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An Overview of Air Quality Issues in Natural Gas Systems

Richard K. Lattanzio
Analyst in Environmental Policy

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Summary

Natural Gas Systems and Air Pollution

Congressional interest in U.S. energy policy has focused in part on ways through which the United States could secure more economical and reliable fossil fuel resources both domestically and internationally. Recent expansion in natural gas production, primarily as a result of new or improved technologies (e.g., hydraulic fracturing, directional drilling) used on unconventional resources (e.g., shale, tight sands, and coal-bed methane), has made natural gas an increasingly significant component in the U.S. energy supply. This expansion, however, has prompted questions about the potential impacts of natural gas systems on human health and the environment, including impacts on air quality.

Natural gas systems contribute to air pollution in several ways, including (1) the leaking, venting, and combustion of natural gas in the course of production operations, and (2) the combustion of other fossil fuel resources during associated operations. Emission sources include pad, road, and pipeline construction; well drilling, completion, and flowback activities; and gas processing and transmission equipment such as controllers, compressors, dehydrators, pipes, and storage vessels. Pollutants include, most prominently, methane and volatile organic compounds—of which the natural gas industry is one of the highest-emitting industrial sectors in the United States—as well as nitrogen oxides, sulfur dioxide, particulate matter, and various forms of hazardous air pollutants.

EPA's Air Standards for the Sector

The U.S. Environmental Protection Agency (EPA), in response to a consent decree issued by the U.S. Court of Appeals, D.C. Circuit, promulgated air standards for several source categories in the crude oil and natural gas sector on August 16, 2012. These standards revised existing rules and promulgated new ones to regulate emissions of volatile organic compounds (VOCs), sulfur dioxide, and hazardous air pollutants (HAPs) from many production and processing activities that had never before been covered by federal standards (including, most notably, VOC controls on new hydraulically fractured natural gas wells). Further, EPA has announced its intention to propose amendments to these standards in the summer of 2015 to address both currently uncovered sources and methane emissions.

EPA's standards control air pollution, in part, through the capture of fugitive releases of natural gas. Thus, compliance with the standards has the potential to translate into economic benefits, as producers may be able to offset abatement costs with the value of product recovered and sold at market. Using this assumption, EPA estimated the annual benefits of the standards to be VOC reductions of 190,000 tons, HAP reductions of 12,000 tons, methane reductions of 1.0 million tons, and a net cost savings of $11 million to $19 million after the sale of recovered product. Industry and other stakeholders have disputed these figures as both too high and too low. Moreover, the expansion of both industry production and government regulation of natural gas has sparked discussion on a number of outstanding issues, including:

- defining the roles of industry, local, state, and federal governments,
- establishing comprehensive emissions data,
- understanding the human health and environmental impacts of emissions,

- determining the proper control of pollutants and sources, and
- estimating the costs of pollution abatement.

Scope and Purpose of This Report

This report provides information on the natural gas industry and the types and sources of air pollutants in the sector. It examines the role of the federal government in regulating these emissions, including the provisions in the Clean Air Act and the regulatory activities of EPA. It concludes with a brief discussion of the aforementioned outstanding issues.

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Background

Congressional interest in U.S. energy policy has focused in part on ways through which the United States could secure more economical and reliable fossil fuel resources both domestically and internationally. Recent expansion in natural gas production, primarily as a result of new or improved technologies (e.g., hydraulic fracturing)[1] used on unconventional resources (e.g., shale, tight sands, and coal-bed methane),[2] has made natural gas an increasingly significant component in the U.S. energy supply. While the practice of hydraulic fracturing is not new, relatively recent innovations have incorporated processes such as directional drilling, high-volume slick-water injection, and multistage fractures to get to previously unrecoverable resources. As a result, the United States has again become the largest producer of natural gas in the world.[3] The U.S. Energy Information Administration projects unconventional gas activity to more than double from 2010 to 2040 and forecasts that it will make up almost 80% of total U.S. natural gas production by 2040.[4] In addition, some analysts believe that by significantly expanding the domestic gas supply, the exploitation of new unconventional resources has the potential to reshape energy policy at national and international levels—altering geopolitics and energy security, recasting the economics of energy technology investment decisions, and shifting trends in greenhouse gas (GHG) emissions.[5]

Many in both the public and private sector have advocated for the increased production and use of natural gas because the resource is domestically available, economically recoverable, and considered a potential "bridge" fuel to a less polluting and lower GHG-intensive economy.[6] Natural gas is cleaner burning than other fossil fuels, emitting, on average, about half as much

[1] Hydraulic fracturing (hydrofracking, fracking, or fracing) is commonly defined as an oil or gas well completion process that directs pressurized fluids typically containing any combination of water, proppant, and any added chemicals to penetrate tight rock formations, such as shale or coal formations, in order to stimulate the oil or gas residing in the formation and that subsequently requires high-rate, extended flowback to expel fracture fluids and solids. The National Petroleum Council estimates that hydraulic fracturing will account for nearly 70% of natural gas development within the next decade. See National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," September 15, 2011. For more discussion on this technology, see CRS Report R43148, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*.

[2] These unconventional resources are commonly defined as follows: Tight sands gas is natural gas trapped in low permeability and nonporous sandstones. Shale gas is natural gas trapped in shale deposits, a very fine-grained sedimentary rock that is easily breakable into thin, parallel layers. Coal-bed methane is natural gas trapped in coal seams. These resources are referred to as "unconventional" because, in the broadest sense, they are more difficult and/or less economical to extract than "conventional" natural gas, usually because the technology to reach them has not been developed fully or has been too expensive. For a more detailed discussion of these definitions, see the Natural Gas Supply Association's website at http://naturalgas.org/overview/resources/.

[3] The United States surpassed Russia as the world's leading producer of dry natural gas beginning in 2009. See U.S. Energy Information Administration, "Today in Energy," March 13, 2012, http://www.eia.gov/todayinenergy/detail.cfm?id=5370.

[4] U.S. Energy Information Administration (EIA), *Annual Energy Outlook, 2014*, http://www.eia.gov/forecasts/aeo/mt_naturalgas.cfm.

[5] For more discussion on natural gas resources, see CRS Report R43636, *U.S. Shale Gas Development: Production, Infrastructure, and Market Issues*.

[6] Support for the natural gas industry has also come from the Obama Administration. In his 2012 State of the Union speech, President Obama stated, "We have a supply of natural gas that can last America nearly 100 years, and my administration will take every possible action to safely develop this energy." President Barack Obama, "Remarks by the President in State of the Union Address," Washington, DC, January 24, 2012, http://www.whitehouse.gov/the-press-office/2012/01/24/remarks-president-state-union-address.

carbon dioxide as coal and one-quarter less than oil when consumed in a typical electric utility plant.[7] Further, natural gas combustion emits no mercury—a persistent, bioaccumulative neurotoxin—virtually no particulate matter, and less sulfur dioxide and nitrogen oxides, on average, than either coal or oil. For these reasons, pollution control measures in natural gas systems have traditionally received less attention relative to those in other hydrocarbon industries. However, the recent increase in natural gas production, specifically from unconventional resources, has raised a new set of questions regarding environmental impacts. These questions centered initially on water quality issues, including the potential contamination of groundwater and surface water from hydraulic fracturing and related production activities. They have since incorporated other issues, such as water management practices (both consumption and discharge), land use changes, induced seismicity, and air pollution. These questions about hydraulic fracturing in unconventional reservoirs has led, in part, to the rise of various grassroots movements, some political opposition, and calls for additional regulatory actions, moratoria, and/or bans on the practice at the local, state, and federal levels.

Currently, the development of natural gas in the United States is regulated under a complex set of local, state, and federal laws that addresses many—but not all—aspects of exploration, production, and distribution. State and local authorities are responsible for virtually all of the day-to-day regulation and oversight of natural gas systems. The organization of this oversight within each gas-producing jurisdiction varies considerably. In general, each state has one or more regulatory agencies that may permit wells, including their design, location, spacing, operation, and abandonment and may regulate for environmental compliance. With respect to pollution controls, state laws may address many aspects of water management and disposal, air emissions, underground injection, wildlife impacts, surface disturbance, and worker health and safety.

Furthermore, several federal statutes address pollution control measures in natural gas systems, and, where applicable, these controls are largely implemented by state and local authorities. For example, the Clean Water Act regulates surface discharges of water associated with natural gas drilling and production as well as contaminated storm water runoff from production sites.[8] The Safe Drinking Water Act regulates the underground injection of wastewater from crude oil and natural gas production and the underground injection of fluids used in hydraulic fracturing if the fluids contain diesel fuel.[9] The Clean Air Act (CAA) limits emissions from associated engines and gas processing equipment as well as some natural gas extraction, production, and processing activities.

[7] These values are averages based on carbon dioxide emitted per unit of energy generated. See EIA, Office of Oil and Gas. Carbon Monoxide: derived from EIA, *Emissions of Greenhouse Gases in the United States 1997*, Table B1, p. 106. Other pollutants derived from U.S. Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors, Vol. 1, Stationary Point and Area Sources*, 1998, http://www.epa.gov/ttn/chief/ap42/.

[8] For more discussion, see CRS Report R42333, *Marcellus Shale Gas: Development Potential and Water Management Issues and Laws*, by Mary Tiemann et al.

[9] For more discussion, see CRS Report R41760, *Hydraulic Fracturing and Safe Drinking Water Act Regulatory Issues*, by Mary Tiemann and Adam Vann.

Natural Gas Systems and Air Pollution

The Industry

Natural gas is a nonrenewable fossil fuel that is used both as an energy source (for heating, transportation, and electricity generation) and as a chemical feedstock (for such varied products as plastic, fertilizer, antifreeze, and fabrics). The natural gas that the nation uses—to heat homes and to fuel electric utilities—is the product of a long process beginning with the exploration and extraction of the resource and leading to its treatment in processing facilities, transportation to distributors, and eventual delivery through a long network of pipelines to consumers. Raw natural gas is commonly recovered from geologic formations in the ground through drilling and extraction activities by the oil and gas industry.[10] This industry includes operations in the production of crude oil and natural gas as well as the processing, transmission, and distribution of natural gas. For both operational and regulatory reasons, the industry is commonly separated into four major sectors: (1) crude oil and natural gas production, (2) natural gas processing,[11] (3) natural gas transmission and storage, and (4) natural gas distribution. This report uses these basic categories to track the various activities in natural gas systems, including the operations, emissions, and regulations discussed below. While the focus of this report is on the production sector, it also highlights air quality issues in other sectors, where appropriate.

The Resource

Raw natural gas is primarily a mixture of low molecular-weight hydrocarbon compounds that are gaseous in form at normal conditions. While the principal component of natural gas is methane (CH_4), it may contain smaller amounts of other hydrocarbons, such as ethane, propane, and butane, as well as heavier hydrocarbons. These nonmethane hydrocarbons include types of volatile organic compounds (VOCs), classified as ozone (i.e., smog) precursors, as well as, in some cases, hazardous (i.e., toxic) air pollutants (HAPs). Nonhydrocarbon gases—such as carbon dioxide (CO_2), helium (He), hydrogen sulfide (H_2S), nitrogen (N_2), and water vapor (H_2O)—may also be present in any proportion to the total hydrocarbon content. The chemical composition of raw natural gas varies greatly across resource reservoirs, and the gas may or may not be "associated" with crude oil resources. When natural gas is found to be primarily methane, it is referred to as "dry" or "pipeline quality" gas. When natural gas is found bearing higher percentages of heavier hydrocarbons, nonhydrocarbon gases, and/or water vapor, it is commonly referred to as "wet," "rich," or "hot" gas. Similarly, quantities of VOCs, HAPs, and H_2S can vary significantly depending upon the resource reservoir. VOC and HAP compositions typically account for only a small percentage of natural gas mixtures; however, this ratio increases the "wetter" the gas. Natural gas mixtures with a higher percentage of H_2S are generally referred to as "sour" or "acid" gas. These varying characteristics may cause both industry operations and regulatory oversight to differ across resource reservoirs.

[10] Natural gas can also be recovered as a byproduct from various other sources including mining, industrial, or agricultural processes. These secondary sources are not discussed in this report. For a more detailed description of the oil and gas industry, see CRS Report R40872, *U.S. Fossil Fuel Resources: Terminology, Reporting, and Summary*, by Carl E. Behrens, Michael Ratner, and Carol Glover.

[11] Petroleum refining (i.e., crude oil processing after the production phase) is classified as another industry sector for regulatory purposes and is not discussed in this report.

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Types of Emissions

Natural gas systems release air emissions in several different ways. The report categorizes these emissions into three types: *fugitive, combusted*, and *associated*.

Fugitive refers to the natural gas vapors that are released to the atmosphere during industry operations. Fugitive emissions can be either intentional (i.e., vented) or unintentional (i.e., leaked). Intentional emissions are releases that are designed specifically into the system: for example, emissions from vents or blow-downs used to guard against over-pressuring or gas-driven equipment used to regulate pressure or store or transport the resource. Conversely, unintentional emissions are releases that result from uncontrolled leaks in the system: for example, emissions from routine wear, tear, and corrosion; improper installation or maintenance of equipment; or the overpressure of gases or liquids in the system. Fugitive emissions can contain several different kinds of air pollutants, including methane, VOCs, and HAPs.

Combusted refers to the byproducts that are formed from the burning of natural gas during industry operations. Combusted emissions are commonly released through either the flaring of natural gas for safety and health precautions[12] or the combustion of natural gas for process heat, power, and electricity in the system (e.g., for compressors and other machinery). The chemical process of combusting natural gas releases several different kinds of air pollutants, including CO_2, carbon monoxide (CO), nitrogen oxides (NO_x), and trace amounts of sulfur dioxide (SO_2) and particulate matter (PM).

Associated refers to secondary sources of emissions that arise from associated operations in natural gas systems. Associated emissions may result from the combustion of other fossil fuels (i.e., other than the natural gas stream) to power equipment, machinery, and transportation as well as the associated release of dust and PM from construction, operations, and road use. Associated emissions have the potential to contribute significantly to air pollution.[13]

The focus of this report is on fugitive and combusted natural gas emissions. Notwithstanding the additional emissions from associated sources, the primary focus of this report is on air quality issues related to the resource itself (i.e., the fugitive release of natural gas and its combustion during operations). It is this release of natural gas—and the pollutants contained within it—that makes air quality considerations in the crude oil and natural gas sector unique from other industrial-, construction-, and transportation-intensive sectors.

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[12] Flaring is a means to eliminate natural gas that may be impracticable to use, capture, or transport. As with venting, the primary purpose of flaring is to act as a safety device to minimize explosive conditions. Gas may be flared at many points in the system; however, it is most common during the drilling and well completion phases, specifically at oil wells with associated gas. Compared to vented emissions, combustion is generally considered a better pollution control mechanism because the process serves to incinerate many of the VOCs and HAPs that would otherwise be released directly into the atmosphere.

[13] Air standards for various mobile and stationary source engines are covered in several parts of the *Code of Federal Regulations*, including 40 C.F.R. Part 60, Subpart JJJJ—Standards of Performance for Stationary Spark Ignition (SI) Internal Combustion Engines (ICE) and 40 C.F.R. Part 60, Subpart IIII—Standards of Performance for Stationary Compression Ignition (CI) ICEs as well as 40 C.F.R. Part 80, et seq.—Regulations of Fuels and Fuel Additives. For more information about standards for particulate matter, see CRS Report R40096, *2006 National Ambient Air Quality Standards (NAAQS) for Fine Particulate Matter (PM2.5): Designating Nonattainment Areas*, by Robert Esworthy.

Sources of Emissions

Natural gas systems include many activities and pieces of equipment that have the potential to emit air pollutants.

Production Sector (Upstream). Production operations include the wells and all related processes used in the extraction, production, recovery, lifting, stabilization, separation, and treating of oil and/or natural gas. Production operations span the initial well drilling, hydraulic fracturing, and well completion activities and include not only the "pads" where the wells are located but also the sites where oil, condensate, produced water, and gas from several wells may be separated, stored, and treated as well as the gathering pipelines, compressors, and related components that collect and transport the oil, gas, other materials, and wastes from the wells to the refineries or natural gas processing plants. Emissions of fugitive gas can be released both intentionally and unintentionally from many of these activities and pieces of equipment.

Since production operations occur upstream from gas processing, any fugitive release of gas may include quantities of VOCs, H_2S, HAPs, and other pollutants at concentrations found within the reservoirs. Further, as some of these processes involve the removal of wastes and byproducts from the natural gas stream, the types and quantities of emissions may be dependent upon how the wastes are managed (e.g., venting, flaring, separation and storage). Historically, the greatest concern over air emissions from the production sector has focused on leaks from equipment and pipelines as well as combustion exhaust from compressor stations. Recently, however, concern has incorporated other activities such as drilling, hydraulic fracturing, well completion, and workovers.

Processing Sector (Midstream). Processing operations are used to separate out the byproducts and wastes from raw natural gas in order to produce "pipeline quality" or "dry" natural gas for consumption. Due to the many and varied activities involved in these operations, natural gas processing plants have the potential to release significant quantities of air pollutants. These emissions result from the combustion of natural gas and other fossil fuels in compression engines as well as from the fugitive release of VOCs, SO_2, and HAPs from separators, dehydrators, and sweetening units used to extract byproducts and wastes from the natural gas stream.

Transmission, Storage, and Distribution Sectors (Downstream). After processing, dry natural gas enters pipelines in the transmission, storage, and distribution sectors for delivery to utilities and consumers. Nationwide, natural gas systems consist of thousands of miles of pipe, including both mains and customer service lines, as well as compressors, storage facilities, and metering stations, which allow companies to both move and monitor the natural gas in the system. Due to the extensive network of pipelines, valves, pumps, and other components within the transmission, storage, and distribution sectors, fugitive releases of gas collectively can be a significant source of emissions. However, because these activities generally occur after processing, VOC, H_2S, and HAP content can be minimal, with methane remaining the primary component.

Pollutants

Air pollutants associated with natural gas systems include, most prominently, methane and volatile organic compounds—of which the crude oil and natural gas sector is one of the highest-emitting industrial sectors in the United States—as well as nitrogen oxides, sulfur dioxide, particulate matter, and various forms of hazardous air pollutants.

Methane (CH_4). Methane—the principal component of natural gas—is both a precursor to ground-level ozone formation (i.e., smog)[14] and a potent GHG,[15] albeit with a shorter climate-affecting time horizon than carbon dioxide. Every process in natural gas systems has the potential to emit methane. EPA's *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013* (released February 11, 2015) estimates 2013 methane emissions from "Natural Gas Systems" to be 6,396 gigagrams (Gg) (equivalent to 332.1 billion standard cubic feet (bscf), or 1.3% of the industry's marketed production that year.[16] In 2013, natural gas systems represented nearly 25% of the total methane emissions from all domestic sources and accounted for approximately 3% of all GHG emissions in the United States (this figure does not include the GHG emissions associated with the end-use combustion of the gas). Natural gas systems are currently the second largest contributor to U.S. anthropogenic (i.e., man-made) methane emissions, behind enteric fermentation.[17] Because of methane's effects on climate, EPA has found that it, along with five other well-mixed GHGs, endangers public health and welfare within the meaning of the CAA.[18]

Volatile Organic Compounds (VOCs)—A Ground-Level Ozone (O_3) Precursor. The oil and natural gas sector is currently one of the largest sources of VOC emissions in the United States, accounting for approximately 18% of VOC emissions nationwide (and representing almost 40% of VOC emissions released by industrial source categories).[19] VOCs—in the form of various hydrocarbons—are emitted throughout a wide range of natural gas operations and equipment. The interaction between VOCs and NO_x in the atmosphere contributes to the formation of ozone (i.e., smog). Ozone exposure is linked to several respiratory ailments.

[14] While methane is a precursor to ground-level ozone formation, it is less reactive than other hydrocarbons. Thus, EPA has officially excluded it from the definition of regulated hydrocarbons called volatile organic compounds (VOCs). See EPA, *Conversion Factors for Hydrocarbon Emission Components*, Washington, DC, EPA-420-R-10-015, July 2010, p. 2, http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2010/420r10015.pdf.

[15] As a GHG, methane emitted into the atmosphere absorbs terrestrial infrared radiation, which contributes to increased global warming and continuing climate change. According to the Intergovernmental Panel on Climate Change *Fifth Assessment Report 2013*, in 2011, methane concentrations in the atmosphere exceeded preindustrial levels by 150%. Further, they contributed about 16% to global warming due to anthropogenic GHG sources, making methane the second-leading climate forcer after CO_2 globally. While the perturbation lifetime for methane is 12 years, CO_2's is considerably longer and does not undergo a simple decline over a single predictable timescale. For further discussion on climate change and its potential impacts, see CRS Report RL34266, *Climate Change: Science Highlights*, by Jane A. Leggett.

[16] EPA reported 2013 methane emissions from natural gas systems as 6,396.0 Gg, equivalent to 159.9 million metric tons of carbon dioxide equivalent ($MMtCO_2e$). EPA reported 2013 methane emissions from all sources as 654.1 $MMtCO_2e$ and 2013 total GHG emissions from all sources as 6,742.2 $MMtCO_2e$. EPA, *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013,* February 11, 2015, http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html. Here, as elsewhere in the report, GHGs are quantified using a unit measurement called carbon dioxide equivalent (CO_2e), wherein gases are indexed and aggregated against one unit of CO_2. This index is commonly referred to as the Global Warming Potential. The EIA reports 2013 U.S. natural gas marketed production as 25,691 bscf. See http://www.eia.gov/dnav/ng/hist/n9050us2a.htm. CRS used a conversion of 1 Gg = 0.051921 bscf. For more discussion of methane, see CRS Report R43860, *Methane: An Introduction to Emission Sources and Reduction Strategies*.

[17] Enteric fermentation refers to emissions produced by the digestive processes in ruminant livestock.

[18] EPA, "Endangerment and Cause or Contribute Findings for Greenhouse Gases," 74 *Federal Register* 66496-66516, December 15, 2009.

[19] The 2011 National Emissions Inventory estimated VOC emissions from "petroleum and related industries" at 2.7 million tons. Mobile sources are the highest category for VOC emissions domestically at 32.9% in 2011. Data for VOCs, as well as the other criteria and HAP pollutants, are derived from EPA's National Emissions Inventory and can be found at http://www.epa.gov/ttn/chief/eiinformation.html.

Nitrogen Oxides (NO_x)—A Ground-Level Ozone (O_3) Precursor. Significant amounts of NO_x are emitted at natural gas sites through the combustion of natural gas and other fossil fuels (e.g., diesel). This combustion occurs during several activities, including (1) the flaring of natural gas during drilling and well completions, (2) the combustion of natural gas to drive the compressors that move the product through the system, and (3) the combustion of fuels in engines, drills, heaters, boilers, and other production, construction, and transportation equipment.[20] In addition to its contribution to ozone formation, NO_x exposure is linked to several other respiratory ailments.

Hazardous Air Pollutants (HAPs). HAPs, also known as air toxics, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive diseases, or birth defects. Of the HAPs emitted from natural gas systems, VOCs are the largest group and typically evaporate easily into the air. The most common HAPs in natural gas systems are n-hexane, the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and hydrogen sulfide.[21] HAPs are found primarily in natural gas itself and are emitted from equipment leaks and from various processing, compressing, transmission, distribution, or storage operations. They are also a byproduct of fuel combustion and may be components in various chemical additives.

Further, **carbon monoxide (CO)** is emitted from combustion processes in stationary and mobile sources. CO exposure is linked to several respiratory ailments. **Sulfur dioxide (SO_2)** is emitted from crude oil and natural gas production and processing operations that handle and treat sulfur-rich, or "sour," gas. SO_2 exposure is linked to several respiratory ailments. **Particulate matter (PM)** may occur from dust or soil entering the air during well-pad construction, traffic on access roads, and fuel exhaust from drilling machinery, vehicles, and other engines. PM exposure is linked to several respiratory and cardiovascular ailments.

The Clean Air Act and the Federal Role

The CAA[22] seeks to protect human health and the environment from emissions that pollute ambient, or outdoor, air.[23] It requires EPA to establish minimum national standards for air emissions from various source categories (e.g., "Crude Oil and Natural Gas Production" and the "Natural Gas Transmission and Storage" are defined as source categories), and assigns primary responsibility to the states to assure compliance with the standards. EPA has largely delegated day-to-day responsibility for CAA implementation to all 50 states, including permitting, monitoring, inspections, and enforcement. In many cases, states have further delegated program implementation to local governments. Sections of the CAA that are most relevant to air quality issues in natural gas systems are outlined in the following sections.

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[20] NO_x emissions from engines and turbines are covered by 40 C.F.R. Section 60, Subpart JJJJ and KKKK respectively.

[21] Hydrogen sulfide was on the original list of hazardous air pollutants in the CAA, Section 112(b), but was subsequently removed by Congress. Currently, hydrogen sulfide is regulated under the CAA's Accidental Release Program, Section 112(r)(3). According to EPA, there are 14 major areas found in 20 different states where hydrogen sulfide is commonly found in natural gas deposits. As a result of drilling in these areas, "the potential for routine [hydrogen sulfide] emissions is significant." See EPA, *Report to Congress on Hydrogen Sulfide Air Emissions Associated with the Extraction of Oil and Natural Gas*, EPA-453/R-93-045, October 1993, at ii, III-35; see also ii, II-5 to II-11.

[22] 42 U.S.C. 7401 et seq. For a summary of the CAA and EPA's air and radiation activities and its authorities, see EPA's website at http://www.epa.gov/air/basic.html; and CRS Report RL30853, *Clean Air Act: A Summary of the Act and Its Major Requirements*, by James E. McCarthy and Claudia Copeland.

[23] "Outdoor" is defined as that to which the public has access (see 40 C.F.R. §50.1(e)).

National Ambient Air Quality Standards

Section 109 of the CAA requires EPA to establish National Ambient Air Quality Standards (NAAQS) for air pollutants that may reasonably be anticipated to endanger public health or welfare and whose presence in ambient air results from numerous or diverse sources. Using this authority, EPA has promulgated NAAQS for sulfur dioxide (SO_2), particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), and lead. States are required to implement specified air pollution control plans to monitor these pollutants and ensure the NAAQS are met or "attained." Additional measures are required in areas not meeting the standards, referred to as "nonattainment areas." "Nonattainment" findings for ground-level ozone, nitrogen oxides, and sulfur dioxide in areas with crude oil and natural gas operations may result in states establishing specific pollution control mechanisms that could affect the industry.

Air Permits

The CAA Amendments of 1990 add Title V,[24] which requires major sources of air pollution to obtain operating permits. Primary responsibility for Title V permitting has been delegated by EPA to state and local authorities. Sources subject to the permit requirements generally include new or modified sources that emit or have the potential to emit 100 tons per year of any regulated pollutant, plus new or existing "area sources" that emit or have the potential to emit lesser specified amounts of HAPs. While some natural gas processing facilities are covered as "major sources" under Title V, most crude oil and natural gas production activities upstream from the processing plant are not classified as "major sources."[25]

Greenhouse Gas Reporting

In the FY2008 Consolidated Appropriations Act (H.R. 2764; P.L. 110-161), Congress directs EPA to develop regulations that establish a mandatory GHG reporting program that applies to emissions that are "above appropriate thresholds in all sectors of the economy." EPA issued the Mandatory Reporting of Greenhouse Gases Rule,[26] which became effective on December 29, 2009. It includes reporting requirements for many facilities in the crude oil and natural gas sector.[27] EPA collects these data to inform the agency's annual *Inventory*.

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[24] 42 U.S.C. §§7661-7661f. For background, see CRS Report RL33632, *Clean Air Permitting: Implementation and Issues*, by Claudia Copeland.

[25] EPA's guidance for "major source" determinations includes consideration of proximity, ownership, and industrial grouping. For a more detailed discussion on major source determination for facilities in the crude oil and natural gas sector, see the "Major Source Aggregation" section of this report.

[26] EPA, "Mandatory Reporting of Greenhouse Gases," 74 *Federal Register* 56260, October 30, 2009.

[27] EPA, "Mandatory Reporting of Greenhouse Gases: Petroleum and Natural Gas Systems," 75 *Federal Register* 74458, November 30, 2010; see final rule revision to Subpart W—Petroleum and Natural Gas Systems—amending 40 C.F.R. §98 (i.e., the regulatory requirements for the program). Several amendments to the reporting methodology have been proposed and promulgated since 2010. See EPA's GHGRP data at http://www.epa.gov/ghgreporting/ghgdata/reported/petroleum.html; and a summary of the amendments at http://www.epa.gov/ghgreporting/reporters/subpart/w-regdocs.html.

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New Source Performance Standards

Section 111 of the CAA requires EPA to promulgate regulations establishing emission standards that are applicable to new, modified, and reconstructed sources—if such sources cause or contribute significantly to air pollution that may reasonably be anticipated to endanger public health or welfare. A New Source Performance Standard (NSPS) reflects the degree of emission limitation achievable through the application of the "best system of emission reduction," which EPA determines has been adequately demonstrated. EPA has had minimum standards for VOCs and SO_2 at processing facilities in the oil and gas industry for over a decade.

On August 16, 2012, EPA promulgated new standards for several sources in the "Crude Oil and Natural Gas Production" and the "Natural Gas Transmission and Storage" source categories never before regulated at the federal level. The 2012 standards aim to control VOC emissions from new or modified onshore natural gas wells, centrifugal compressors, reciprocating compressors, pneumatic controllers, storage vessels, and leaking components at onshore natural gas processing plants as well as SO_2 emissions from new or modified onshore natural gas processing plants.[28]

The 2012 standards include, most prominently, a requirement for producers to reduce VOC emissions by 95% from an estimated 11,000 new hydraulically fractured gas wells each year through the use of "reduced emissions completions" (RECs) or "green completions." RECs are defined by EPA as "well completion[s] following fracturing or refracturing where gas flowback that is otherwise vented is captured, cleaned, and routed to the flow line or collection system, re-injected into the well or another well, used as an on-site fuel source, or used for other useful purpose that a purchased fuel or raw material would serve, with no direct release to the atmosphere." The rule also requires certain pneumatics, storage vessels, and compressors to achieve at least a 95% reduction of VOC emissions.

On April 12, 2013, EPA made several amendments to the 2012 standards, including (1) establishing the definition of "flowback period" for the purposes of compliance, (2) making several changes to storage vessel provisions, and (3) removing an affirmative defense provision that shielded facility operators from civil penalties for violations resulting from malfunction.[29]

On January 14, 2015, EPA announced several new initiatives with respect to the 2012 standards, including its intentions to (1) "set standards for methane and VOC emissions from new and modified oil and gas production sources, and natural gas processing and transmission sources" uncovered by the 2012 NSPS; and (2) extend VOC reduction requirements to existing oil and gas sources in ozone nonattainment areas and states in the Ozone Transport Region.[30] A proposed rule is scheduled for release in the summer of 2015.

[28] EPA, "Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews, Final Rule," 77 *Federal Register* 49489, August 16, 2012. These standards, in part, revised existing standards promulgated by EPA, including NSPS for Equipment Leaks of VOCs from Onshore Natural Gas Processing Plants (40 C.F.R. Part 60, Subpart KKK) and NSPS for SO_2 Emissions for Onshore Natural Gas Processing (40 C.F.R. Part 60, Subpart LLL). The new NSPS are codified as 40 C.F.R. Part 60, Subpart OOOO.

[29] EPA, "Oil and Natural Gas Sector: Reconsideration of Additional Provisions of New Source Performance Standards," 79 *Federal Register* 79018, December 31, 2014.

[30] Executive Office of the President, "FACT SHEET: Administration Takes Steps Forward on Climate Action Plan by Announcing Actions to Cut Methane Emissions," January 14, 2015, https://www.whitehouse.gov/the-press-office/2015/01/14/fact-sheet-administration-takes-steps-forward-climate-action-plan-anno-1.

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National Emission Standards for Hazardous Air Pollutants

Section 112 of the CAA requires EPA to promulgate National Emissions Standards for Hazardous Air Pollutants (NESHAPs). NESHAPs are applicable to both new and existing sources of HAPs, and there are NESHAPs for both "major" sources and "area" sources of HAPs.[31] The aim is to develop technology-based standards that require emission levels met by the best existing facilities (commonly referred to as maximum achievable control technology, or MACT, standards). The pollutants of concern in natural gas systems are, most prominently, the BTEX compounds, carbonyl sulfide, and n-hexane. EPA promulgated NESHAPs for both the "Crude Oil and Natural Gas Production" and the "Natural Gas Transmission and Storage" sectors in 1999. These standards contain provisions for both major sources and area sources of HAPs and include storage vessels with flash emissions (major sources only), equipment leaks (major sources only), and dehydrators (major and area sources).[32] The air standards promulgated on August 16, 2012, revised the existing NESHAPs to establish MACT standards for "small" dehydrators (which were unregulated under the initial NESHAPs), strengthen the leak detection and repair requirements, and retain the existing NESHAPs for storage vessels.

Issues for Congress

The expansion of both industry production and government regulation of natural gas systems has sparked discussion on a number of outstanding issues. Some of the more significant debates involving air quality concerns are outlined in the following sections.

The Regulatory Role of Federal, State, and Local Governments

Federal regulation of air emissions in the oil and gas industry remains controversial. According to EPA, the 2012 federal air standards are designed to provide minimum requirements for emissions of air pollutants from the crude oil and natural gas sector that can both protect human health and the environment and allow for continued growth in production. However, some believe that state and local governments are better positioned to develop these emission standards. They argue that a distant federal bureaucracy unfamiliar with local conditions is rarely the best entity to ensure that environmental needs are balanced with economic growth and job creation. They claim that states can more readily address the regional and state-specific character of many crude oil and natural gas activities, including differences in geology, hydrology, climate, topography, industry characteristics, development history, state legal structures, population density, and local economics and the effects these components have on air quality. They argue that federal rules add unnecessary and often repetitive requirements on the industry, which may increase project costs and delays with little added benefit. Others, attesting to the "patchwork" of state and local requirements, support the need for the federal government to institute minimum standards for emissions that are consistent and predictable and reach across state lines. They claim that a federal standard could extend regulatory certainties to the industry and would best ensure health and environmental protections for all stakeholders.

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[31] A major source of HAPs is one with the potential to emit in excess of 10 tons per year (Tpy) of any single HAP or 25 Tpy of two or more HAPs combined. Area sources are those sources that are not "major."

[32] See NESHAPs from Oil and Natural Gas Production Facilities (40 C.F.R. Part 63, Subpart HH) and NESHAPs from Natural Gas Transmission and Storage Facilities (40 C.F.R. Part 63, Subpart HHH).

Covered Sources and Pollutants

The 2012 federal air standards focus primarily on the upstream sectors of the oil and gas industry and cover only some of the pollutants and potential sources of emissions. The standards regulate emissions of VOCs from some, but not all, of the equipment and activities at new or modified onshore natural gas well sites, gathering and boosting stations, and processing plants. Similarly, the standards regulate emissions of SO_2 from new or modified sweetening units at some natural gas processing plants as well as HAPs from some dehydration units and storage facilities in the sector. The scope of the 2012 federal standards are the result of several factors, including (1) EPA-conducted cost-benefit and risk analyses, (2) stakeholder comments provided to the agency during rulemaking, and (3) statutory limitations placed upon the agency by provisions in the CAA.[33] Some pollutants from natural gas systems remain uncovered by any federal law or regulation, and critics point specifically to methane emissions from the midstream and downstream sectors, as well as hydrogen sulfide, as the most significant omissions.[34] Further, federal standards do not cover emissions from the following sources in the sector: oil wells; offshore sources; coal-bed methane production facilities; field engines, drilling rig engines, and turbines; well-head, transmission, and storage segment compressors; well-head activities such as liquids unloading; heater-treaters; pneumatic devices other than controllers; storage cellars, sumps, and produced water ponds; and leak detection and repair for nonprocessing plant facilities. Finally, due to statutory limitations in the CAA, federal emission standards do not cover VOC or SO_2 emissions from existing sources unless they are classified as HAPs. Since promulgation of the 2012 standards, some of these omissions have led to legal challenges by industry, state, or citizen groups. This, in turn, has led EPA to announce that it may propose changes to the 2012 air standards in the summer of 2015.

Major Source Aggregation

The 2012 federal air standards exempt well completions, pneumatic controllers, compressors, and storage vessels from "major source" determination with respect to CAA Title V permit requirements. Viewed at the component level, these smaller "emissions units" at natural gas facilities may not generate enough pollution on their own to be classified as "major sources." However, it may be possible that an entire natural gas operation (e.g., a well site, a field, or a station) is a "major source" (i.e., one that emits typically 10 tons to 250 tons per year, depending upon the pollutant and the area's attainment status). Determining which equipment and activities should be grouped together, or "aggregated," in the crude oil and natural gas sector for permitting purposes remains an open issue for the states, the courts, EPA, and the regulated entities.[35]

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[33] In the CAA, as amended, Congress sets statutory limitations on EPA's authority to regulate emissions from natural gas systems in several instances. These include specific limitations, such as major and area source determinations for HAPs in Section 112(n), as well as more general limitations, such as the classification of some pollutants prevalent in the industry (e.g., hydrogen sulfide).

[34] Methane is defined as a GHG in the CAA, and EPA has concluded that methane causes or contributes to air pollution, which may reasonably be anticipated to endanger public health or welfare under Section 202(a)(1). At this time, emission controls for methane have not been promulgated for natural gas systems. H_2S is covered under the Accidental Release Program, Section 112(r)(3) of the CAA; however, it is not listed as a HAP under Section 112(b)(1).

[35] For a summary of EPA's most recent determination of major source aggregation for natural gas systems, see Gina McCarthy, "Withdrawal of Source Determinations for Oil and Gas Industries," memorandum to regional administrators, September 22, 2009, http://www.epa.gov/region7/air/nsr/nsrmemos/oilgaswithdrawal.pdf. EPA's determination was vacated in the U.S. Court of Appeals for the Sixth Circuit; see *Summit Petroleum Corp. v. EPA*, 6th Cir., Nos. 09-4348, 10-4572, 8/7/12, http://www.ca6.uscourts.gov/opinions.pdf/12a0248p-06.pdf. EPA is expected to (continued...)

(Contrary to this, "major" and "area" source determinations for NESHAPs in the sector are clearly outlined in the CAA. In Section 112(n)(4), Congress specifically exempts upstream crude oil and natural gas operations from aggregation to determine both major and area source categories for HAPs, excepting some activities near metropolitan areas with populations in excess of 1 million.)

Measurement of Emissions

The 2012 federal air standards are based on EPA's emissions estimates for the crude oil and natural gas sector. While emissions from certain activities and equipment lend themselves to credible estimates, others—specifically fugitive emissions from production activities such as hydraulically fractured well completions, flowback, and produced water ponds—are more difficult to evaluate, have fewer data available, and remain under considerable debate. Currently, the primary source of information on emissions from the sector is a methane study published in 1996 by EPA and the Gas Research Institute (GRI).[36] EPA annually calculates industry emissions using the methodology derived from this report, and while many of the factors have been representative over the period of 1996 to the present, several have been recalculated due to new information (e.g., emission factors for gas well cleanups, condensate storage tanks, and centrifugal compressors). Emission factors for gas well completions in unconventional resources with hydraulic fracturing—which were not industry practice at the time of the EPA/GRI study—have also been added.[37] EPA's inventory has been criticized by industry groups and other sources, many of which have put forth competing, and sometimes conflicting, estimates over the past few years.[38] At this time, a comprehensive national inventory that directly measures the quantity and composition of fugitive emissions from natural gas systems does not exist.[39]

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issue a proposal to address aggregation by May 2015, according to the agency's most recent Unified Agenda of pending regulations, http://www.reginfo.gov/public/do/eAgendaMain. The rule will define "source terms" as they apply to the oil and gas industry under CAA permitting requirements.

[36] Gas Research Institute and EPA, *Methane Emissions from the Natural Gas Industry, Volumes 1-15*, GRI-94/0257 and EPA 600/R-96-080, June 1996.

[37] For greater discussion and detail regarding current emission estimates and historical trends, see CRS Report R43860, *Methane: An Introduction to Emission Sources and Reduction Strategies*.

[38] See, for example, Scott Miller, "Anthropogenic Emissions of Methane in the United States," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 110 no. 50 (December 10, 2013), http://www.pnas.org/content/110/50/20018.abstract, which provides methane emission estimates for the industry roughly 50% greater than that reported by EPA, and Karin Ritter et al., *Understanding GHG Emissions from Unconventional Natural Gas Production*, 2012, http://www.epa.gov/ttnchie1/conference/ei20/session3/kritter.pdf, which provides methane emission estimates roughly half of that reported by EPA for several source categories.

[39] There are several efforts underway aimed at producing a current, comprehensive, and consistent emissions data set for the sector. These include (1) EPA's efforts to update its *Inventory*, as outlined under the White House, "Climate Action Plan: Strategy to Reduce Methane Emissions," March 2014, http://www.whitehouse.gov/blog/2014/03/28/strategy-cut-methane-emissions; (2) the Environmental Defense Fund's *Methane Leakage Study*, http://www.edf.org/methaneleakage; and (3) data harmonization studies of existing inventories (e.g., Adam Brandt, et al., "Methane Leaks from North American Natural Gas Systems," *Science*, vol. 343, no. 6172 [February 14, 2014], pp. 733-735, http://www.sciencemag.org/content/343/6172/733.summary; Garvin Heath et al., "Harmonization of Initial Estimates of Shale Gas Life Cycle Greenhouse Gas Emissions for Electric Power Generation," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 111, no. 31 [August 5, 2014], http://www.pnas.org/content/111/31/E3167.abstract).

Impacts of Emissions

The 2012 federal air standards are based on EPA's expectations that the avoided emissions under the rules would result in improvements in air quality and reductions in health effects associated with exposure to HAPs, ozone, and methane. However, the relationship between air pollution from natural gas systems and its impacts on human health and the environment has yet to be fully quantified and assessed. EPA acknowledges this shortcoming in the rule's proposal, stating that a full quantification of health benefits for the 2012 standards could not be accomplished due to the "unavailability of data and the lack of published epidemiological studies correlating crude oil and natural gas production to respective health outcomes."[40] Nevertheless, it should be noted that comprehensive epidemiological studies are generally difficult, rare, and expensive to conduct, requiring data that are typically absent or inadequate for assessment (e.g., precise and accurate estimates of emissions, fate and transport, and exposure levels as well as impact data on relatively large populations of exposed individuals over extended durations of time). Various stakeholders assert that the lack of published and peer-reviewed literature makes it challenging to scientifically assess the impacts of natural gas operations. Some contend that this uncertainty argues against additional pollution controls at this time. Others maintain that the relevant question for determining whether pollution controls are necessary is whether natural gas systems impact an area's ability to attain air quality standards (NAAQS).

Of the studies that are currently in circulation, some of the impacts of emissions from natural gas systems have been reported as follows:

- Some reports have shown significant increases in VOC and/or ozone levels in several areas of the country with heavy concentrations of drilling, including the Piceance and Denver-Julesburg Basins in Colorado,[41] the Green River Basin in Wyoming,[42] and the Uinta Basin in Utah.[43] The rise in industry-related VOC emissions has been attributed to increased traffic, combustion exhaust, and the fugitive release of natural gas. However, researchers note that the presence of VOCs in the atmosphere is only one of the many factors that contribute to ground-level ozone formation. Several other in-depth surveys of air quality in these regions have shown increases in ozone values due to effects such as stratospheric ozone intrusions[44] as well as drops in ozone values due to mitigating circumstances such as reductions in NO_x concentrations and changes in weather patterns (e.g., the Fort Worth[45] and Uinta[46] Basins).

[40] EPA, *Regulatory Impact Analysis: Proposed New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry*, July 2011, p. 4-1.

[41] Colorado Department of Public Health and Environment, Air Pollution Control Division, *Oil and Gas Emission Sources Presentation for the Air Quality Control Commission Retreat*, May 15, 2008, pp. 3-4.

[42] Wyoming Department of Environmental Quality, *Technical Support Document I for Recommended 8-hour Ozone Designation of the Upper Green River Basin*, March 26, 2009.

[43] Randal Martin et al., *Final Report: Uinta Basin Winter Ozone and Air Quality Study, December 2010-March 2011*, Energy Dynamics Laboratory, Utah State University, for Uintah Impact Mitigation Special Service District, June 14, 2011.

[44] Technical Services Program, Air Pollution Control Division, Colorado Department of Public Health and Environment, "Technical Support Document for the May 24, 2010, Stratospheric Ozone Intrusion Exceptional Event," October 7, 2011.

[45] Texas Commission on Environmental Quality, "A Commitment to Air Quality in the Barnett Shale," *Natural Outlook Newsletter*, Fall 2010.

- Several local, state, and national health agencies have expressed concerns about the health impacts of HAP emissions from natural gas facilities, including the Centers for Disease Control and Prevention (CDC),[47] the Agency for Toxic Substances and Disease Registry (ATSDR),[48] the Association of Occupational and Environmental Clinics and the Pediatric Environmental Health Specialty Units,[49] and the Colorado School of Public Health,[50] among others. These investigations were spurred by community health complaints in regard to natural gas operations such as strong odors, dizziness, nausea, respiratory problems, and eye and skin irritation to more severe concerns including cancer. Some of the reports identified, on average, slightly elevated cancer risks at some sites. Most recommended further investigation into HAP emissions and risks at all sites.
- Finally, a variety of studies have examined the impacts—both positive and negative—of GHG emissions from natural gas systems. Many observe that the combustion of natural gas is less carbon-intensive than other fossil fuels (i.e., on a per-unit-of-energy basis) and claim that fuel switches to natural gas would benefit the climate by reducing overall CO_2 emissions. Other studies, however, focus on the potential impacts of fugitive methane releases and argue that they may contribute significantly to GHG emissions from the sector.[51]

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[46] *2012 Uintah Basin Winter Ozone and Air Quality Study—Summary of Interim Findings, Ongoing Analyses*, *and Additional Recommended Research*, August 7, 2012.

[47] See comments made by Dr. Christopher Portier, head of CDC's National Center for Environmental Health and Agency for Toxic Substances and Disease Registry (ATSDR), as covered on January 5, 2012, by Kevin Begos of the Associated Press, http://www.slopefarms.com/2012/01/08/shale-gas-drilling-and-public-health-first-publication-of-full-text-email-on-public-health-risks-of-from-cdcs-national-center-for-environmental-health-and-agency-for-toxic-substances-and-dis/.

[48] ATSDR, *Health Consultation: Public Health Implications of Ambient Air Exposure to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas Garfield County, Colorado,* 2008, http://www.atsdr.cdc.gov/hac/pha/Garfield_County_HC_3-13-08/Garfield_County_HC_3-13-08.pdf.

[49] Pediatric Environmental Health Specialty Units, *Information on Natural Gas Extraction and Hydraulic Fracturing for Health Professionals*, 2011, http://aoec.org/pehsu/documents/hydraulic_fracturing_and_children_2011_health_prof.pdf.

[50] Roxana Witter et al., *Draft Health Impact Assessment for Battlement Mesa, Garfield County, Colorado*, Colorado School of Public Health, 2011, http://www.garfield-county.com/index.aspx?page=1408; Lisa McKenzie et al., "Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources," *Sci Total Environ.*, May 1, 2012, 424:79-87, http://www.ncbi.nlm.nih.gov/pubmed/22444058.

[51] Methane's global warming potential (or the relative measure of how much heat a greenhouse gas traps in the atmosphere) has been calculated to be 25 to 86 times more potent than carbon dioxide, depending upon the time interval used to express warming impacts; however, its perturbation lifetime in the atmosphere is much shorter. Hence, the climatic effect of replacing other fossil fuels with natural gas may vary widely depending upon the examined time horizon (e.g., 20, 100, or 500 years), the end-use sector (e.g., electricity generation, heating, or transportation) and the fuel replaced (e.g., coal, gasoline, or diesel). For examples of these analyses, see Aranya Venkatesh et al., "Uncertainty in Life Cycle Greenhouse Gas Emissions from United States Natural Gas End-Uses and its Effects on Policy," *Environmental Science and Technology*, vol. 45, no.19 (August 16, 2011), http://pubs.acs.org/doi/abs/10.1021/es200930h; Tom Wigley, "Coal to Gas: The Influence of Methane Leakage," *Climate Change*, vol. 108, no. 3 (October 2011), http://link.springer.com/article/10.1007%2Fs10584-011-0217-3; and Ramón A. Alvarez et al., "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure," *Proceedings of the National Academy of Sciences*, vol. 109, no. 17 (April 24, 2012), http://www.pnas.org/content/109/17/6435.

Cost-Benefit Analysis of Federal Standards

Natural gas is a product of—and thus a source of revenue for—the oil and gas industry. It is also a main source of pollution from the industry when it is emitted into the atmosphere. Due to this unique linkage, pollution abatement has the potential to translate into economic benefits for the industry, as producers may be able to offset compliance costs with the value of natural gas products recovered and sold. To capitalize on these incentives, many recovery technologies have been incorporated into industry practices.[52] The 2012 federal air standards require natural gas producers to use recovery technologies to capture approximately 95% of the methane and VOCs that escape into the air as a result of hydraulic fracturing operations. At the time, EPA reported the potential environmental benefits of the 2012 standards as follows: VOC reductions of 190,000 tons annually, air toxics reductions of 12,000 tons annually, and methane reductions of 1.0 million tons annually.[53] The agency estimated that the equipment and the activities required to comply with the 2012 standards would cost producers about $170 million per year but calculated that incorporating the sale of recovered products into the cost would result in an estimated net gain of about $11 million to $19 million per year. The industry disagreed with these estimates and countered with compliance cost estimates at more than $2.5 billion annually.[54] Third parties, such as Bloomberg Government, projected a net cost between $316 million and $511 million, or less than 1% of industry's annual revenue.[55] All estimates are based on assumptions regarding the quantity of captured emissions, the cost and availability of capital equipment, and the market price for natural gas.

Conclusion

U.S. natural gas production has grown markedly in recent years. This growth is due in large part to increased activities in unconventional resources brought on by technological advance. Many have advocated for the increased production and use of natural gas in the United States for economic, national security, and environmental reasons. They argue that natural gas is the cleanest-burning fossil fuel, with fewer emissions of carbon dioxide, nitrogen oxide, sulfur dioxide, particulate matter, and mercury than other fossil fuels (e.g., coal and oil) on a per-unit-of-energy basis. For these reasons, many have looked to natural gas as a "bridge" fuel to a less polluting and lower GHG-intensive economy. However, the recent expansion in natural gas production in the United States has given rise to a new set of concerns regarding human health and environmental impacts, including impacts on air quality.

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[52] For examples of available technologies and operating practices and the marginal costs associated with their employment, see, for example, ICF International, "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries," prepared for the Environmental Defense Fund, March 2014, http://www.edf.org/sites/default/files/methane_cost_curve_report.pdf.

[53] EPA, "Oil and Natural Gas Sector."

[54] See, for example, Advanced Resources International, *Estimate of Impacts of EPA Proposals to Reduce Air Emissions from Hydraulic Fracturing Operations*, prepared for the American Petroleum Institute, February 2012, http://www.api.org/~/media/Files/Policy/Hydraulic_Fracturing/NSPS-OG-ARI-Impacts-of-EPA-Air-Rules-Final-Report.ashx.

[55] Rich Heidorn Jr., *Fracking Emission Rules: EPA, Industry Miss Mark on Costs, Consequences*, Bloomberg Government, 2012, http://about.bgov.com/2012/07/19/fracking-emissions-rules-re-estimating-the-costs/.

To address air quality and other environmental issues, the oil and gas industry in the United States has been regulated under a complex set of local, state, and federal laws. Currently, state and local authorities are responsible for virtually all of the day-to-day regulation and oversight of natural gas systems, and many states have passed laws and/or promulgated rules to address air quality issues based on local needs. Further to this, organizations such as the State Review of Oil and Natural Gas Environment Regulations (STRONGER) are available to help states assess the overall framework of environmental regulations supporting oil and gas operations in their regions.[56] At the federal level, EPA has promulgated minimum national standards for VOCs, SO_2, and HAPs for some source categories in the crude oil and natural gas sector. The federal air standards focus primarily on the production and processing sectors of the industry and were drawn, in part, from existing requirements found in the state codes of Colorado and Wyoming. Further to this, many producers in the crude oil and natural gas sector have set forth a series of recommended practices. These practices are sustained by the economic incentives provided by capturing the fugitive releases of natural gas and its byproducts to be sold at market. Several voluntary partnerships sponsored by various federal and international agencies also serve to facilitate recommended practices for emissions reductions in the oil and gas industry. EPA's Natural Gas STAR Program, the Global Methane Initiative (formerly the Methane to Markets Partnership), and the World Bank Global Gas Flaring Reduction Partnership are three such programs.[57]

Many believe that air standards similar to those promulgated by Colorado, Wyoming, and the federal government are sufficient to control VOC, SO_2, and HAP emissions from the natural gas production sector. Some argue that the cost of compliance with state and federal air standards could affect industry profits, thereby reducing economic interest to invest and slowing production activities. Others are concerned that some pollutants and some emission sources remain unregulated by any federal standard, including methane, hydrogen sulfide, oil wells, offshore wells, conventional gas wells, equipment in existence prior to the 2012 standards, and most operations downstream of the gas processing plant. Debate over the costs of compliance, covered sources and pollutants, and the proper regulatory institutions (i.e., local, state, or federal) continues. Complicating this debate is the fact that a comprehensive national inventory that directly measures the quantity and composition of fugitive emissions from natural gas systems does not exist due to many factors, including costs and technical uncertainties.

Author Contact Information

Richard K. Lattanzio
Analyst in Environmental Policy
rlattanzio@crs.loc.gov, 7-1754

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[56] STRONGER is a nonprofit, multi-stakeholder organization that specializes in assessing the overall framework of environmental regulations supporting oil and gas operations. Its collaborative review teams encompass industry, regulators, and environmental/public interest stakeholders. For more information, see http://www.strongerinc.org/.

[57] For more information about EPA's Natural Gas STAR Program, see http://www.epa.gov/gasstar/. For the Global Methane Initiative, see EPA's website, http://www.epa.gov/globalmethane/index.htm. For the Global Gas Flaring Reduction Partnership, see the World Bank's website, http://go.worldbank.org/KCXIVXS550.

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