Summary for Policymakers

CLEARING THE AIR: REDUCING UPSTREAM GREENHOUSE GAS EMISSIONS FROM U.S. NATURAL GAS SYSTEMS

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KEY FINDINGS

1. Fugitive methane emissions from natural gas systems represent a significant source of global warming pollution in the U.S. Reductions in methane emissions are urgently needed as part of the broader effort to slow the rate of global temperature rise.

2. Cutting methane leakage rates from natural gas systems to less than 1 percent of total production would ensure that the climate impacts of natural gas are lower than coal or diesel fuel over any time horizon. This goal can be achieved by reducing emissions by one-half to two-thirds below current levels through the widespread use of proven, cost-effective technologies.

3. Fugitive methane emissions occur at every stage of the natural gas life cycle; however, the total amount of leakage is unclear. More comprehensive and current direct emissions measurements are needed from this regionally diverse and rapidly expanding energy sector.

4. Recent standards from the Environmental Protection Agency (EPA) will substantially reduce leakage from natural gas systems, but to help slow the rate of global warming and improve air quality, further action by states and EPA should directly address fugitive methane from new and existing wells and equipment.

5. Federal rules building on existing Clean Air Act (CAA) authorities could provide an appropriate framework for reducing upstream methane emissions. This approach accounts for input by affected industries, while allowing flexibility for states to implement rules according to unique local circumstances.

For full text of the working paper go to: http://www.wri.org/publication/clearing-the-air.

Natural gas production in the United States has increased rapidly in recent years, growing by 23 percent from 2007 to 2012. This development has significantly changed projections of the future energy mix in the U.S. Advances combining horizontal drilling and hydraulic fracturing have enabled producers to access vast supplies of natural gas deposits in shale rock formations. This shale gas phenomenon has helped to reduce energy prices, directly and indirectly supporting growth for many sectors of the U.S. economy, including manufacturing.

This paper seeks to clarify what is known about methane emissions from the natural gas sector, what progress has been made to reduce those emissions, and what more can be done. Box S-1 describes the scope of this study.

Shale gas development has triggered divisive debates over the near- and long-term environmental implications of developing and using these resources, including concerns over air quality, water resources, and community impacts. One point of controversy concerns the climate change implications of shale gas development, in part due to uncertainty about emissions of methane, a potent greenhouse gas (GHG) that is the primary component of natural gas. Fugitive methane emissions reduce the net climate benefits of using lower-carbon natural gas as a substitute for coal and oil for electricity generation and transportation, respectively.

While a shift in electric generation to natural gas from coal has played a significant role in recent reductions in U.S. carbon dioxide (CO_2) emissions, more will need to be done for the U.S. to meet its goal of reducing GHG emissions by 17 percent below 2005 levels by 2020. A related WRI report found that cost-effective cuts in methane leakage from natural gas systems are among the most important steps the U.S. can take toward meeting that goal.[1] To achieve climate stabilization in the longer term, policies are needed to address combustion emissions through carbon capture and storage or by other means.

In addition to methane emissions, natural gas sector operations and infrastructure represent a significant source of CO_2; volatile organic compounds (VOCs), which are chemicals that contribute to ground-level ozone and smog; and hazardous air pollutants (HAPs). In 2012, EPA finalized air pollution standards for VOCs and HAPs from the oil and natural gas sector. These rules will improve air quality and have the co-benefit of reducing methane emissions. As discussed below, these standards can be complemented by additional actions to further reduce methane emissions, which will help to slow the rate of global temperature rise in the coming decades.

Fortunately, most strategies for reducing venting and leaks from U.S. natural gas systems are cost-effective, with payback periods of three years or less. The case for policy action is particularly strong considering that recent research shows that climate change is happening faster than expected. In addition, the projected expansion in domestic oil and natural gas production increases the risk of higher emissions if proper protections are not in place.

Box S-1 | The Scope of this Study

This study focuses primarily on evaluating and reducing upstream methane emissions in the natural gas sector. This has two important implications. First, this paper in no way aims to diminish the urgent need to achieve GHG emissions reductions from other segments of the economy. For example, significant cost-effective opportunities also exist to reduce carbon dioxide emissions from both upstream and downstream stages of the natural gas life cycle, and to reduce methane emissions from coal mines, landfills, and other sources. Longer term, addressing combustion emissions will be increasingly important, whether through carbon capture and storage or by other means. Second, this paper does not address other aspects of natural gas development that pose significant risks for public health and the environment, including potential effects on drinking water and other community impacts. We focus on actions to reduce methane emissions, and generally do not consider additional policies that may be necessary to protect the public interest from these other risks. The one exception is that toxic and VOC emissions are frequently discussed—because the technologies and practices that effectively reduce those emissions typically also achieve reductions in methane emissions.

LIFE CYCLE ASSESSMENTS

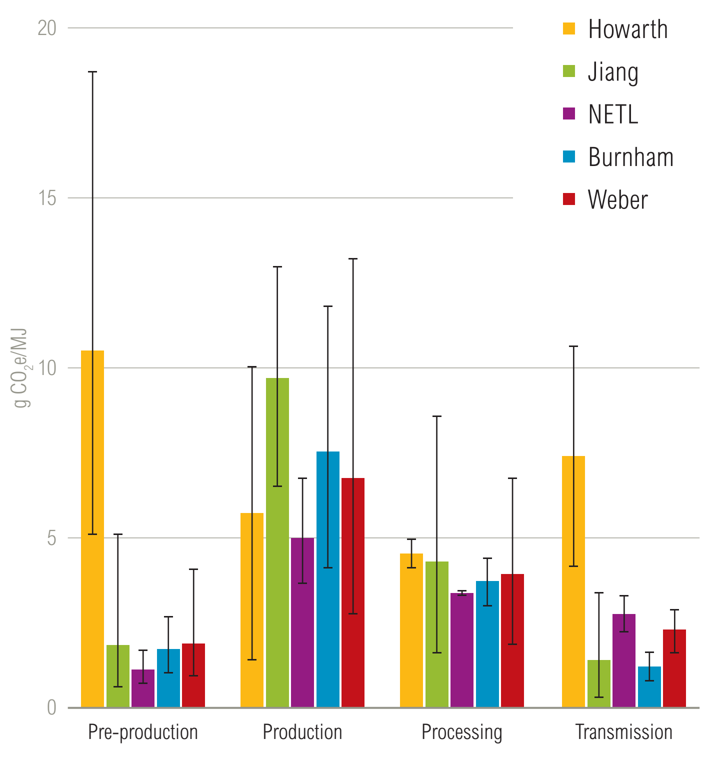
While natural gas emits about half as much carbon dioxide as coal at the point of combustion, the picture is more complicated from a life cycle perspective. There is considerable uncertainty about the scale of upstream methane emissions from natural gas systems due to variations between production basins and a scarcity of recent, direct emissions measurements from several key processes. Ultimately, the question of whether or not gas has a lower climate impact than coal depends on the life cycle methane leakage rates, plus other factors that include subjective policy considerations. The full working paper includes more extensive discussion of this and related questions.

Most life cycle studies agree, based primarily on data from EPA's U.S. GHG Inventory, that carbon dioxide (CO_2) emissions from end-use combustion of natural gas represents roughly 70 to 80 percent of total life cycle GHG emissions.[2] Most studies also agree that upstream GHG emissions associated with shale gas and conventional gas production are roughly comparable to one another, within the margin of error. EPA's GHG inventory data imply a methane leakage rate of less than 3 percent of total natural gas production.[3] At this leakage rate, natural gas produces fewer GHG emissions than coal over any time horizon and regardless of how the fuels are used. Additionally, according to a 2012 study published in the Proceedings of the National Academy of Sciences, reducing the methane leakage rate to below 1 percent would ensure that heavy-duty vehicles, like buses and long-haul trucks, fueled by natural gas would have an immediate climate benefit over similar vehicles fueled by diesel. Thus, reducing total methane leakage to less than 1 percent of natural gas production is a sensible performance goal for the sector to achieve.

Accurate life cycle emissions estimates from the natural gas sector require reliable data for a broad range of industry activities and emissions factors associated with those activities. Regarding the quality of available data, there are uncertainties at all life cycle stages. With the exception of one study published by researchers at Cornell University, findings from life cycle assessments of methane emissions from unconventional wells have varied the most on production stage emissions (see Figure S-1). This is because of differing assumptions regarding how frequently the average well requires hydraulic fracturing and liquids unloading[4], and the extent to which control technologies are used when these activities are performed. Hydraulic fracturing is often an emissions-intensive process used to initiate production at both conventional and unconventional wells (i.e., "well completions"; Figure S-2). It may be repeated to re-stimulate production multiple times over a well's estimated 20-to-30-year lifetime (during "workovers"; Figure S-2). Liquids unloading is a practice used to clean up all types of onshore wells, removing liquids to increase the flow of gas, and potentially causing significant emissions.

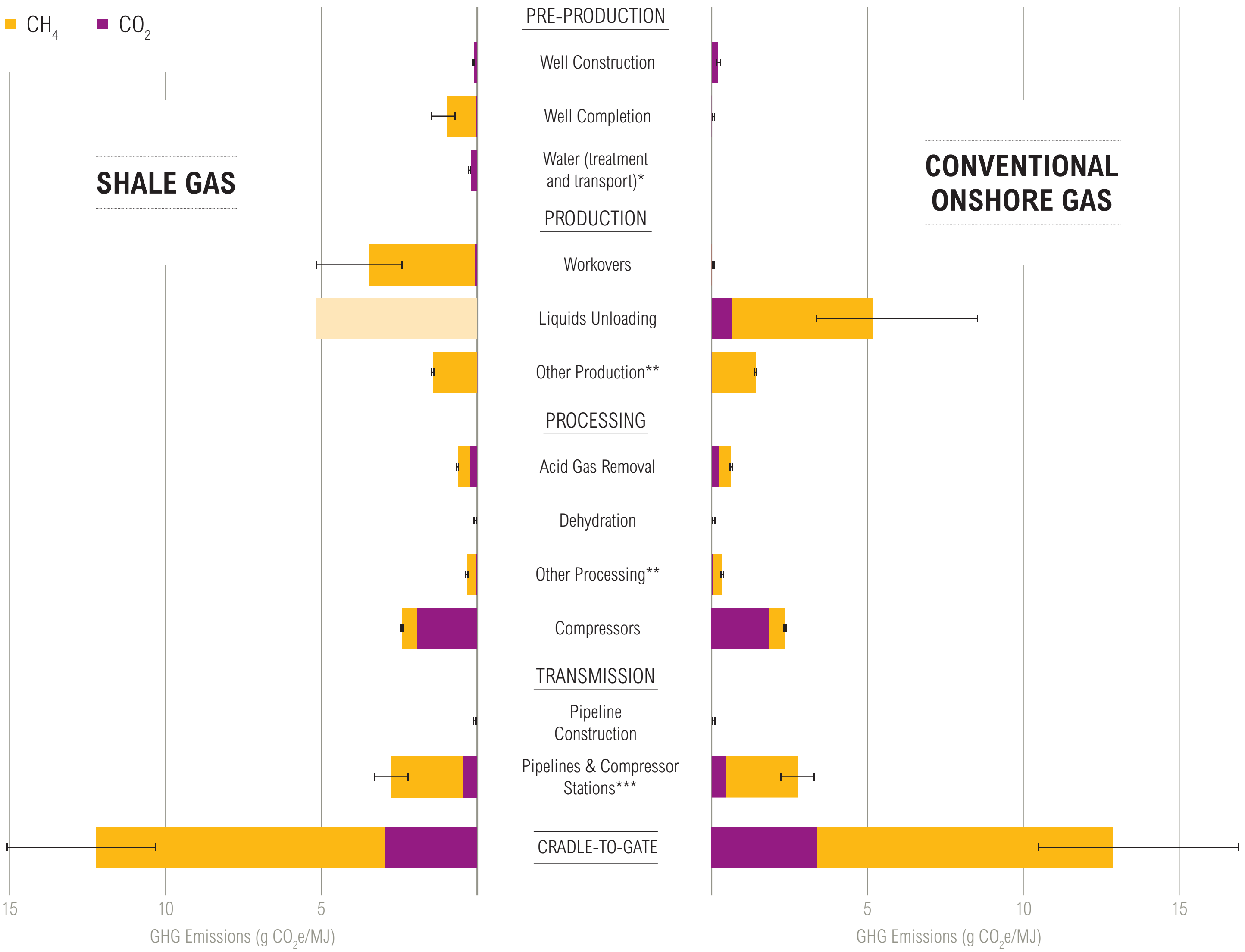
Since 2009, EPA's annual GHG inventory has dramatically adjusted their emissions factors associated with these production-stage activities. In EPA's draft 2013 GHG inventory, there is a 90 percent reduction in their estimates of emissions associated with liquids unloading in response to self-reported industry data showing that unloading events are less emissions-intensive than previously thought; that is, industry reported more frequent use of control technologies than EPA had assumed in earlier inventories.

Figure S-1 | **Upstream GHG Emissions from Shale Gas, by Life Cycle Stage**



Sources: All data presented in this figure are derived from the referenced studies, with only unit conversions and minor adjustments for heating rates. See the full working paper for complete study references and more detailed discussion.

Figure S-2 | **Comparing Detailed Estimates of Life Cycle GHG Emissions from Shale Gas and Conventional Onshore Natural Gas Sources**



* Data available from Marcellus only
** "Other Production" and "Other Processing" each include point source and fugitive emissions (mostly from valves)
*** Includes all combustion and fugitive emissions throughout the entire transmission system (mostly from compressor stations)

Notes: Recent evidence suggests that liquids unloading is a common practice for both shale gas and onshore conventional gas wells. Therefore, contrary to data originally published by NETL, showing zero emissions, liquids unloading during shale gas development may result in GHG emissions that are comparable to those associated with conventional onshore natural gas development. GWP for methane is 25 over a 100-year time frame.
Source: National Energy Technology Laboratory.

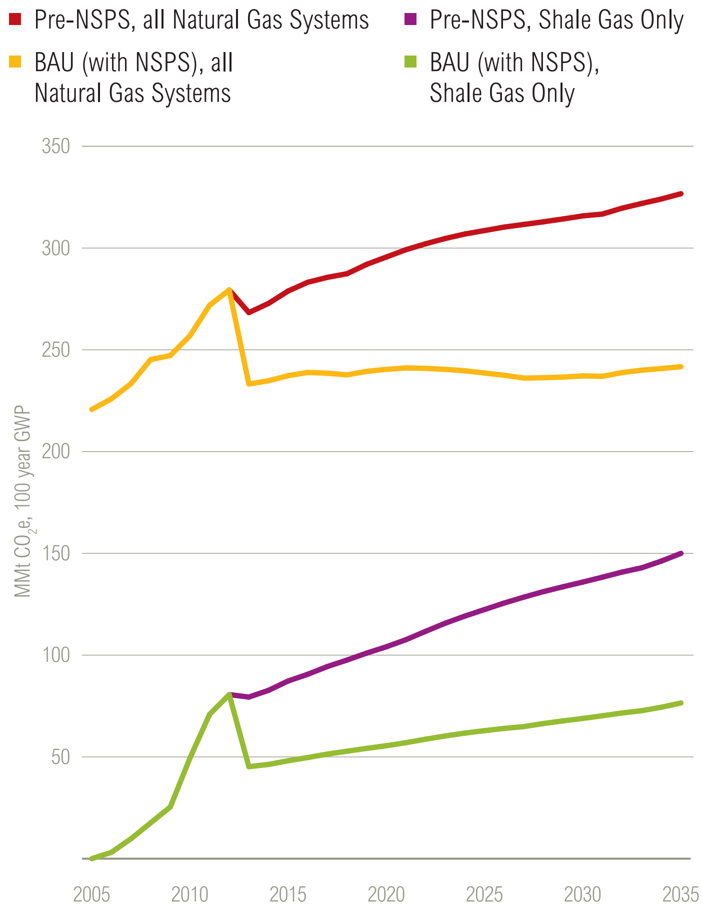
Meanwhile, recent research based on field measurements of ambient air near natural gas well-fields in Colorado and Utah suggest that more than 4 percent of well production may be leaking into the atmosphere at some production-stage operations.[5] With hundreds of thousands of wells and thousands of natural gas producers operating in the U.S., this will likely remain an active debate, even as forthcoming data from EPA and other sources aims to clarify these questions in the coming months. For example, independent researchers at the University of Texas at Austin are teaming up with the Environmental Defense Fund and several industry partners to directly measure methane emissions from several key sources. When results are published in 2013 and 2014, these data will provide valuable points of reference to help inform this important discussion.

While uncertainties remain regarding exact methane leakage rates, the weight of evidence suggests that significant leakage occurs during every life cycle stage of U.S. natural gas systems, not just the production stage (Figures S-1 and S-2). A recent expert survey by Resources for the Future identified methane emissions as a consensus environmental risk that should be addressed through government and industry actions.

THE IMPACT OF EPA'S NEW SOURCE PERFORMANCE STANDARDS

In April 2012 EPA finalized regulations for New Source Performance Standard (NSPS) and National Emissions Standards for Hazardous Air Pollutants (NESHAP) that primarily target VOC and air toxics emissions but will have the co-benefit of reducing methane emissions. The new EPA rules require "green completions," which reduce emissions during the flow-back stage of all hydraulic fracturing operations at new and re-stimulated natural gas wells. The rules will also reduce leakage rates for compressors, controllers, and storage tanks. We estimate that this will reduce methane emissions enough to cut all upstream GHG emissions from shale gas operations between 40 to 46 percent below their projected trajectory in the absence of the rules (Figure S-3; bottom two lines). For all natural gas systems (including shale gas), methane emissions reductions resulting from the NSPS/NESHAP rules are projected to lower upstream GHG emissions by 13 percent in 2015 and 25 percent by 2035 (Figure S-3; top two lines). These rules will have a greater impact over time as the proportion of domestic gas production coming from shale formations—the source of the greatest emissions reductions resulting from the new rules—rises from one-third to one-half during the next twenty years, and as old equipment is gradually replaced with new equipment that is covered by the rules.

Figure S-3 | **GHG Emissions from Shale Gas Systems and All Natural Gas Systems**



Notes: Upstream GHG emissions before and after application of the EPA NSPS rule, for all natural gas systems (top two lines) and for shale gas systems (bottom two lines).

FURTHER POTENTIAL TO REDUCE METHANE EMISSIONS

With the implementation of just three technologies that capture or avoid fugitive methane emissions, we estimate that upstream methane emissions across all natural gas systems could be cost-effectively cut by up to an additional 30 percent (Figure S-4). The technologies include (a) the use of plunger lift systems at new and existing wells during liquids unloading operations; (b) fugitive methane leak monitoring and repair at new and existing well sites, processing plants, and compressor stations; and (c) replacing existing high-bleed pneumatic devices with low-bleed equivalents throughout natural gas systems. By our estimation, these three steps would bring down the total life cycle leakage rate across all natural gas systems to just above 1 percent of total production. Through the adoption of five additional abatement measures that each address smaller emissions sources, the 1 percent goal would be readily achieved.

NEXT STEPS TO REDUCE METHANE EMISSIONS

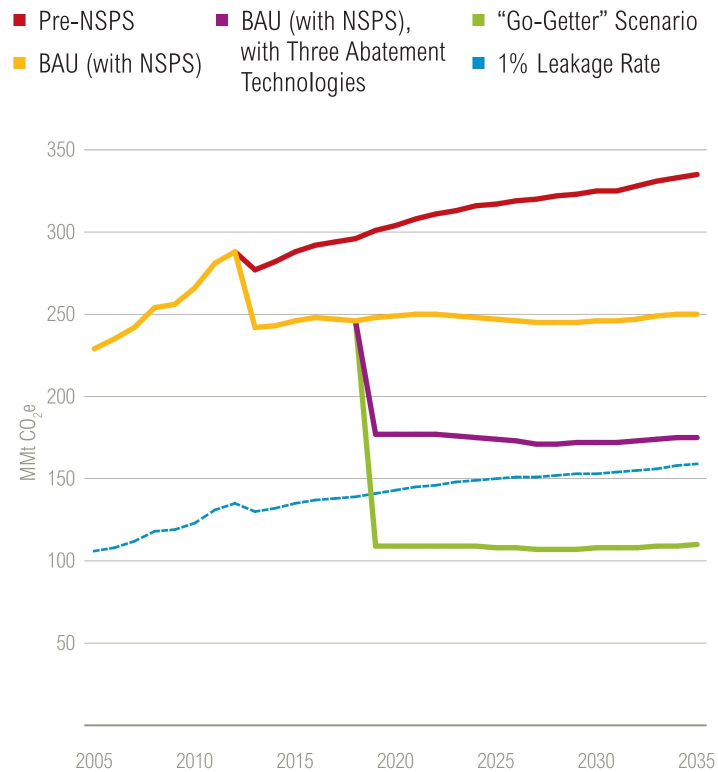
New public policies will be needed to reduce methane emissions from both new and existing equipment throughout U.S. natural gas systems because market conditions alone are not sufficient to compel industry to adequately or quickly adopt best practices. Minimum federal standards for environmental performance are a necessary and appropriate framework for addressing cross-boundary pollution issues like air emissions. Federal CAA regulations are generally developed in close consultation with industry and state regulators and are often implemented by states. This framework allows adequate flexibility to enable state policy leadership and continuous improvement in environmental protection over time.

We have identified a range of actions that can be taken to reduce methane emissions.[6] These tools are listed in this summary, and discussed in more detail in section 5 of the full working paper.

Federal Approaches to Address Emissions

In addition to the recently enacted NSPS/NESHAP rules, EPA has a number of additional tools to either directly or indirectly reduce methane emissions from U.S. natural gas systems, most of which would also support more protective actions at the state level. For example, EPA could do the following:

Figure S-4 | **Projections of GHG Emissions from All Natural Gas Systems after Additional Abatement**



Notes: Potential for additional upstream methane emissions reductions for all natural gas systems based on implementation of a hypothetical rule in 2019 requiring plunger lift systems, leak detection and repair, and replacing existing high-bleed pneumatic devices with low-bleed equivalents (purple line); or a rule requiring those technologies and five additional abatement measures (green line). The light blue dashed line shows the total amount of GHG emissions (MMt CO_2e) that would result from 1 percent fugitive methane emissions relative to total dry gas production in each year, plus estimated annual CO_2.

- *Direct regulation of GHG emissions.* EPA could directly regulate GHG emissions under section 111 of the CAA, which could achieve greater reductions in methane and CO_2 emissions from new and existing sources than would otherwise be achieved indirectly through standards for VOCs or HAPs.

- *Emissions standards for air toxics.* Under section 112 of the CAA, EPA could set emissions standards for HAPs from production-stage infrastructure and operations in urban areas.

- *Supporting best practices*. EPA could do more through Natural Gas STAR and other programs to recognize companies that demonstrate a commitment to best practices. They could further encourage voluntary actions by maintaining a clearinghouse for technologies and practices that reduce all types of air emissions from the oil and natural gas sector.

Enabling State Policy Leadership

State governments play an important role in developing new approaches to reducing air emissions, and they are largely responsible for implementing many federal rules under the CAA. However, they are often short on resources and could benefit from additional policy and technical assistance, particularly given the current rate of expanding U.S. oil and natural gas development and expectations for additional growth in the future. As a first step, state governments could raise new revenues through fees, royalty payments, and severance taxes levied on oil and gas industry activities to secure adequate funding for emissions monitoring and associated regulatory actions. In addition, state governments and EPA could:

- *Provide technical assistance*. Recognizing the central role of state governments in achieving federal National Ambient Air Quality Standards, EPA could provide targeted technical and regulatory assistance to states with expanding oil and natural gas development.

- *Address smog and other air quality problems*. States concerned about smog and other air quality problems associated with unconventional oil and gas development can voluntarily engage with EPA's Ozone Advance Program. Addressing local air quality problems related to this sector will likely have co-benefits, including reduced methane emissions.

- *Develop a policy database*. States with limited recent experience managing oil and natural gas sector development would benefit from a comprehensive and current database of existing state policies and regulatory practices that have been used by others to address environmental risks, including air emissions. This resource, which could be developed and maintained by any credible research organization, would serve as a practical resource for policymakers. It could also be used to help recognize policy gaps or to identify and promulgate model rules or model legislation, as needed.

- *Assistance with environmental regulations*. With more funding, the organization STRONGER (State Review of Oil and Natural Gas Environmental Regulations) could provide more states with timely assistance with the development and evaluation of environmental regulations.

Improve Understanding of Emissions

Basic information on actual air emissions from the oil and natural gas sector is difficult to come by. As noted in Appendix 1 in the full working paper, current emissions estimates are based on assumed emissions factors—as opposed to direct measurements—because there are hundreds of thousands of natural gas wells in the U.S. and direct emissions measurements are expensive. As a result of these data uncertainties, persistent questions remain about the effectiveness of commonly used emissions control technologies. This both raises compliance concerns and reduces the likelihood that a company would invest in pollution control, since the resulting level of product recovery is in question. To improve understanding of emissions, the following actions could be taken by EPA, states, or non-governmental organizations:

- *Analyze emissions data*. EPA and independent researchers should analyze recently published emissions data from the GHG Reporting Rule to better understand regional variability in methane leakage, support regulatory development, and track industry performance over time.

- *Add oil and gas emissions to the TRI*. To better determine which cities and surrounding communities face the greatest risk of exposure to HAPs from oil and natural gas operations, EPA could add oil and natural gas sector emissions to the Toxic Release Inventory (TRI).

- *Estimate production-stage emissions from tight oil wells*. Associated natural gas production is increasing as unconventional oil and gas development shifts toward more oil-rich shale plays (such as North Dakota). Research by EPA and other federal agencies could better understand the climate implications of this trend, including a detailed assessment of production-stage methane emissions from tight-oil well completions.

- *Update emissions factors for key processes*. To help resolve questions regarding the scale of methane emissions from U.S. natural gas infrastructure and operations, EPA or non-governmental organizations could convene a working group of industry experts to develop updated emissions factors for key processes such as liquids unloading operations. Findings of this research could be used to improve subsequent emissions estimates reported under the GHG Reporting Program.

- *Establish a database for voluntary air emissions reporting*. To encourage greater transparency regarding emissions from oil and natural gas sector companies, EPA or states could establish a database for voluntary reporting of all types of air emissions from the sector.

Research to Improve Technology and Policy Options

While this paper has identified a suite of technology and policy options for reducing methane emissions from natural gas systems, the expected expansion of natural gas production means continued improvement will be necessary to keep pace.

- Efforts to reduce upstream GHG emissions from natural gas systems could be aided by applied technology research and development to improve emissions measurements, and to develop new and lower cost methane emission reduction strategies.

- Further policy research is needed to identify policy solutions to regulatory barriers and market failures that prevent companies from investing in cost-effective projects that reduce methane emissions and more efficiently use fossil fuels throughout the natural gas life cycle.

Through these and other steps, governments will have the tools they need to achieve continuous air quality improvements over time and slow the rate of climate change by reducing methane emissions to below 1 percent of total natural gas production.

ABOUT WRI

WRI focuses on the intersection of the environment and socio-economic development. We go beyond research to put ideas into action, working globally with governments, business, and civil society to build transformative solutions that protect the earth and improve people's lives.

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ENDNOTES

1. For more details on how the Obama administration can achieve this goal using existing authorities, see the recent WRI report "Can the U.S. Get There from Here? Using Existing Federal Laws and State Actions to Reduce Greenhouse Gas Emissions," available at: http://www.wri.org/publication/can-us-get-there-from-here.
2. This assumes a 100 year time-horizon for integrating the global warming potential (GWP) of methane. Over a 20-year time horizon, end-use combustion represents 60 to 70 percent of most life cycle estimates of total GHG emissions from natural gas.
3. Throughout this report we refer repeatedly to EPA's final 2012 GHG inventory published in April 2012. An updated draft inventory was released by EPA in February 2013, but has not yet been finalized at this writing (see Appendix 1 of the full working paper). EPA's draft 2013 GHG inventory revises downward their estimates of methane emissions from U.S. natural gas systems, with an equivalent reduction in the implied methane leakage rate to approximately 1.54 percent of total production.
4. Note: Definitions of these and other terms can be found in the glossary at the end of the full working paper.
5. This 4 percent methane leakage rate estimate, published by Gabriele Petron and colleagues in the Journal of Geophysical Research, was subsequently challenged in a peer-reviewed article published in the same journal by Michael Levi, who estimated a lower methane leakage rate based on Petron's data.
6. We gratefully acknowledge the experts who attended an all-day workshop that WRI co-hosted with the Environmental Defense Fund, on October 16, 2012. The policy options in this paper were developed based on WRI research. While these options draw heavily from input provided at the workshop, they are not necessarily endorsed by the workshop participants.