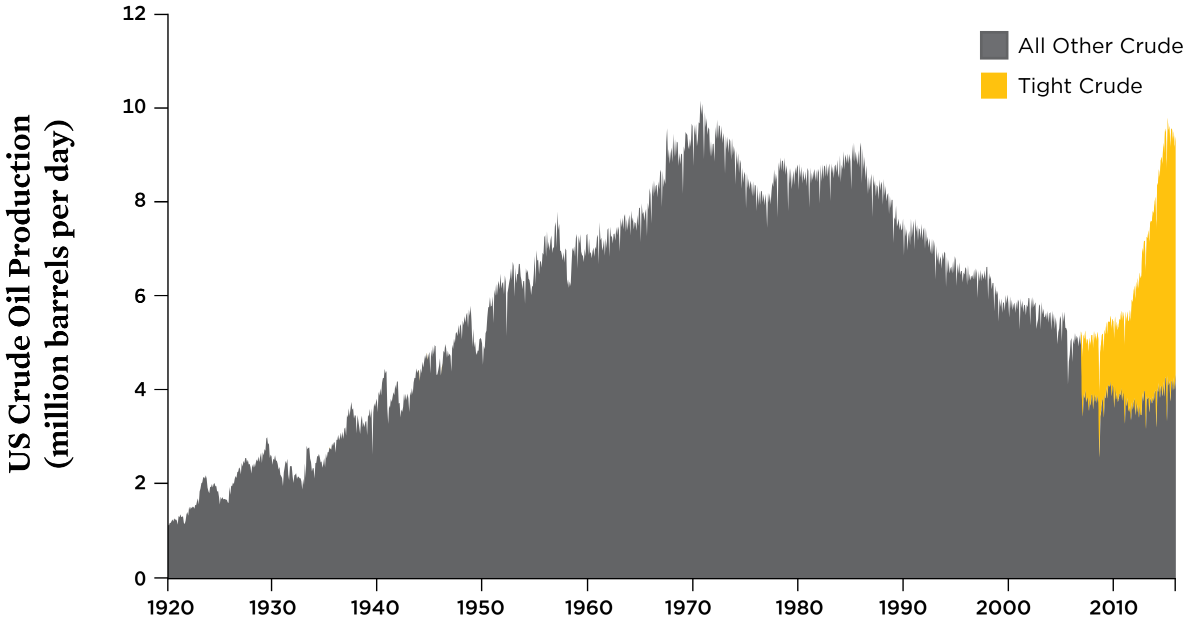
FIGURE 1. Tight Oil Responsible for Rise in US Oil Production



Domestic oil production declined substantially between 1970 and 2005, but has rebounded rapidly over the last decade as a result of tight oil extraction.

SOURCE: EIA 2016.

trapped in the tight layers of shale rock and allows them to flow through the drilled wells (see Figure 3, p. 5).

An important feature of tight oil is that both oil and natural gas are present in the same formations and are produced from the same wells. The relative fraction of oil to gas differs from region to region and even from site to site (see Figure 4, p. 6) and dictates the design, management, and utility of the resources extracted in these regions. For example, the Marcellus and Haynesville shale deposits produce primarily gas, while the Bakken and Permian shale deposits produce primarily liquid oil (EIA 2016). Beyond methane gas, tight oil extraction releases large quantities of “natural gas liquids,” light hydrocarbons that, instead of being processed into gasoline or diesel, can be used as precursors to synthesize more complex chemicals or as sources of liquefied petroleum gas.

Managing Methane from Fracking Operations

Many tight oil formations are located in geographic regions previously undeveloped by the fossil fuel industry, and the infrastructure to safely and efficiently get fuels from the wells to refineries has not kept up with surging demand. Pipelines are the preferred method for transporting most fossil fuels; trucks and trains can also be used for liquid fuels, but the low density of gas can make trucking gas over long distances uneconomic, which leads some producers to waste this resource (Khalilpour and Karimi 2012).

In rapidly expanding oil fields such as the Bakken, operators have prioritized getting liquid fuels to market quickly, even before arrangements can be made to responsibly manage associated natural gas production. As a result, operators may end up releasing natural gas directly into the atmosphere in a process called venting, or burning it at the well site in a process called flaring. These practices can occur even where natural gas pipeline infrastructure exists because early production phases generate much higher levels of natural gas than can be accommodated by capture equipment and pipelines, which are sized for later-stage production levels, or because these sites lack the additional equipment or logistics needed to manage the variations in gas production rates that are typical in tight oil wells (Mauter et al. 2013).

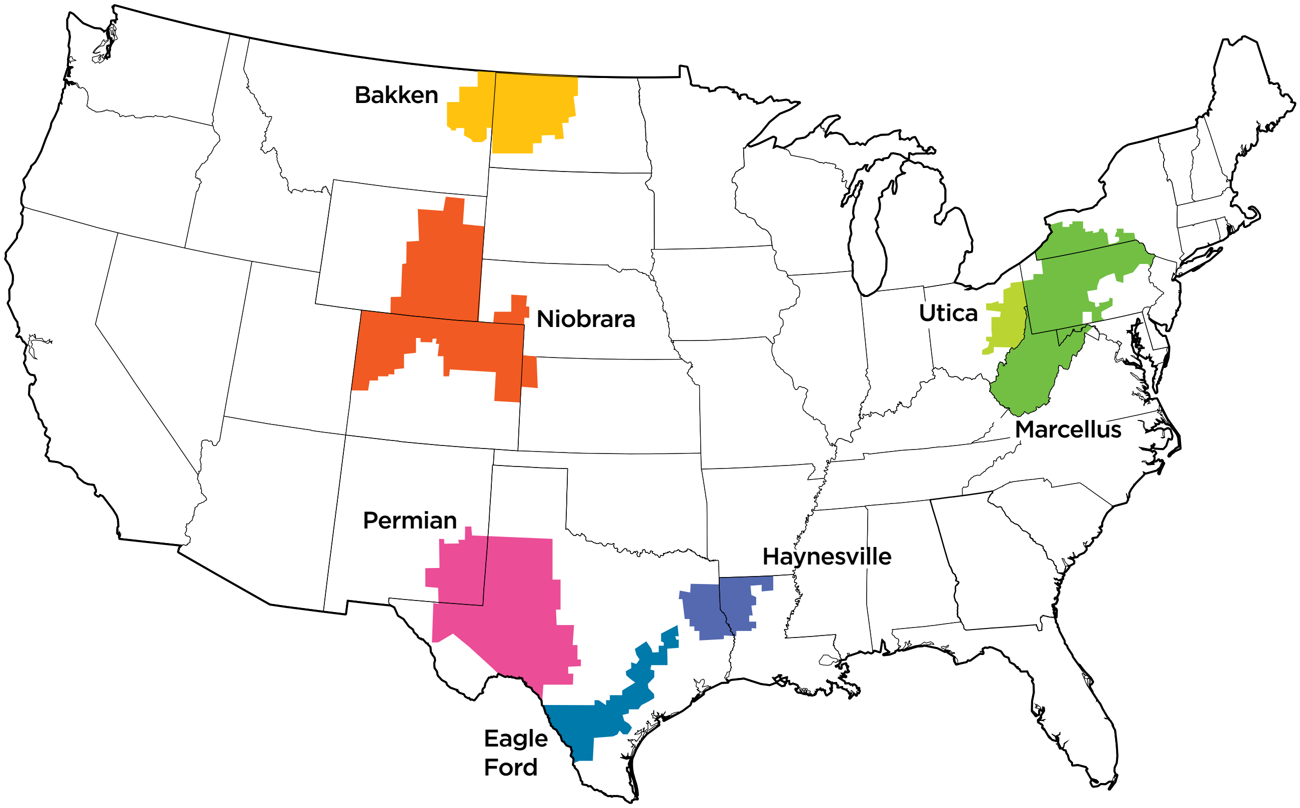
Venting and flaring has increased dramatically in the Bakken region in particular; while less than 5 percent of natural gas produced in this region was vented or flared between 2000 and 2005, tight oil drilling increased this total to more than 30 percent between 2011 and 2013. In addition to the increased *rate* of venting and flaring, the overall *quantity* of gas has substantially increased due to fracking; indeed, the total amount of methane vented and flared between 2011 and 2013 was more than 25 times greater than it was between 2000 and 2005 (EIA 2015b).

Low natural gas prices make the collection of natural gas a low priority for well operators, but this narrow perspective omits the high cost that the wasteful and unnecessary pollution generated by flaring imposes on people and the environment through climate change. While flaring methane is preferable to venting it, it results in far greater total heat-trapping emissions (relative to total usable fuel production) than would be produced if the gas were collected and used as fuel. The Environmental Protection Agency (EPA) estimates that methane emissions from the oil and gas sector in 2014 had the same heat-trapping power as more than 244 million metric tons of carbon dioxide (CO_2) (EPA 2016), equivalent to the emissions from more than 60 million cars (OTAQ 2014). (See Box 1 for more information on comparing methane and CO_2 emissions.) These emissions estimates, which are about 34 percent higher than previous EPA estimates, were released in April 2016 and are based on new scientific data. However, given the EPA's use of an outdated equivalence value for methane, its estimates likely still underrepresent the global warming impacts of emissions from the oil and gas sector.

Not All Flaring Is Created Equal

Routine flaring does not have the same climate impact across all tight oil operations. For example, a pair of reports by researchers at Argonne National Laboratory found vastly different emissions from oil production in the Bakken shale in North Dakota (Brandt et al. 2015) compared with the Eagle Ford shale in Texas (Ghandi et al. 2015). Both are domestic sites, produce oils that are light and gassy, and recover the oil using fracking techniques. Since these oils are so similar, one

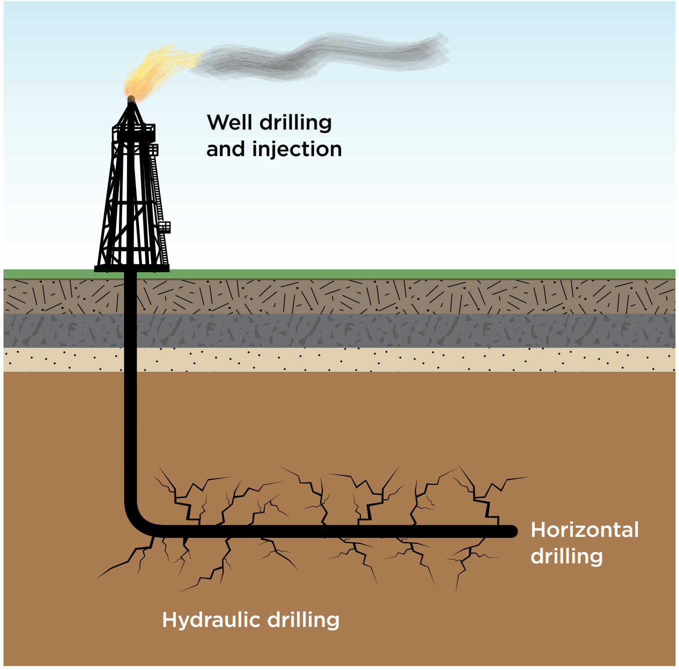
FIGURE 2. Active Shale Plays in the United States



Tight oil is extracted from active shale formations located throughout the central United States and parts of the Northeast. Many of these sites also generate significant amounts of natural gas, but most operators do not value it as highly as oil. As a result, natural gas is often managed inefficiently, leading to increased methane emissions.

SOURCE: EIA 2016.

FIGURE 3. Extracting Tight Oil Using Hydraulic Fracturing



As demand for oil has increased, producers have turned to extracting tight oil using horizontal drilling and hydraulic fracturing. A relatively new process, this involves using pressure to create cracks in porous rocks, and injecting water, sand, and chemicals to keep those cracks open and allow oil (and natural gas) to flow. In some cases, the gas is flared at the well, a wasteful and polluting practice that can be avoided by developing plans and deploying equipment to ensure the gas can be brought to market, used onsite for power generation, or reinjected into the well to assist in the oil-recovery process.

would expect their source sites' emissions to be similar as well. However, flaring emissions from the Bakken region were estimated to be nearly 2.5 times greater than similar emissions from the Eagle Ford region. Indeed, flaring in the Bakken alone wastes energy equivalent to that in 561 million gallons of gasoline each year, and generates nearly 4.4 million metric tons of CO_2 equivalent emissions (Brandt et al. 2015)—equaling the total annual emissions from more than 1 million gasoline-powered cars.

A deeper look at the data reveals that a relatively small number of tight oil operations are responsible for a disproportionately large fraction of the region's climate emissions. For example, operations in the Bakken with the least-efficient flares (those among the lowest fifth percentile for flaring efficiency) produced just over 11 percent of Bakken's oil between 2006 and 2013, yet their flares were responsible for nearly 40 percent of the region's methane emissions from flaring. Given methane's high potency, even marginal increases in its release can have disproportionately large climate impacts (see Figure 5, p. 7).

Flaring efficiency, as measured by the percentage of methane molecules converted to CO_2 during combustion, is a critical factor to consider when structuring regulations to mitigate methane emissions from tight oil operations. The Bakken's emissions estimates assumed an average flare efficiency of 99.62 percent between 2006 and 2013 (Brandt et al. 2015). But flare efficiency values are highly dependent on two parameters: flare tip gas exit velocity and wind speed. Efficiency values are calculated using estimated averages for each parameter and empirical relationships between them, but the underlying parameters change constantly, both independently and in relation to one another, under real-world conditions. Thus, a flare that blows out in the wind or burns in a sputtering manner will have much lower efficiency. Without more data, it is not possible to quantify how long "average" conditions persist or if the two parameters ever converge to adequately represent actual operating conditions during the time interval used to generate the estimate. This is troubling

BOX 1.

Methane's Climate Impact over Time

A number of gases are capable of trapping heat in Earth's atmosphere, and each one differs in both its heat-trapping potency and its residence time in the atmosphere. To enable an apples-to-apples comparison between gases, the global warming potential of each heat-trapping gas is expressed in terms of its carbon dioxide equivalent, or CO_2e—the amount of CO_2 that would result in an equivalent amount of warming.

Methane is a more potent heat-trapping gas than CO_2, but it stays in the atmosphere only a short time—about 12 years—before it is oxidized to produce CO_2. Therefore, the comparison between methane's global warming potential and that of CO_2 is time-dependent. Over a 20-year period, methane has 86 times the global warming potential of CO_2, but over the 100-year timeframe that is often used as the basis for laws and regulations, methane's global warming potential is 34 times CO_2 (Myhre et al. 2013)—still significant, but much lower. Since these differences are so large, the global warming potential timeframe used to estimate climate impacts from methane emissions has a significant impact on how the climate implications of certain practices are perceived. And these different perceptions can greatly influence policy considerations or estimated mitigation costs.

considering that a drop in flaring efficiency of just 1 percent more than triples the amount of methane escaping from flares.

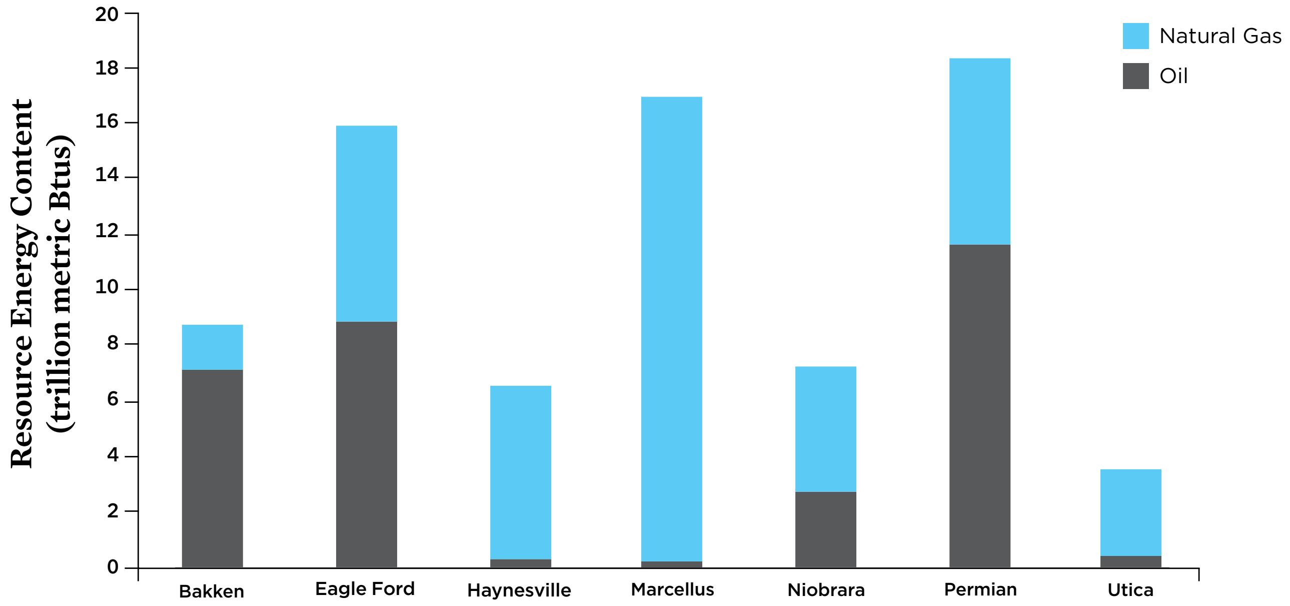
These data indicate that effective regulations around oil and gas extraction need to move beyond measures to simply mitigate methane release and instead include standards that minimize the wasteful practice of flaring by establishing and enforcing performance standards that limit overall emissions as a function of recoverable fuel energy. There are technologies already available to operators that would allow them to utilize more of the gas generated at tight oil facilities (Pederstad, Gallardo, and Saunier 2015), as described in the Recommendations section.

The Science of Measuring Methane Emissions

Our understanding of climate emissions from oil and gas operations, both domestically and throughout the world, rely on estimates that are obtained in one of two ways. The first approach, bottom-up (BU) accounting, is the most common and informs industry regulations by entities such as the EPA. The BU approach identifies emissions factors for each component of the oil and gas production process, including equipment and routine practices, and then sums those estimates to produce expected methane emissions inventories. The second approach is top-down (TD) accounting. This method requires measuring ambient atmospheric methane concentrations at regional (or larger) scales and then apportioning emissions to oil and gas operations by subtracting BU emissions estimates for agriculture, livestock, and other non-fossil-fuel sources.

Ideally, TD and BU results should match, but TD estimates of methane emissions from the oil and gas sector are regularly found to be greater than BU estimates; without greater convergence between these values there will be continued disagreement about the magnitude and impact of emissions from oil and gas operations. Since regulations have been based on inaccurate emissions estimates, their effectiveness in reality may differ substantially than what appears on paper. Another crucial drawback in current accounting methods is that systematic emissions sampling conducted at oil and gas sites can overlook certain large releases of methane that typically result from operating glitches and other circumstances (such as a jammed valve or routine flashing) (Zavala-Araiza et al. 2015). Since these events only occur at a few sites at any one time, last

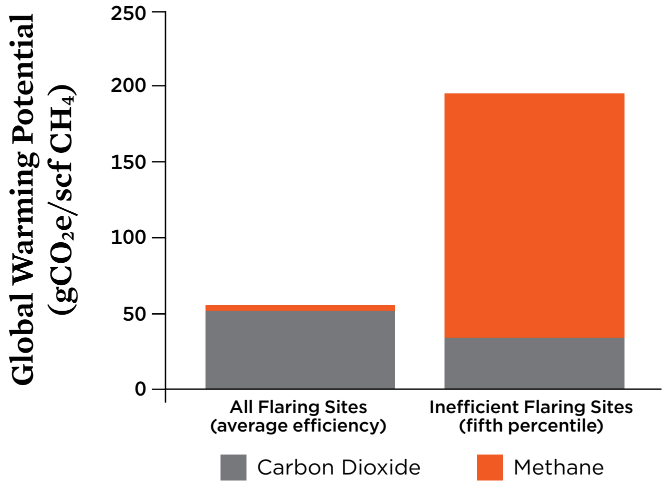
FIGURE 4. Oil and Gas Output at Tight Oil Operations



Not all tight oil operations are created equal. Some wells produce less natural gas than oil (and vice versa); operations that produce less gas than oil may undervalue the gas and inefficiently manage it. Knowing the ratio of gas to oil at these sites can help to inform design and operating decisions to help ensure that gas is more effectively managed, which will reduce methane emissions.

SOURCE: EIA 2016.

FIGURE 5. Inefficient Flaring Drives Up Methane Emissions



If methane is flared at tight oil operations, efficiency is key to keeping methane emissions in check. Inefficient flares generate nearly four times more heat-trapping emissions, and most of it is a result of methane escaping to the atmosphere unburned.

Note: Emissions for efficient flaring are based on the average methane destruction efficiency for all flares at tight oil operations; emissions for inefficient flaring are based on the average efficiency of the lowest-performing (fifth percentile) flares. Emissions are based on the average methane destruction efficiencies for flares at tight oil operations in the Bakken region. g CO$_2$e/scf CH$_4$ = grams of carbon dioxide-equivalent emissions per standard cubic foot of methane flared.

SOURCE: BRANDT ET AL. 2015.

a short period of time, and move from site to site over time, they can substantially increase the overall emissions from a region without being accounted for in typical inventories.

A recent study (Zavala-Araiza et al. 2015) developed new approaches to both TD and BU accounting that show a high level of convergence between the two results—primarily by quantifying the impact of overlooked emissions—and also show promise for more robust and accurate emissions assessment. Researchers in the study sought out high emitters by driving around the Barnett Shale region of Texas looking for methane plumes, which are detectable over long distances. Using field data, researchers then calculated methane concentrations and emissions factors for all similar operations. This research approach enabled them to measure higher levels of methane resulting from avoidable conditions and random malfunctions, events often overlooked in systematic BU accounting. The results show that methane emissions are between 1.9 and 5.5 times higher than previous BU methane inventories from the Barnett Shale region.

Recommendations for Mitigating Methane Emissions from Tight Oil Operations

Compared with conventional oil drilling, tight oil extraction requires different infrastructure and practices to manage emissions and avoid unnecessary global warming pollution. In 2014 the EPA completed a series of white papers characterizing the major sources of emissions from oil and gas operations and describing some mitigation strategies that could be implemented. These strategies fall into one of three basic categories: equipment changes and upgrades (OAQPS 2014a; OAQPS 2014b), changes in operational practices (OAQPS 2014c; OAQPS 2014d), and direct inspection and maintenance improvements (OAQPS 2014e). There are readily available solutions within each of these categories to reduce methane emissions (ICF 2014; Camuzeaux 2011); combined with improved data collection, these solutions would help ensure that methane is recognized as a dangerous pollutant if poorly managed, but a valuable energy resource when it is safely delivered to market.

MITIGATING METHANE AT THE WELL

The most important equipment changes and upgrades relate to pneumatic devices and compressors. Pneumatic devices are powered by pressurized gas (often methane) and compressor components can wear out quickly, making them highly prone to leaks; these components are often the largest sources of fugitive (leaked) methane from drilling operations. The EPA recommends that oil and gas operators:

- Switch from natural gas to compressed air within pneumatic systems
- Replace high-bleed pneumatic devices with low-bleed models to minimize leaks (regardless of which pressurized gas is used)

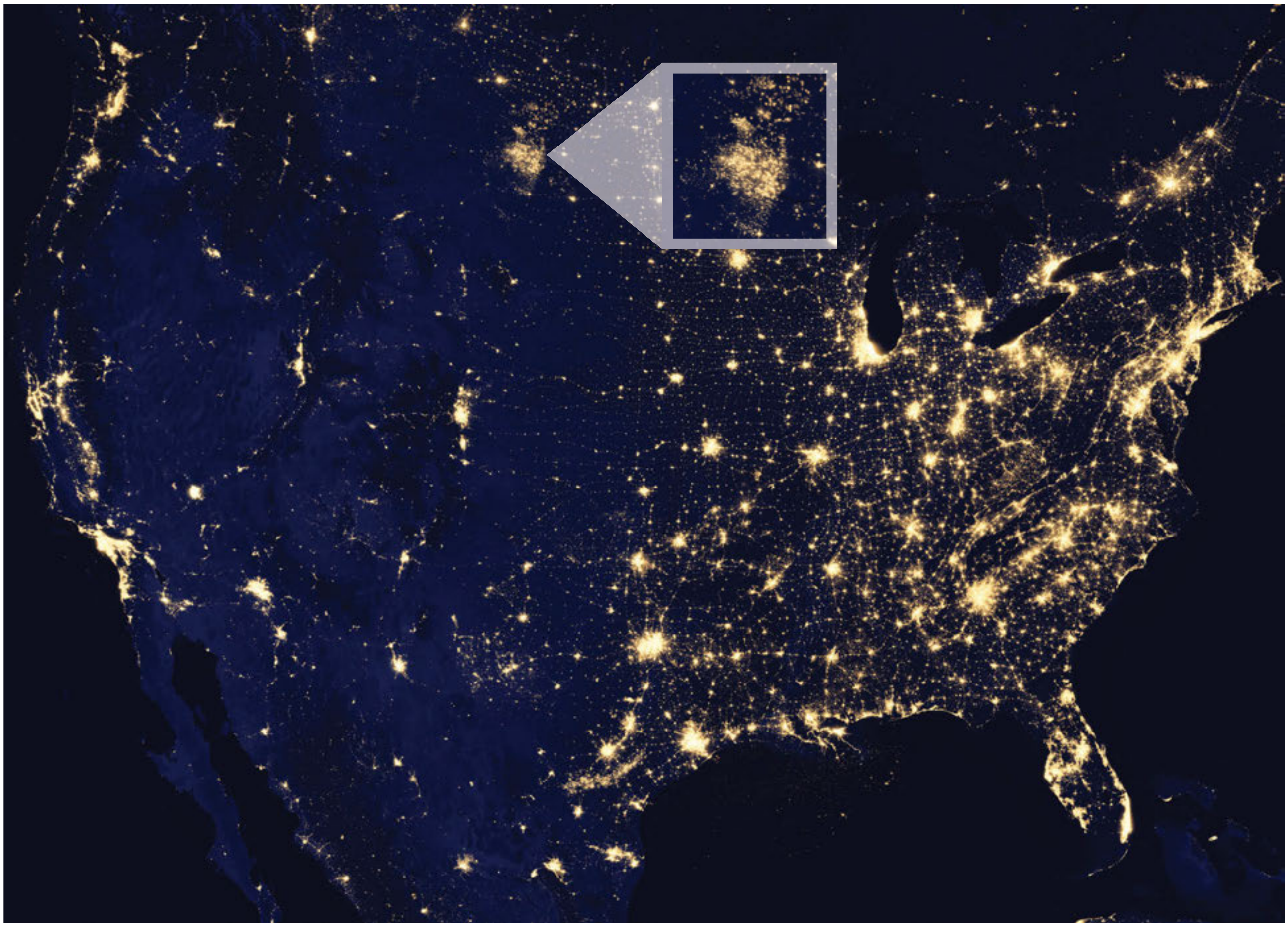
> ***Large releases of methane that typically result from operating glitches and other circumstances can substantially increase the overall emissions from a region without being accounted for in typical inventories.***

BOX 2.

“Eyes in the Sky” Critical to Monitoring Methane Emissions

Understanding the overall extent of flaring, and corresponding climate emissions, at tight oil operations is difficult given the lack of reliable information from operators and the differing data collection and reporting requirements of regional regulations. However, satellite observations are helping to close these data gaps. For example, infrared imaging used by satellites jointly operated by the National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) has proven effective at surveying flaring sites to quantify the amount of gas being burned (Elvidge et al. 2016). While the technology cannot quantify methane emissions, it offers a good starting point for identifying areas and operations throughout the world with the greatest amount of flaring and greatest potential for mitigation. Another recent study has shown that it is possible to track and even spatially resolve methane emissions using satellites (Turner et al. 2016).

The ability to have reliable third-party verification of global methane emissions would serve to buttress greater on-the-ground data acquisition and reporting requirements. Ultimately, the EPA, working with NOAA/NASA satellites, could establish continuous real-time data monitoring to strengthen TD emissions estimates and compliance audits, which could offer policy makers the information needed to tackle methane emissions across the board.



NASA

This NASA satellite image from 2012 shows light pollution across the country. Despite having very few residents, the Bakken region (highlighted in the box) is lit up similarly to heavily populated metropolitan areas due to oil and gas industry activity, including flaring.

- Perform regular maintenance of compressors
- Establish regular intervals at which to replace compressors and compressor components prone to degradation (OAQPS 2014a; OAQPS 2014b)

Certain drilling processes such as well completions (preparing the well for production) and liquids unloading (removing accumulated liquids that impede the flow of gas from a well to the surface) are also substantial and well-documented sources of methane. Specific mitigation strategies for these operational practices would include:

- Capturing gas flowback—instead of flaring it—and using it for onsite power generation, reinjecting it into wells (where it can maintain pressure and assist in the oil-recovery process), and/or selling it as fuel for power plants or other industrial processes
- Implementing one or more lift options to remove accumulated liquids instead of opening the well to the atmosphere during liquids unloading events (OAQPS 2014c; OAQPS 2014d)

Leaks are also a major source of methane emissions, and there simply is no way to deal with them without the ability to detect them. Thus, leak mitigation would include:

- Frequent—or, in some cases, continuous—methane detection
- Mandated leak limits and strict requirements for leak repair (OAQPS 2014e)

Finally, since tight oil recovered via fracking has become the dominant domestic oil resource (Prince 2015), it is critical for producers and regulators to take full responsibility for implementing the changes described above. Planning, design, and development of new wells should proceed in a manner that gives appropriate consideration for methane management and utilization.

IMPROVING DATA COLLECTION AND DISCLOSURE

As noted above, until emissions estimates and emissions measurements align, progress toward meeting emissions reductions cannot be adequately monitored. This starts by requiring transparent, robust data reporting by the oil industry. For example, drill operators using flares that are substantially affected by wind speed should report flaring efficiency in real time as a function of wind speed and flare tip gas exit velocity. Additionally, critical events that lead to fugitive or vented emissions should be reported, detailing the type of event and its duration. These include equipment malfunctions and blown-out flares.

Refining-related emissions, while less than operating-related emissions, are still an important part of the upstream emissions profile for fuels. Better estimates of refining-related emissions can be made by requiring producers to obtain and disclose chemical assay data (i.e., analytical data on composition and characteristics) on all oils extracted from tight oil operations (Gordon et al. 2015). These oil assays would have the dual benefit of providing additional chemical safety and risk information to first responders and oil transport operators as well as providing input data for modelers seeking to quantify the life cycle emissions from the finished fuels.

BOX 3.

Economics and the Environment Cannot Be Mutually Exclusive

For decades, concerns about fuel scarcity have been the driving force behind policies and regulations for the US oil and gas sector. Today the climate implications of policy decisions need to be given equal consideration. For example, late in 2015 Congress and President Obama lifted the ban on US oil exports, a law established more than 40 years ago in the wake of the 1973 Middle East oil embargo. Lifting the ban expands the potential market for domestic oil, making it more profitable to produce for both domestic consumption and export. As a result, this move may spur further expansion of the tight oil industry.

While this decision was made primarily for economic reasons (Weber 2015), without an adequate understanding of present emissions and emissions sources, rapid domestic drilling expansion could significantly increase heat-trapping emissions and other environmental harms. It is therefore critical to not only better understand and more accurately measure methane emissions, but also use this information to establish emissions monitoring and mitigation regulations for the industry.

POLICY EFFORTS TO REDUCE METHANE EMISSIONS

At the 2015 United Nations climate conference in Paris, nearly 200 countries agreed to a historic climate pact, committing to the goal of holding the increase in global average temperature to less than 2°C above preindustrial levels, and to pursue efforts to limit the temperature increase to 1.5°C. New policies affecting the oil and gas sector must both set a progressive tone

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Horizontal drilling and hydraulic fracturing (fracking) has spurred the rapid growth of the US oil industry in the last decade. However, the ability and economic incentives to capture and transport natural gas (a byproduct of oil extraction) have not kept up with the surging demand for oil. As a result, many operators burn the gas on site, which wastes resources and generates global warming pollution.

for regulating this industry in the context of the climate agreements and ensure that emissions from fossil fuel sources decrease in order to meet the goals outlined by the agreements.

Two such policies were proposed in late 2015 and early 2016 by the EPA and Bureau of Land Management (BLM). Both agencies are seeking to drive down methane emissions and reduce waste from the oil and gas sector by establishing necessary inspection, repair, and maintenance requirements (BLM 2016; EPA 2015). Although the EPA and BLM each derive their authority to regulate emissions differently—the EPA can regulate heat-trapping emissions under the Clean Air Act, and the BLM manages natural resources on federal lands—the proposed rules both seek to drive down methane emissions and reduce waste. The BLM rule is driven primarily by reducing waste, and goes somewhat further in setting standards for when and how flaring can be used.

Both rules are an important first step to mitigate excessive emissions from the oil and gas sector, but each could go further to establish and enforce strict performance standards for flaring efficiency while setting targets for phasing out flaring altogether. It is critical that the science underlying these rules is as accurate and up to date as possible, and that climate pollution reduction requirements are strengthened.

For more than a century, concerns about energy scarcity have been the primary focus of energy policy. But today energy policy and climate stability must be addressed together. The strategies outlined above can be deployed and implemented *today* to substantially reduce both climate emissions and wasted energy. Greater transparency from simple data collection and disclosure requirements would allow much better emissions estimates to be made going forward; this would better inform new polices and drive technology innovations that ensure our continued need for reliable energy is met in a way that minimizes environmental harm.

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The Truth about Tight Oil

Methane from Unconventional Oil Extraction Poses Significant Climate Risks

> ***Methane is a dangerous pollutant if poorly managed, but US oil operators can improve their practices to transform this heat-trapping gas into a valuable energy resource.***

The domestic oil boom facilitated by hydraulic fracturing, or fracking, has led to a significant increase in methane emissions. Methane, an extremely potent heat-trapping gas, is being released as a result of leaks and inefficiencies at domestic oil operations, and recent evidence suggests that these emissions are much greater than previously thought. Today's policies and regulatory frameworks were established in an age of traditional oil well drilling and do not adequately prioritize climate change impacts.

This approach must be updated to effectively address the changing nature of unconventional oil production and rein in methane emissions. There are solutions available that would achieve these goals; combined with greater transparency from simple data collection and disclosure requirements, these solutions would better inform new polices and drive technology innovations that ensure our continued need for reliable energy is met in a way that minimizes environmental harm.

Union of Concerned Scientists

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The Union of Concerned Scientists puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with citizens across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

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