Methane Emissions in the Natural Gas Life Cycle

Final Report: Implications for Policymakers

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More information about M.J. Bradley & Associates is available at www.mjbradley.com.

More information about WIEB and SPSC is available with a link to the full report at www.westernenergyboard.org.

Methane Emissions in the Natural Gas Life Cycle: Implications for Policymakers

The Western Interstate Energy Board (WIEB) and State-Provincial Steering Committee (SPSC) commissioned M.J. Bradley & Associates (MJB&A) to develop a report to better understand the life cycle greenhouse gas (GHG) emissions of natural gas and coal used for electricity generation. WIEB/SPSC asked MJB&A to evaluate and summarize the current state of knowledge about methane leakage throughout the natural gas fuel cycle, with a particular focus on the differences between methane emission estimates developed from bottom-up analyses and top-down inventories of methane and other hydrocarbons. One of WIEB/SPSC's major objectives was to identify the key reasons for the significant variability in total methane leakage estimates from prominent published studies, and to put these differences into context. With this understanding, WIEB/SPSC asked MJB&A to identify key methane emission points within the natural gas fuel cycle and review strategies and technologies available to reduce these emissions.

This summary document synthesizes the findings of the report into key takeaways for policymakers, and is included as the final section of the full report.[i] The full report provides a detailed discussion of these issues and includes detailed appendices with information on the more than 20 methane emissions studies reviewed by MJB&A as part of this project. The key takeaways are:

- Based on latest science and estimates of upstream methane leakage from natural gas systems, natural gas combined cycle power plants have about half the life cycle GHG emissions of coal-fired power plants.
- Emerging and ongoing research suggests a super emitter issue where a small percentage of sources across the natural gas value chain are responsible for a large percentage of emissions.
- There is significant regional variation in methane emissions from upstream natural gas systems. While much research has focused on improving estimates of national emissions, consideration of regional methane emissions may be more informative for local system planners and GHG policymakers.
- Allocation of methane emissions between natural gas and other products, such as petroleum or natural gas liquids, is an emerging research topic and will have implications for life cycle GHG emissions estimates.
- Significant actions have been taken by EPA, states, and companies in recent years to reduce emissions associated with the natural gas system.
- An upcoming rulemaking process at EPA will set new requirements for unregulated sources at new and modified facilities.
- While requirements for new and modified sources will reduce emissions over time as the system is expanded and upgraded, the majority of emissions come from existing sources. There is no comprehensive federal regulatory program to address these emissions; however, Wyoming and Colorado have been leaders in establishing state programs. New near-term federal policies addressing existing sources include guidelines for states with ozone nonattainment areas and voluntary programs.

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[i] The full report is available at http://westernenergyboard.org/.

To help inform state and regional policymakers as they consider the implications of upstream vented and fugitive methane emissions for resource and transmission planning, we include brief discussions of each of these takeaways along with implications.

Natural Gas Combined Cycle (NGCC) Life Cycle Emissions

Upstream methane emissions and power plant efficiency are the primary drivers of life cycle GHG emissions, with EGU efficiency being the most significant factor. As shown in Figure 1, using a 100-year global warming potential (GWP)[ii] and emission estimates associated with average U.S. natural gas, we find that life cycle NGCC emissions are about 40 percent of those from an average coal-fired boiler.[iii] Our analysis assumes power plants receive gas directly from transmission systems. The advantage of NGCC over an average coal-fired boiler is robust across a range of upstream emission scenarios. In the extreme scenario, which assigned all observed excess atmospheric methane to natural gas systems, we found life cycle emissions associated with NGCC to be about 60 percent of life cycle emissions associated with an average coal-fired boiler. The gap between NGCC and an average coal-fired boiler is less when we use a 20-year GWP but there is still a benefit across the reviewed emission scenarios.

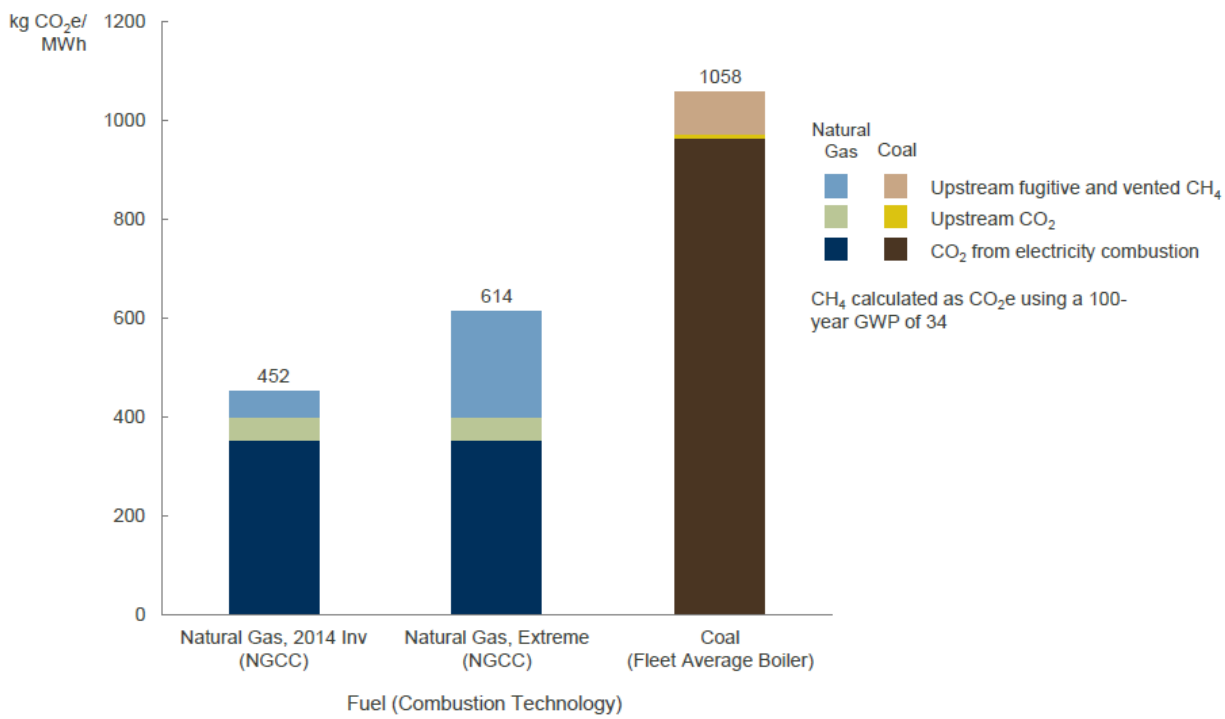

Figure 1. MJB&A Estimated Life Cycle Emissions for Natural Gas- and Coal-based Electricity Generation

Exploring the role of power plant efficiency, Figure 2 shows the 100-year GWP crossover point for a range of natural gas power plant efficiencies as compared to an average coal-fired boiler

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[ii] Methane is a more significant radiative forcer when compared to CO_2 and is assigned a GWP, based on the ratio of methane's radiative force to that of CO_2, that reflects that impact. The resulting value is represented in carbon dioxide equivalents (CO_2e). For methane, we use a 100-year GWP of 34.

[iii] We calculate the emissions associated with average U.S. natural gas as the total estimated emissions from the GHG Inventory divided by total U.S. natural gas production. We assume an NGCC efficiency of 51 percent and a coal boiler efficiency of 34 percent.

with an efficiency of 34 percent and a supercritical coal-fired boiler with an efficiency of 39 percent. As shown, less efficient natural gas power plants have a lower vented and fugitive emissions crossover point.

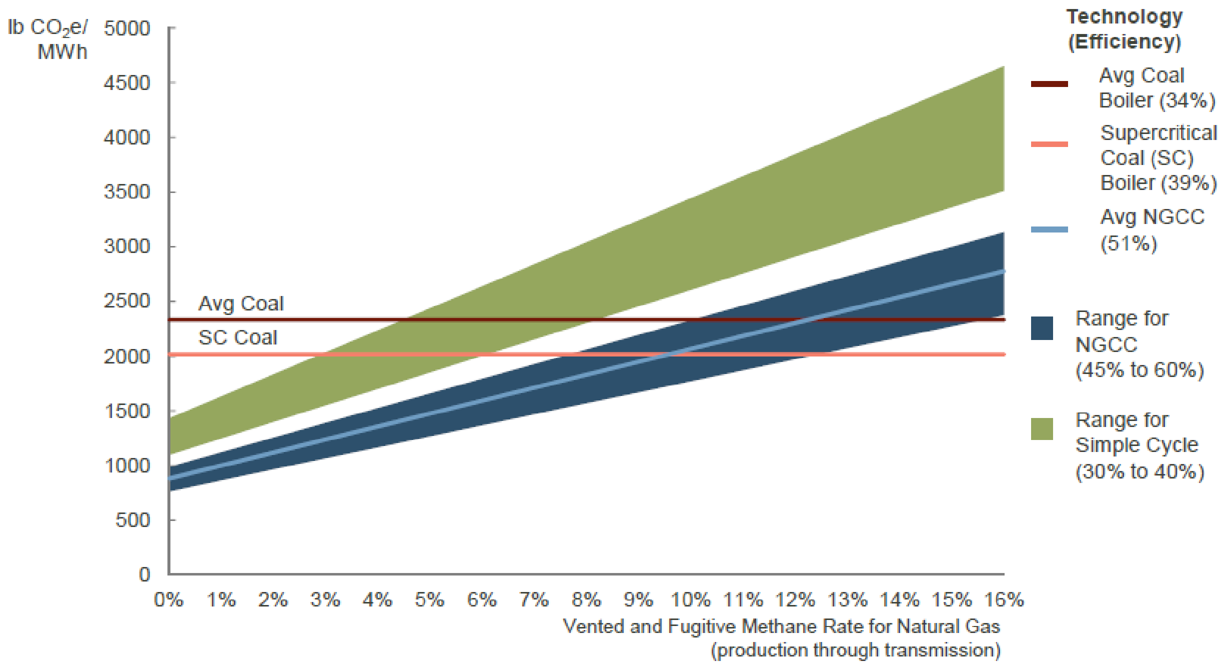

Figure 2. Life Cycle Emissions at Different Power Plant Efficiencies, 100-year GWP

As state and regional policymakers are making decisions about the resource mix, it seems clear that there are GHG benefits of NGCC relative to coal boilers. However, it is important to remember that power plant efficiency is a key variable in shaping life cycle emissions. For the average natural gas combined cycle and subcritical coal boilers we reviewed, power plant CO_2 emissions contribute 80 and 90 percent of life cycle GHG emissions, respectively. Regional generating fleets consist of EGUs with varying efficiencies and capacity factors, resulting in unique combustion CO_2 profiles. While our analysis compares generic combined cycle and coal plants, power plants are not directly interchangeable. Policymakers may want to evaluate how changes to distinct generating fleets will impact GHG emissions. The most relevant comparison may not be a coal boiler versus an NGCC unit but the existing fossil fleet versus a portfolio of alternative options. For example, system planners may evaluate different types of dispatchable resources to provide system flexibility as more variable resources, such as wind or solar projects, are added to the grid. Different types of flexible resources including simple cycle turbines or NGCC power plants designed to cycle, will have different GHG emissions profiles. It would be informative to review the life cycle emissions of specific power plants and implications of different resource decisions for the entire system.

Emerging Understanding of "Super Emitters"

Research suggests that vented and fugitive emissions are not normally distributed across emission source categories. This has implications for understanding significant emission sources as well as identifying the most cost-effective control strategies.

From the perspective of understanding emission potential, the uneven distribution of emissions contributes to the differences between top-down and bottom-up studies of emissions. By relying on average emission factors, bottom-up studies may underestimate actual emissions if high-emitters were not part of the sampling conducted to develop the emission factor. On the other hand, top-down studies that are based on observed emissions at a particular place at a particular time may overestimate emissions if their observations are extrapolated across a broad geographic area and across an entire year. At the same time, top-down studies may be particularly useful at identifying specific areas with elevated methane emissions. However, pin-pointing the source of emissions and attributing them to current natural gas systems, as opposed to other geologic sources of methane such as coal seams or abandoned wells, remains a challenge. Although most studies that directly measured emissions identified the presence of super emitters, more data is needed to understand if the observed frequency and magnitude of these sources is equally distributed across a specific region or the U.S.

Ongoing research should help to reconcile the differences between top-down and bottom-up studies of emissions and contribute to understanding of the potential super emitter issue. Research to date suggests that it may be appropriate to develop regional emissions inventories using region- or basin-specific emission factors that are informed by both equipment sampling (as in bottom-up studies) and atmospheric methane measurements (as in top-down studies). Such an approach has the potential to provide more accurate emissions estimates than national inventories developed with generic emissions factors.

From a control strategy perspective, unevenly distributed emissions create a challenge for regulators or firms trying to identify emission sources and controls. While there will continue to be normally distributed sources of emissions where traditional regulatory approaches may be appropriate, there may also be a need to develop approaches where a range of potential emission sources are monitored or evaluated on a regular basis to identify unexpected leaks. As an example, the recent Colorado regulations included revised emission control requirements for storage vessels but also included a requirement for regular review of the storage vessels to ensure the ongoing integrity of the system.

Regional Context

Although the main focus of the report is a comparison of average U.S. life cycle GHG emissions of natural gas-fired generation versus coal-fired generation, implications for regional system planning are dependent on regional gas supplies and electric generation infrastructure. While we have found that natural gas combusted at a combined cycle unit generates roughly half the life cycle GHG emissions of coal burned at the average boiler, the relative benefit of natural gas will vary from region to region.

Many regions source their natural gas from specific production areas and top-down studies suggest some areas may have higher emissions than others. With the majority of gas supplies in regions coming from specific basins, consideration of national emissions rates may not be as informative in the development of regional GHG policies. Regional policy planners may want to consider the unique upstream GHG characteristics of their gas supply.

Emissions Allocation

A key emerging issue is how to properly allocate methane emissions to natural gas and petroleum systems. Across U.S. production fields, there are oil wells that also produce gas and gas wells that also produce oil and other liquid hydrocarbons. EPA's GHG Inventory does not currently allocate methane emissions associated with these co-produced commodities proportionately across natural gas and petroleum systems. As such, all methane from wells defined as oil wells is attributed to petroleum systems and all methane from wells defined as gas wells is attributed to natural gas systems, regardless of their co-production. In our calculation of life cycle emissions from natural gas, we followed the methodology of Alvarez et al.[1] in assigning 35 percent of methane emissions from petroleum systems to natural gas to account for co-produced gas. A more recent study by researchers at the University of Texas at Austin suggests that only 85 percent of methane emissions from gas wells should be attributed to natural gas systems, with the remaining 15 percent assigned to liquid hydrocarbons.[2] While we did not factor this consideration into our life cycle analysis, it would have the effect of reducing life cycle GHG emissions from natural gas.

In addition to more direct measurement of methane emissions from oil and gas sources, efforts to reconcile differences between top-down and bottom-up emissions estimates will improve understanding of emissions allocation. Included in this is more data on emissions from abandoned oil and gas wells, which are not well understood. While existing literature has suggested specific percentages for allocating methane across natural gas and petroleum systems, there is significant regional variation in co-production at oil and gas wells across the U.S. Using a national average to assign methane emissions across both value chains may therefore be inappropriate, especially in the context of regional planning. Regardless of which value-chain methane emissions are ultimately associated with, oil and gas production are closely interrelated from a GHG mitigation perspective.

Recent Actions to Address Natural Gas Value Chain Emissions

EPA's most significant regulatory action to date related to upstream methane emissions from natural gas systems was the 2012 Oil and Gas New Source Performance Standards (NSPS), which regulated volatile organic compound (VOC) emissions from a range of upstream sources. At the time the rule was proposed and finalized, EPA touted the methane co-benefits of the rule. EPA estimated that when fully implemented, the NSPS would reduce annual methane emissions from affected sources by 1 to 1.7 million tons.[3] A key aspect of the 2012 Oil and Gas NSPS is that it applies to new and modified sources, not existing sources. With the exception of well completions, which occur at the beginning of the life of a well and are considered "new" emission sources, control technologies and strategies required as part of the rule have not had a dramatic impact on the annual emission estimates from the industry.

In addition to the federal rulemaking, states have taken action to control emissions from sources in the natural gas sector. One of the leading states is Colorado, which has a history of regulating emissions from the oil and gas sector as part of its strategy to reduce emissions of ozone precursors. In 2014, Colorado finalized regulations that implemented the 2012 Oil and Gas NSPS regulations and expanded the coverage to include first-in-the-country methane regulations. The methane regulations include leak detection and repair (LDAR) requirements for natural gas well production facilities and compressor stations. The Colorado regulations apply to both new and existing sources and require reduced emission completions (RECs)[iv] on hydraulically fractured gas and oil wells. Together, Colorado estimates that these regulations will reduce methane emissions by 65,000 tons per year.[4]

In addition to regulatory action, EPA's long-standing voluntary partnership program, Natural Gas STAR, has resulted in significant reported emission reductions from the industry. These

[iv] A REC is a process that reduces methane and VOC emissions during the flowback period by capturing gas that would otherwise be vented.

emission reductions are accounted for in the GHG Inventory. According to the 2014 GHG Inventory, Natural Gas STAR resulted in 2,211 Gg (2.4 million tons) of CH_4 reductions from natural gas systems (including distribution) in 2012.[5] Without these reductions, methane emissions from natural gas systems would have been 36 percent higher. These reductions are across a range of sources, both new and existing.

Certification of production companies by third parties to recognize industry leading best management practices has also emerged with the development of the Center for Sustainable Shale Development (CSSD) standards in the Appalachian region. This voluntary certification process allows industry companies to demonstrate environmental stewardship and commitment to operations that meet or exceed regulatory requirements.

Future Actions to Address Natural Gas Value Chain Emissions

In January 2015, the Obama Administration provided an update to its Methane Strategy describing specific actions focused on emission reductions from the oil and gas sector.[v] The Administration's expressed goal is to reduce methane emissions from the oil and gas sector by 40 to 45 percent from 2012 levels by 2025. As summarized in Table 1, the strategy involves a range of agencies pursuing both regulatory and voluntary efforts.

Table 1. Summary of Administration Oil & Gas Methane Strategy

Agency	Rule/Program	Action	Likely Affected Segment (s)	Timeline
EPA	111(b) regulations for methane and VOC emissions	Regulatory (New Sources)	Production & Gathering, Processing, Transmission & Storage	Propose Summer 2015 Final Summer 2016
	Control Technology Guidelines	Regulatory (Existing Sources)	Production	Propose Summer 2015 Final 2016
	GHG Reporting Program	Regulatory (All Sources)	All Segments	Proposed December 9, 2014 Final 2015
	Enhanced Natural Gas STAR	Voluntary (All Sources)	All Segments	Stakeholder Outreach Summer 2015 Program Launch Fall 2015 Implementation January 2016
DOI (BLM)	Onshore Order 9	Regulatory	Production & Gathering	Propose late spring 2015
DOT	PHMSA Monitoring	Regulatory	Transmission	2015
DOE	Methane Roundtables	Pre-Regulatory	All segments	Spring 2014
	Natural Gas Modernization Initiative	Information Sharing	Transmission & Distribution	FOA to be issued with 2015 Appropriations

[v] The Administration's announcement can be found at https://www.whitehouse.gov/the-press-office/2015/01/14/fact-sheet-administration-takes-steps-forward-climate-action-plan-anno-1

Most notably, the Administration directed EPA to promulgate new VOC and methane regulations. The VOC portion of these regulations would follow up on the 2012 Oil and Gas NSPS. Sources likely to be targeted by the new standards include those discussed in EPA's 2014 Methane White Papers:[vi] hydraulically fractured oil well completions, pneumatic devices, compressors, liquids unloading, and equipment leaks. The proposed regulations are scheduled to be released in summer 2015, with a final rule in summer 2016.

While requirements for new and modified sources will reduce emissions over time as the system is expanded and upgraded, the majority of emissions come from existing sources. A 2014 study by ICF International projected that despite recent growth in oil and gas production, existing sources (existing in 2011) will be responsible for nearly 90 percent of methane emissions in 2018.[6] Reductions from existing sources are therefore a key component of reducing overall emissions from the oil and gas industry. However, there is no comprehensive federal regulatory program to address these emissions. While the regulation of GHGs from new sources triggers an obligation to review the need for state guidance to establish emission performance standards for existing sources, EPA has not established a timeframe for developing such guidance for existing sources of methane emissions from the oil and gas industry.

To begin to address emissions from existing sources, the Methane Strategy announced by the Administration includes an evaluation of emission control technologies for existing sources through the development of control technology guidelines (CTGs). CTGs provide states with strategies to reduce VOC emissions in areas that do not attain ozone NAAQS. States with areas designated as having moderate or higher nonattainment areas must implement EPA CTGs or alternative measures as part of their strategies to achieve attainment. Implementation of the CTGs to reduce VOCs will result in methane co-benefit reductions from existing oil and gas sources. Under the 2008 ozone standard, Texas and California are the only states with oil and gas production to have areas designated as moderate or higher nonattainment. However, EPA has proposed more stringent ozone standards which are scheduled to be finalized in October 2015. Under the revised standard, it is likely that more states will have nonattainment areas and will have to implement CTGs or alternative measures for oil and gas sources. The process of designating areas in nonattainment and developing state plans will take a number of years.

While broad federal regulation of existing sources does not appear to be imminent, most states have significant regulatory discretion. States often lead the federal government in terms of regulatory programs. In the oil and gas sector, this has been the case with Wyoming and Colorado.[vii] In states with less experience with oil and gas production, rules are also likely to evolve as regulation catches up with the initial rush of unconventional hydrocarbon development. For example, Ohio recently incorporated LDAR requirements for production facilities into its permitting process.[viii]

[vi] The white papers are available at: http://www.epa.gov/airquality/oilandgas/whitepapers.html.
[vii] Wyoming has proposed new rules that would regulate certain existing sources, available at: http://sgirt.webfactional.com/filesearch/content/Air%20Quality%20Division/Programs/Rule%20Development/Proposed%20Rules%20and%20Regulations/AQD_Rule-Development_Chapter-8-NAA-Existing-Source-IBR-draft_02-02-15-Strike-and-Underline.pdf
[viii] Model general permits for oil and gas well-site production operations in Ohio are available here: http://www.epa.ohio.gov/dapc/genpermit/oilandgaswellsiteproduction.aspx

Voluntary emission reduction activities may also expand in the future. This includes action under both EPA's revamped Gas STAR program and certification programs such as CSSD. More companies may take voluntary action as reduction technologies evolve and become more cost effective. Industry executives may also see advantages in voluntarily reducing emissions as a response to increased public and investor scrutiny of potential environmental impacts.

Endnotes

[1] Alvarez et al. (2012) "Greater focus needed on methane leakage from natural gas infrastructure." PNAS. Available at: http://www.pnas.org/content/early/2012/04/02/1202407109.abstract.
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