WHITE PAPER

# Methane Emissions from the Oil and Gas Industry: "Making Sense of the Noise"

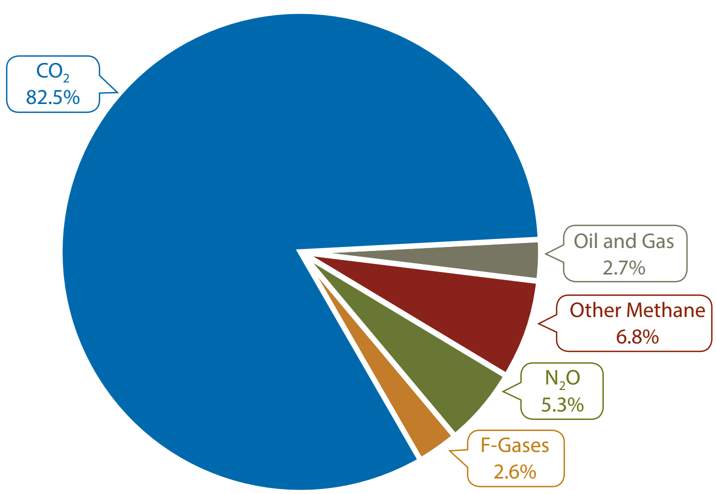
*By Joel Bluestein, Hemant Mallya, Louis Yandoli, Michael Polchert, and Natalie Amarin*

**The Bottom Line**

1. Methane is an important greenhouse gas (GHG) with a potentially low cost of reduction relative to $CO_2$.
2. New data are becoming available from various sources. However, they use different methodologies and represent diverse samples of the numerous oil and gas facilities.
3. This information is changing our understanding of sources, quantities, and patterns of methane emissions from the oil and gas sectors.
4. Our new understanding will affect estimates of emissions and future approach to mitigation and regulation of these sources. "Making sense of the noise" in judiciously applying all the new information is critical to successful mitigation and regulation.
5. ICF is making sense of this noise for clients on all sides of the debate and helping to reach consensus on what can be done.

Methane ($CH_4$) is a primary component of natural gas and the second largest source of U.S. greenhouse gas emissions. Figure 1 below shows the breakdown of GHGs, including methane, across the U.S. economy. Methane emissions make up approximately 9 percent of total U.S. GHG emissions. The agricultural sector is the largest source of methane emissions, followed by oil and gas systems. The focus has increased on reducing methane emissions from the oil and natural gas industry from fugitives (leaks), venting, and incomplete combustion because the value of methane as a natural gas can make recovery of reduced emissions a very cost-effective emission reduction measure.

**Figure 1: Total U.S. GHG Emission 2013 in Million Metric Tonnes of $CO_2e$**




Oil and Gas industry emits roughly 29 percent of total U.S. methane emissions

Source: 2013 Inventory of U.S. Greenhouse Gas Emissions and Sinks, 2015

## Describing Methane Emissions

All methane emissions are sometimes described as fugitives or leaks. However they are more accurately classified as:

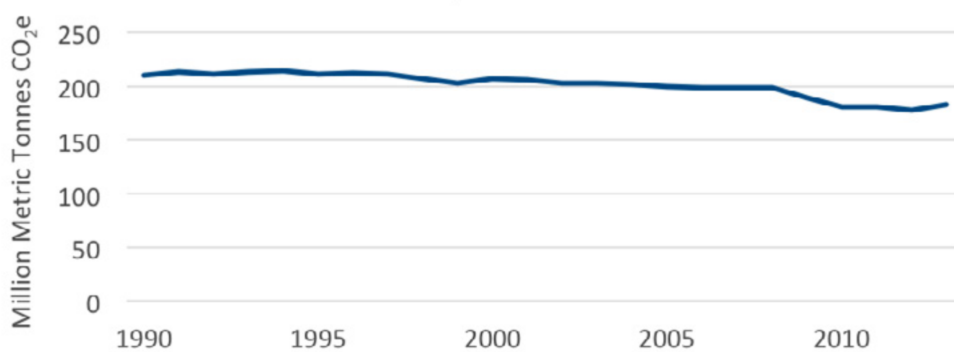
- Fugitive emissions—unintentional emissions due to randomly occurring leaks in flanges, valves, or other equipment because of operational wear and tear.
- Vented emissions—emissions resulting from equipment design or operating practices such as pneumatic devices or blowdowns.
- Incomplete combustion—uncombusted methane in the exhaust of equipment such as compressor engines and turbines.

Each one has different characteristics and must be addressed differently.

## Recent Methane Emissions Trends

The figures below present recent methane emissions trends from the oil and gas industries. Figure 2 shows methane emissions from petroleum and natural gas systems based on the U.S. Environmental Protection Agency (EPA) Inventory 2015 Release for 2013 emissions.[1] Methane emissions have decreased from 1990 due to equipment turnover, voluntary industry actions, and in the past few years, regulations limiting methane emissions.

**Figure 2: Methane Emissions from Petroleum and Natural Gas Systems**




Source: 2013 Inventory of U.S. Greenhouse Gas Emissions and Sinks, 2015

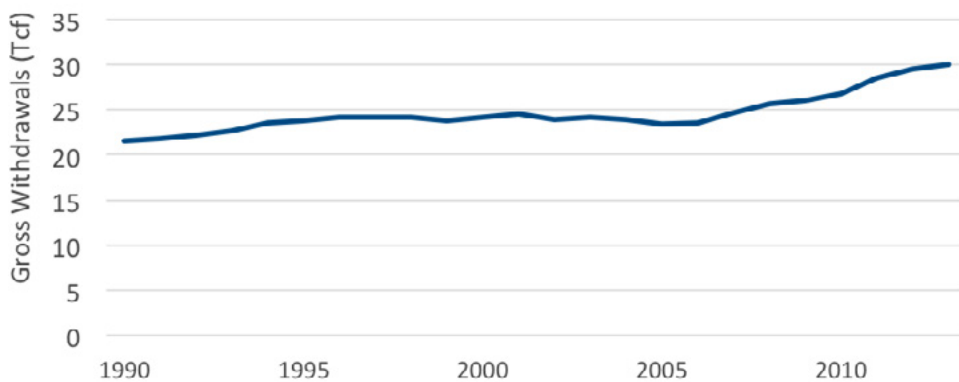
Figure 3 displays gross natural gas gross withdrawal from oil and gas wells based on U.S. Energy Information Administration (EIA) data.[2] Gross withdrawals are defined by EIA as "full well-stream volumes, including all natural gas plant liquids and all nonhydrocarbon gases but excluding lease condensate."[3] Natural gas gross withdrawals have increased significantly over the past years as emissions have declined. Figure 4 combines the two trends to show the ratio of emissions to gross withdrawals and exhibits a declining trend as emissions decrease and withdrawals increase.

[1] Inventory of U.S. Greenhouse Gas Emissions and Sinks, available at http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf.

[2] EIA Natural Gas Withdrawals and Production, available online at http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_nus_m.htm.

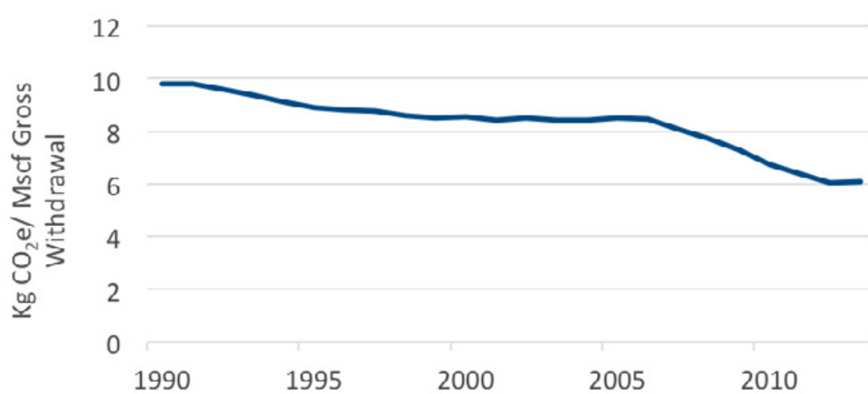
[3] Definition available at http://www.eia.gov/dnav/ng/TblDefs/ng_prod_sum_tbldef2.asp.

**Figure 3: Gross Natural Gas Withdrawal from Oil and Gas Wells**




Source: EIA Natural Gas Gross Withdrawals and Production

**Figure 4: Methane Emissions per Mcf Produced**




Source: 2013 Inventory of U.S. Greenhouse Gas Emissions and Sinks, 2015, and EIA Natural Gas Withdrawals and Production

### How are $CH_4$ emissions measured?

**Volumetric basis:** Expresses gaseous emissions in units of cubic feet ($ft^3$) or meters ($m^3$).

- 2013 U.S. inventory value—379 billion cubic feet (Bcf) of methane emitted from oil and gas operations.

**Mass basis:** Expresses the mass of methane emission emissions in units such as million metric tonnes (MMT) or gigagrams (Gg).

- 2013 U.S. inventory value—7.3 million metric tonnes of methane emitted from oil and gas operations.

**$CO_2e$ basis:** Expresses the mass of GWP- weighted methane emission in units such as million metric tons of $CO_2e$ (MMT)

- $CO_2e$ has a GWP value of 1
- 2013 U.S. Inventory value, 182.5 $CO_2e$ emitted from oil and gas operations

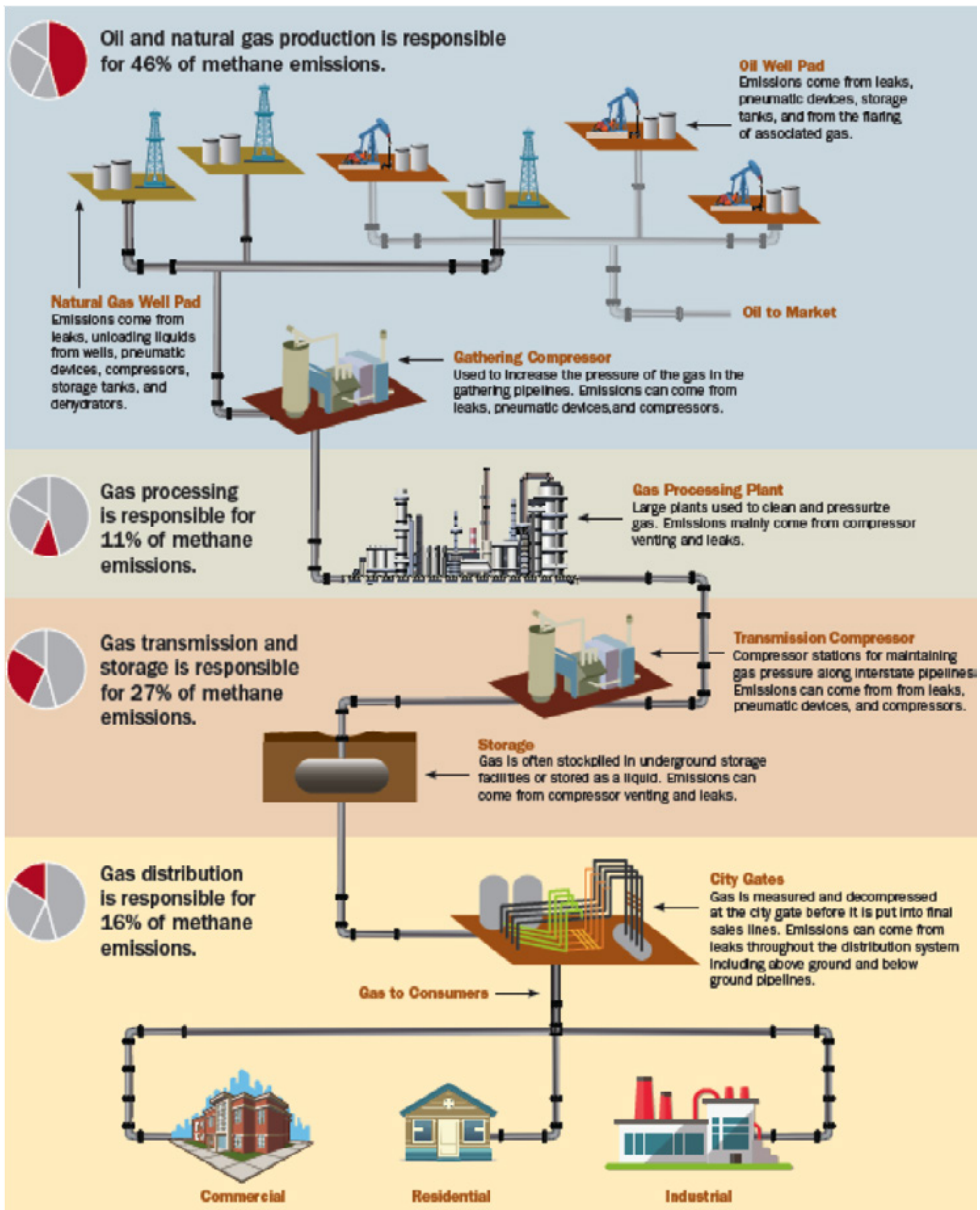
**Percent of production:** Expresses methane emissions as a percentage of natural gas produced annually in the U.S. – sometimes referred to as a "leakage rate".

- 2013 U.S. Inventory value, 1.3 percent emitted from oil and gas operations

## A Look at the Oil and Natural Gas Supply Chain

Figure 5 below identifies the major components and major sources of emissions across the oil and gas supply chain.[4] Production is the largest source, with 46 percent of total emissions. Transmission is the second largest source.

**Figure 5: Oil and Natural Gas Supply Chain[5]**




[4] EPA, available at http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf.

[5] Clean Air Task Force, "Waste Not: Common Sense Ways to Reduce Methane Pollution from the Oil and Natural Gas Industry," 2014.

## Global Warming Potential, Methane, and Climate Change

Certain gases are have a greater heat trapping effect in the earth's atmosphere than others. Global warming potential (GWP) characterizes different molecules and their climate change-inducing effects. Because different gases also have different lifetimes in the atmosphere, the GWP is calculated over 20 years and over 100 years. GWP values describe the warming effect of a gas relative to $CO_2$ (which has a GWP of 1). The International Panel on Climate Change (IPCC) is the authoritative source on GWP values for greenhouse gas and has published five assessment reports[6] to date on the topic of the scientific and technical aspects of climate change, the most recent AR-5 in 2014, preceded by the AR-4 in 2007. Table 1 shows the 100-year and 20-year GWP values for methane. For example, a GWP value of 25 for methane means 1 pound of methane emitted to the atmosphere is equivalent to 25 pounds of $CO_2$.

**Table 1: GWP Values**

| | 100-Year | 20-Year |
|---|---|---|
| AR-4 | 25 | 72 |
| AR-5 | 36 | 86 |

Source: IPCC Fourth and Fifth Assessment Reports

The selection of GWP values clearly has a significant effect on estimates of greenhouse gas emissions from oil and gas operations. National emissions estimates reported to the United Nations Framework Convention on Climate Change (UNFCCC), including the U.S. Inventory of Greenhouse Gas Emissions, use the AR-4, 100-year value of 25. The U.S. EPA Greenhouse Gas Reporting Rule (GHGRP—see below) uses the same value.

## Methane Emissions Estimation and Reporting

There are two primary sources of U.S. national information on GHG emissions in general and methane in particular—the U.S. EPA Inventory of Greenhouse Gas Emissions and Sinks and GHGRP.

### *U.S. Inventory*

U.S. GHG emissions from human activities (anthropogenic emissions) are compiled annually in the U.S. EPA Inventory of Greenhouse Gas Emissions and Sinks and submitted to the INFCCC according to IPCC guidelines.[7] The latest Inventory report was released in April 2015 and documents emissions from 1990–2013. (A two year lag exists in publishing emission estimates for the current year.) The U.S. inventory is the only economy-wide estimate of U.S. GHG emissions and also is the most complete compilation of methane emissions in the oil and gas segments across regions and segment levels (production, processing, transmission, and distribution). Many of the equipment and process emissions estimates in the Inventory are based on 1996 Gas Research Institute (GRI) measurement studies coordinated by EPA.[8] EPA is gradually updating these data sources as more recent information becomes available. As noted above, the most recent Inventory estimates methane emissions from the oil and gas industries to be 182.5 MMT $CO_2e$ or about 1.3 percent of production.

[6] Available online at https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml.

[7] Background on the UNFCC inventory submittal reporting requirements is available at http://unfccc.int/national_reports/items/1408.php.

[8] EPA and GRI. The primary measurement studies include Volumes 1–12 of from the title "Methane Emissions from the Natural Gas Industry," available at: http://www3.epa.gov/gasstar/tools/related.html.

### *Greenhouse Gas Reporting Program Subpart W*

GHGRP is mandated by the U.S. Congress and described in the U.S. Code of Federal Regulations Title 40, Part 98, established by EPA in 2009. GHGRP requires operators across various industrial sectors to report GHG emissions from specific emission sources. Reporting requirements for methane emission sources in the oil and gas sectors are described in Subpart W of the federal regulations. The reporting requirements apply to facilities that emit 25,000 metric tons or greater of GHG emissions (expressed in $CO_2e$) across one of the eight oil and gas segments: onshore production, offshore production, natural gas processing, natural gas transmission, natural gas storage, natural gas distribution, liquefied natural gas (LNG) import and export, and LNG storage. Specific emission sources within these segments include common field, plant equipment, and infrastructure such as storage tanks, distribution and transmission pipelines, pneumatic devices, dehydrators, combustion equipment and flares, and centrifugal and reciprocating compressors as well as production processes such as hydraulic fracturing and well completions, unrepaired equipment leaks, and gas well liquids unloading. Subpart W data are published by EPA yearly and are a resource for GHG emissions analysis. Emissions from natural gas gathering and boosting segment—the operations downstream of the wellhead involved in collecting produced natural gas and oil and sending it to other operations—are not subject to the original GHGRP but will be included under amendments proposed in 2014.

### *Methane Emission Studies*

Beyond the federal emission data collection and reporting, a large number of recent methane emission studies reflect the growing interest in this topic. These studies can be classified into three main categories:

Bottom Up—These studies are based on on-site measurements of emissions from individual components. They are the most detailed but also the most time-consuming and expensive and must be extrapolated to the national level for comparison with high-level estimates. Several organizations, including the Gas Technology Institute,[9] have done recent bottom-up studies of different sectors. The Environmental Defense Fund (EDF) has organized a major effort of 16 studies[10] (top-down and bottom-up) of all of the segments of the oil and gas industry in coordination with companies and various academic institutions. The studies have provided a wealth of new direct measurement information. The major findings include:

- The importance of "super emitters"—the result that a small number of facilities or components account for a very larger share of emissions, possibly because of skewed distribution of leaking or malfunctioning equipment or a predominance of very large facilities.
- Revision of some old emission—At the same time, the studies show that the emission rates of the many of the emissions sources can be lower than indicated from older studies. This result may be due to a combination of equipment turnover, industry voluntary reduction programs, and recent regulation of methane emissions. For example, the Washington State University study[11] showed the emissions from gas distribution company systems are much lower than the 1990s GRI studies, largely due to equipment replacement.

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[9] Gas Technology Institute, "Improving Methane Emissions Estimates for Natural Gas Distribution Companies, Phase II, PE Pipes," 2013, available at https://www.otd-co.org/reports/Documents/710c_OTD-14-0001-Improving-Methane-Emission-Estimates-NG-Distribution-Companies-PE-Pipes-FinalReport.pdf.

[10] EDF, "Methane Research: The 16 Study Series," available at https://www.edf.org/sites/default/files/methane_studies_fact_sheet.pdf.

[11] Lamb et al., "Direct Measurements Show Decreasing Methane Emissions from Natural Gas Distribution Systems in the United States," 2015, available at http://pubs.acs.org/doi/ipdf/10.1021/es505116p.

Much work still needs to be done to interpret the results and extrapolate them to the national level. Many follow-up questions to be addressed, but these studies have certainly improved the state of knowledge of equipment operations.

Top-Down—One approach of these studies is to measure the ambient concentration of methane in the atmosphere by taking samples from airplanes or tall towers. Another approach is to monitor the methane plume from facilities using tracer gas. These approaches tell us more about the actual level of methane emissions overall but require disaggregating the emissions contributions from different sources (e.g., oil and gas compared with agriculture and landfill) and may require complex modeling of airflows. Also, even if all the emissions are from an oil and gas facility, further allocation of emissions to individual sources within the facility is a challenging task. Several top-down studies indicate methane emission rates to be higher than indicated by the EPA inventory,[12,13] although the authors did not believe that they were representative of all oil and gas operations nationally. Another study found much lower estimated emission rates, particularly in the Marcellus shale region.[14] A metastudy of top-down studies[15] estimated that overall methane emissions could be 1.5 times higher than indicated by the EPA inventory. However, many of the studies predate recent voluntary and regulatory reduction efforts.

Finally, as part of the EDF study program, a study[16] attempted to correlate the top-down and bottom-up approaches by doing the studies at the same time in one area along with a concentrated effort to quantify the non-oil and gas sources. The study was successful in reconciling all of the sources and measurements, and noted that one source of variability was underrepresentation of the natural gas gathering segment in the EPA inventory.

Lifecycle Analysis (LCA)—Lifecycle analysis tabulates the emissions from the combustion and use of a fuel along with all of the upstream emissions from extraction, processing, delivery, and end use of the fuel, i.e., wellhead to burner tip. In the GHG realm, these emissions include both $CO_2$ and methane. LCA often is used to compare different fuels. Methane is an important component of the gas LCA because it is the primary component of gas and because of the multiplier aspect of its GWP. Although earlier gas LCAs were conducted, the work by Howarth and Ingraffea[17] in 2011 attracted a lot of attention because of its conclusion that shale gas had higher lifecycle emissions than coal. This result was largely due to the use of a very high factor for 20-year GWP and some assumptions about the emissions from shale gas operations. For example, the study assumed no mitigation of completion emissions although mitigation was required in a least one state and was reported by companies in voluntary programs. In any case, these emission reductions now are required by federal law (see below). Several studies refuted

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[12] Petron et al., "New Look at Methane and Nonmethane Hydrocarbon Emissions from Oil and Natural Gas Operations in the Colorado Denver-Julesberg Basin," 2014, available at http://onlinelibrary.wiley.com/doi/10.1002/2013JD021272/epdf.

[13] Karion et al., "Methane Emissions Estimate from Airborne Measurements over a Western United States Natural Gas Field," 2013, available at http://www.achd.net/shale/pubs/Karion_et-al_2013_Methane.pdf.

[14] Pesichl et al., "Quantifying Atmospheric Methane emissions from Haynesville, Fayettesville, and Northeastern Marcellus Shale Gas Production Regions," 2015, available at http://onlinelibrary.wiley.com/doi/10.1002/grl.50811/epdf.

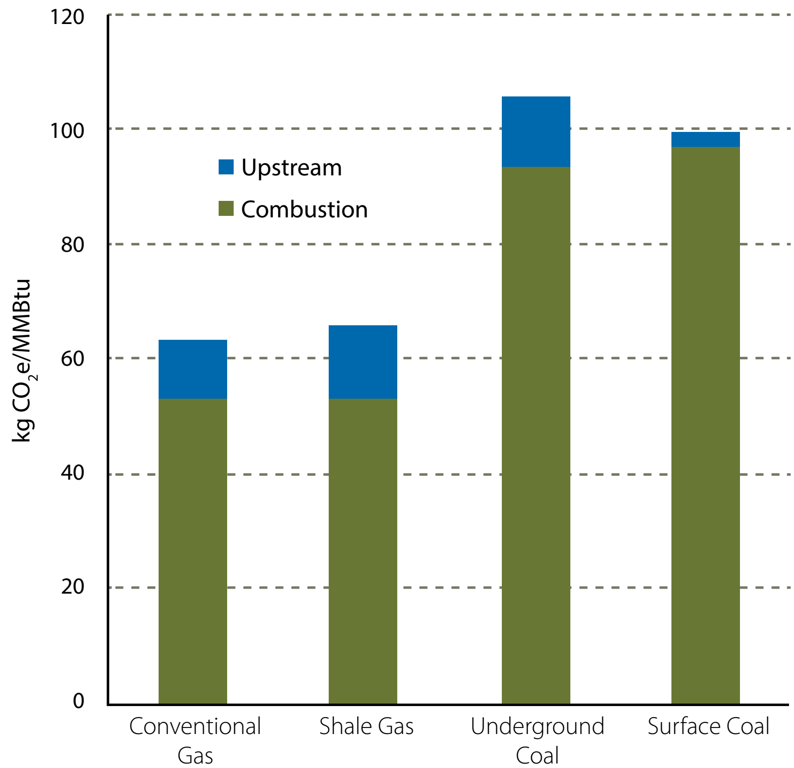
[15] Brandt, et al., "Methane Leaks from North America Natural Gas Systems," 2014, available at http://www.novim.org/images/pdf/ScienceMethane.02.14.14.pdf.

[16] Harriss et al., "Using Multi-Scale Measurements to Improve Methane Emission Estimates from Oil and Gas Operations in the Barnett Shale Region, Texas," 2015, available at http://pubs.acs.org/doi/pdf/10.1021/acs.est.5b02305.

[17] Howard et al., "Methane and the Greenhouse Gas Footprint of Natural Gas Shale Formations," 2011, available at: http://www.acsf.cornell.edu/Assets/ACSF/docs/attachments/Howarth-EtAl-2011.pdf.

the Howarth conclusions,[18] and multiple studies addressed the issue independently. Several of the most detailed studies have been done by the National Energy Technology Laboratory (NETL). Figure 6 summarizes the results of one of the studies[19] that showed the burner tip lifecycle emissions of natural gas are about half those of coal, which is similar to the results of most of the studies.

**Figure 6: Lifecycle Emissions of Natural Gas and Coal**




Source: Role of Alternative Energy Sources: Natural Gas Technology Assessment DOE/NETL-2012/1539

Another important LCA study, performed by Alvarez et al.,[20] used a time-dependent weighting of the climate-forcing effect of methane rather than the average GWP. This study found that the use of gas would always have lower lifecycle emissions than coal. However, the average emission rate would need to be reduced to 1 percent of production for the lifecycle emissions to be lower than petroleum use in transportation over its full lifetime.

These studies are one way of bringing together the results of recent measurement studies. They highlight the importance of specifying the basis for comparison when evaluating emissions across different fuel types in addition to assumptions regarding methane leak rates across segments and fuels.

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[18] Cathles et al., "Responses to Howarth et al.'s Reply," 2012, available at http://www.geo.cornell.edu/eas/PeoplePlaces/Faculty/cathles/Natural%20Gas/Response%20to%20Howarth's%20Reply%20Distributed%20Feb%2030,%202012.pdf.

[19] NETL, "Life Cycle Greenhouse Gas Inventory of Natural Gas Extraction, Delivery and Electricity Production," 2011, available at http://www.netl.doe.gov/energy-analyses/pubs/NG-GHG-LCI.pdf.

[20] Alverez et al., "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure," 2012. Available online at: http://www.pnas.org/content/109/17/6435.full.pdf

## Federal and State Methane Regulations

States, including Colorado and Wyoming, had started to regulate gas industry operations that emit methane in the 2000s. Federal regulation of the oil and gas industry had historically been focused on control of gaseous volatile organic compound (VOC) and hazardous air pollutants (HAPs) emissions from specified equipment and process sources. An update to the New Source Performance Standards (NSPS OOOO) for VOCs from new and modified sources and the National Emission Standards for Hazardous Air Pollutants (NESHAP) in 2012 for oil and gas operations had the added benefit of limiting methane emissions from some significant sources. Methane emissions were directly regulated from oil and gas operations under the Colorado Regulation Number 7 in 2014, focusing primarily on fugitive emissions from upstream sources. In 2015, EPA proposed updates to federal NSPS OOOO (NSPS OOOOa) requirements, which regulate methane from some additional new and modified sources directly. The new sources include hydraulically fractured oil well completions, fugitive emissions from well sites and compressor stations, and pneumatic pumps. Table 2 presents a review of prominent federal and state emissions regulations for the oil and gas industries.

**Table 2: Federal and State Regulation of Emissions from the Oil and Gas Industry**

| Regulation | Type | Sources Covered and Highlights |
|---|---|---|
| NSPS OOOO (2012) | Federal Regulation | • Regulates VOCs from oil and gas operations but results in methane emissions as a co-benefit.<br>• Applied to new and modified sources only. |
| NESHAP Subpart HHHH (2012) | Federal Regulation | • Regulates HAPs but results in methane emission reductions as a co-benefit.<br>• Covers sources such as equipment leaks, storage vessels, and glycol dehydrators. |
| Colorado Regulation #7 (2014) | State Regulation | • Directly regulates methane.<br>• Focuses on fugitive emissions from upstream sources. |
| Proposed NSPS OOOOa (2015) | Proposed Federal Regulation | • Applies to new and modified sources only.<br>• Specifically covers methane emissions.<br>• Addresses additional sources such as hydraulically fractured oil well completions and re-completions, fugitive emissions, compressor seals, and pneumatic pumps. |

## Federal Voluntary Emission Reduction Programs

Several very successful voluntary methane reduction partnerships between EPA and industry have been created. The EPA Natural Gas STAR program was initiated in 1993 to foster government and industry collaboration in knowledge sharing and implementation of cost-effective emission reduction strategies and measures. EPA states that 109 domestic oil and gas companies have eliminated 1.15 trillion cubic feet of methane emissions by adopting roughly 150 technologies and mitigation practices.[21] The Natural Gas STAR International program was launched internationally under the Global Methane Initiative (GMI) in 2006. Since GMI's inception, EPA estimates that international companies have succeeded in mitigating 77.8 Bcf of methane emissions.[22]

### New Proposed $CH_4$ Regulations: NSPS OOOOa

These regulations propose control of the following emission sources in the industry:

**Compressors (Centrifugal and Reciprocating)**

- 95 percent proposed reduction of methane and volatile organic compound (VOC) emissions from wet seal compressors.
- Regular rod packing replacement or emissions capture.

**Pneumatic Controllers**

- Emission controls (either 6 scfh emission reduction or zero bleed rate for controllers at natural gas processing plants).

**Pneumatic Pumps**

- Emission controls (including 95 percent emission reduction for gas-driven chemical and methanol pumps and diaphragm pumps).

**Hydraulically Fractured Oil Well Completions**

- Increased use of reduced emission completions.

**Production Well and Compressor Station Fugitive Emissions**

- Includes regulator optical gas imaging survey requirements and repair of equipment component leaks.

[21] EPA, Natural Gas STAR Program, available at http://www.epa.gov/gasstar/.

[22] EPA, Natural Gas Star International, available at http://www3.epa.gov/gasstar/international/index.html.

More recent government-industry partnerships include the Natural Gas STAR Methane Challenge program (anticipated to launch at the end of 2015 and designed to incorporate industry emission reduction goals into Subpart W GHG reporting requirements) and the Climate and Clean Air Coalition (CCAC) Oil and Gas Methane Partnership (OGMP). Launched in 2014, the CCAC OGMP began as a collaboration between seven founding oil and gas companies—BG Group, ENI, PEMEX, Southwestern Energy, Statoil, PTT, and Total—and national governmental and nongovernmental organizations, including EPA, Environmental Defense Fund (EDF), and the World Bank's Global Gas Flaring Reduction Program. CCAC partners are engaged to evaluate cost-effective emission control technology for nine core emissions sources and share findings and successes.

### *Industry Voluntary Emission Reduction Programs*

Industry-led emission reduction partnerships also aim to reduce methane emissions from the lifecycle of oil and gas production operations. Two illustrative voluntary partnerships include ONE Future and the Center for Sustainable Shale Development (CSSD). The goal of ONE Future members is to reduce industry-wide methane emissions to 1 percent of production through flexible voluntary actions. The members include Southwestern Energy Company, AGL Resources, Hess Corporation, Apache Corporation, Kinder Morgan, Inc., BHP Billiton, and National Grid. ONE Future has been recognized by EPA as alternative approach for participation in the proposed Methane Challenge program.

CSSD includes industry partners and nongovernmental environmental organizations that aim to incorporate industry best practices in developing shale resources in the Appalachian Basin. CSSD has established performance standards addressing water, waste, and conventional pollutants as well as methane. The methane standards focus on flaring limitations, use of green completions, and storage tank emission controls.[23] CSSD partners established the performance standards to achieve greater methane emission mitigation results than those obtainable through adherence to state and federal government requirements and standards.

## Conclusions

Methane is an important greenhouse gas due to its magnified effect on warming. It also has a potentially low cost of reduction relative to $CO_2$ due to the value of gas that can be recovered through mitigation efforts. A large amount of new information on methane emissions is becoming available and changing our understanding of the sources, quantities, and patterns of methane emissions from the oil and gas sectors. The new data have been collected by using different estimation and measurement techniques and over across diverse geographic locations. This new understanding will affect our estimates of emissions and the future approach to mitigation and regulation of these sources. "Making sense of the noise" is essential for success. ICF is providing help to clients on all sides of the debate and facilitating consensus on what can and should be done.

[23] Center for Sustainable Shale Development, "Performance Standards," available at https://www.sustainableshale.org/performance-standards/.

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## About ICF International

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**Joel Bluestein** is a Senior Vice President at ICF where he co-leads the Fuels and Power line of business. He is a nationally recognized expert on the impacts of environmental and energy regulation, with over 30 years of experience in the energy and environmental arenas. He recently has authored several papers on the lifecycle GHG emissions of natural gas production. He participates in the national debate on new energy sources, environmental policies, and their energy implications. He has testified before the Senate Environment and Public Works Committee on natural gas supply issues and their implications for multipollutant regulation of the electric generating sector. He holds a B.S. in mechanical engineering from the Massachusetts Institute of Technology.

**Hemant Mallya** is a Senior Manager at ICF and leads the Emissions Management group. Since joining ICF in April 2004, he has been working on several oil and gas industry projects. Mr. Mallya has led the oil and gas sector inventory modeling and analysis for EPA's National Inventory for Greenhouse Gases. He has assisted EPA in its Natural Gas STAR and Global Methane Initiative programs that promote cost-effective methane emissions reduction to oil and gas companies, both domestically and internationally. For these programs he has supported and presented at several conferences, directed the development of numerous prefeasibility analysis for methane mitigation, and led multiple methane emissions measurement studies inernationally. Mr. Mallya has provided technical assistance to the development of the EPA GHG Reporting Program and led ICF's development of Subpart W.

**Louis Yandoli** is a Senior Associate in ICF's Emissions Management group. He has 10 years of experience in consulting, mostly in the commercial oil and gas business. Hired into ExxonMobil's downstream headquarters as a chemical engineer in 2005, he gained experienced both domestically and internationally by assisting clients in areas of refinery and chemical plant scheduling, process engineering troubleshooting, and measurement and emissions management. He independently managed a major scheduling program in Singapore, spearheaded measurement and custody transfer surveys with various upstream and downstream clients, and led the team tasked with developing the GHG Reporting Program for U.S. refineries in 2014. Mr. Yandoli joined ICF in the fourth quarter of 2014 after completing his international M.B.A. in Tokyo, Japan

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