U.S. NATURAL GAS INFRASTRUCTURE

CENTER FOR CLIMATE
AND ENERGY SOLUTIONS

Discussion Questions:

1. **What are the bottlenecks in our natural gas infrastructure, and how should expansion of the system be prioritized?**
2. **What is necessary to make all stakeholders interested in expanding access of natural gas infrastructure to new and existing buildings for low-emitting uses?**
3. **Should we have access between residential and commercial customers and large consumers, like power plants and industrial users, be balanced during periods of high demand?**
4. **How can federal, state, and local regulations be streamlined to expedite infrastructure upgrades and development while protecting stakeholders?**
5. **How significant are pipeline leaks and what are the options for reducing them?**
6. **How can natural gas infrastructure for vehicles be developed for home and public refueling?**
7. **How can biogas supplies be better integrated into U.S. natural gas supplies?**

HIGHLIGHTS

- There are more than 2.3 million miles of natural gas infrastructure in the United States in the form of gathering, transmission, and distribution pipelines.
- Greenhouse gas (GHG) emissions from natural gas infrastructure totaled 72.3 million metric tons of carbon dioxide equivalent (CO2e) in 2010, 1.06 percent of total U.S. emissions.
- Natural gas infrastructure can reduce emissions directly, through lower emissions from equipment and leaks, or indirectly, by providing natural gas access to consumers to replace of higher-emitting fuels, such as coal, petroleum, and home-heating oil.
- In order to leverage natural gas to reduce GHG emissions, natural gas must be accessible where it can have the most impact for fuel switching and electricity replacement.

Natural gas infrastructure includes long-lived capital assets and expanded deployment faces significant financial, environmental, pipeline location siting, and regulatory.

This is a joint project between the Center for Climate and Energy Solutions and the University of Texas Energy Management and Innovation Center

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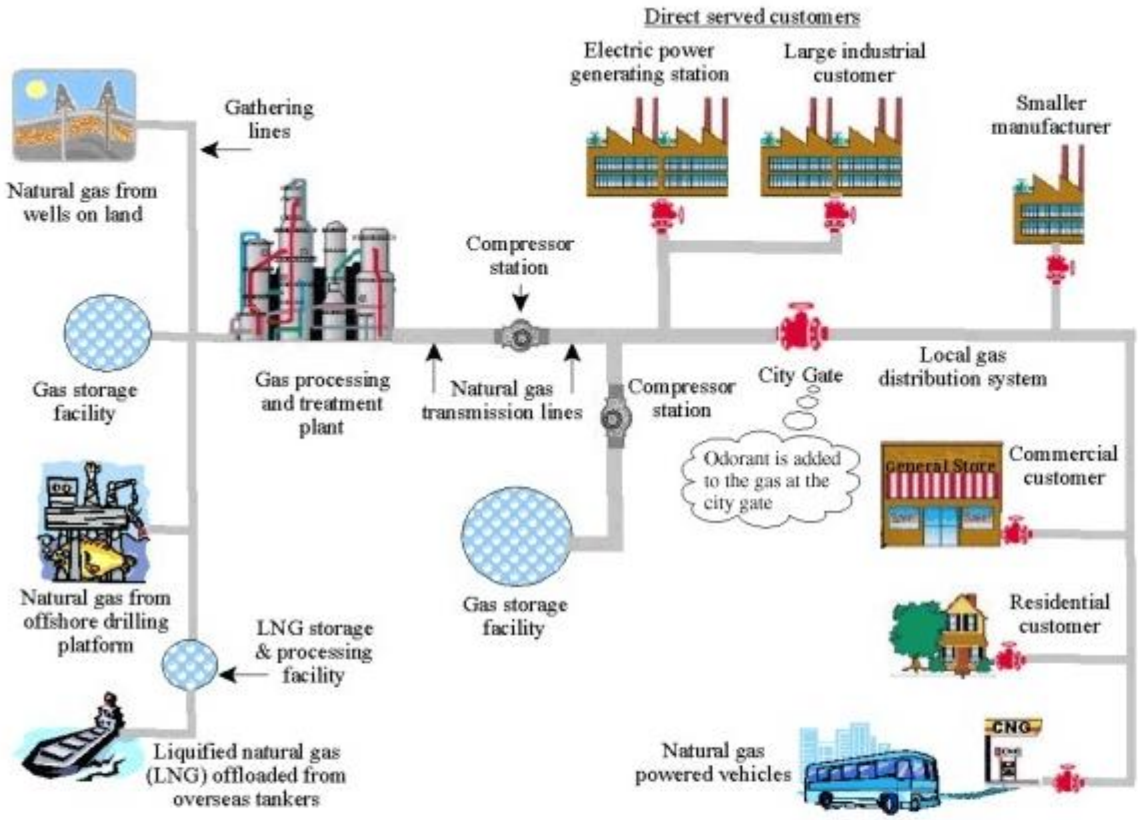
FIGURE 1: U.S. Natural Gas System



Source: Pipeline & Hazardous Materials Safety Administration 2011

INTRODUCTION

The United States has the world's most extensive infrastructure for transporting natural gas from production and importation sites to consumers all over the country. This transport infrastructure[1] is made up of three main components: gathering pipelines, transmission pipelines, and distribution pipelines. Though fundamentally similar in nature, each of these components is designed for a specific purpose, operating pressure and condition, and length. These components are linked together in networks, as illustrated in **Figure 1**, to form our natural gas infrastructure system. Increasing demand for natural gas in the power, transportation, and industrial sectors as well as in residential and commercial buildings requires significant system expansion to take advantage of potential greenhouse gas (GHG) emission reductions, cost savings, and energy security benefits, while at the same time minimizing methane leakage.

Almost all natural gas used in the United States is produced in North America, from onshore or offshore wells, or to a much lesser extent, biogas production sites. It first enters the transport network through gathering pipelines which collect natural gas from the point of production or importation and transport it to processing facilities. Gathering pipelines are usually short, small in diameter, operate at low pressures and are used to transport natural gas from the wellhead to processing facilities. In 2011, there were 19,662 miles of gathering pipelines in the United States originating at over 460,000 wellheads.[2] Most renewable biogas from landfills or animal waste is currently used onsite. It may also be carried by the transport system, but further research is needed to ensure that it can be processed properly and safely added to the existing system, which was built to withstand the constituents of geologically-formed natural gas.[3]

Once gathered from well sites, natural gas must be processed to remove any impurities like sulfur or carbon dioxide (CO_2), and dehydrated (to remove any water). After processing, it is then piped to where there is consumer demand, often hundreds of miles away, through transmission pipelines. Large- diameter (20 to 42 inch), high- pressure transmission pipelines, often called "interstate pipelines" or "trunk lines," are used to efficiently move the gas these vast distances. In 2011, there were 304,087 miles of transmission pipeline in the United States.[4] In order to ensure pressure in the pipeline and keep the natural gas flowing over all these miles, compressor stations are placed every 40 to 100 miles. These stations reduce the volume of gas and often filter the gas again to maintain purity. Meters are also placed along transmission pipelines to monitor the flow and valves are located at routine intervals can be used to stop flow if needed.[5]

At various points along the gathering and transmission networks, natural gas can be stored temporarily underground in depleted oil or natural gas fields, aquifers, and salt caverns. This storage is used to avoid temporary imbalances between supply and demand on the network, such as during a relatively warm winter with unexpectedly low demand for natural-gas generated power. In 2007, there were 400 of these storage facilities in existence.

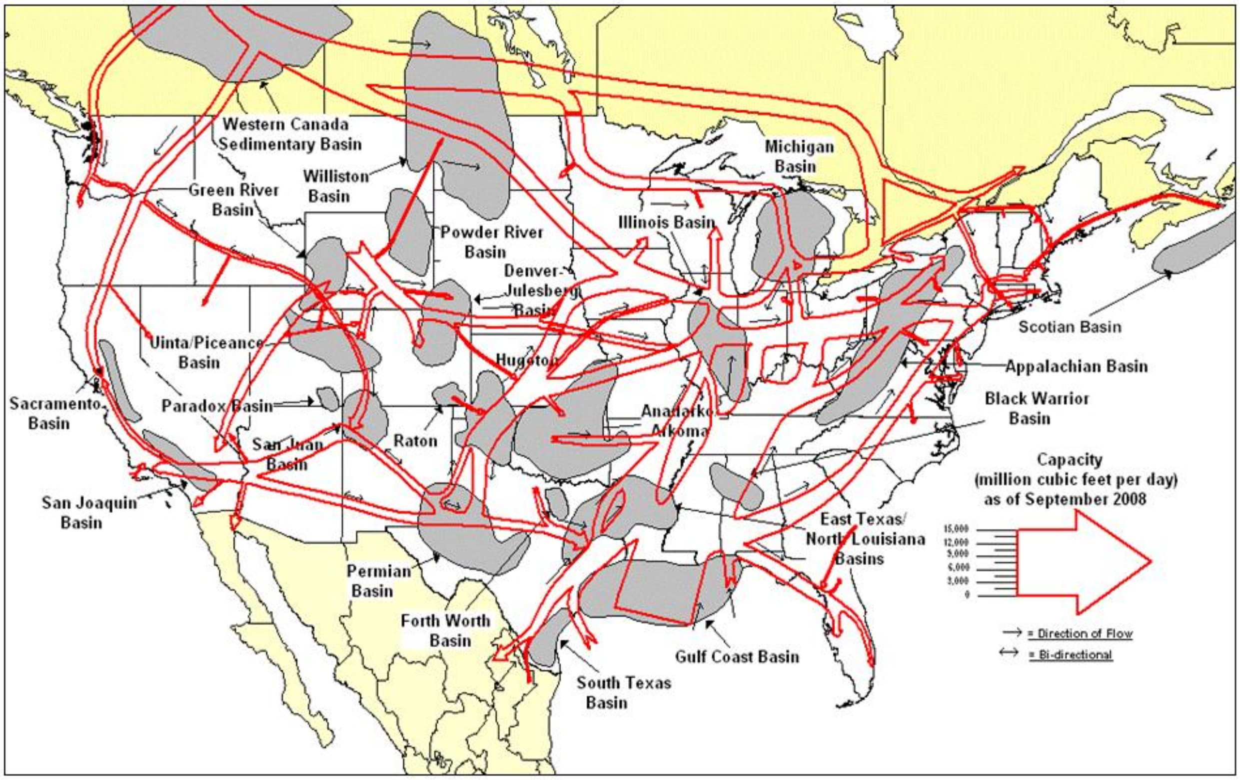
To reach homes and businesses, natural gas leaves the transmission pipeline network and enters the "city gate station", where local distribution companies (LDCs, local gas utilities) add odorant, and lower the pressure before distributing it to residential and commercial customers. Local distribution companies move the gas through a series of main pipelines throughout the LDC service territory with individual service lines that branch off of the main lines to reach each consumer. Natural gas "regulators" are devices in homes and businesses that accept the incoming gas from the highly-pressured pipelines and employ a series of valves to lower the pressure of the gas to meet appliance specifications. Distribution pipelines are much smaller pipelines, often only 0.5 to 2 inches in diameter, with pressures at only a fraction of those of larger transmission pipelines. They may be made of plastic, which is less likely to leak than metal. Although made up of narrow pipes, the distribution networks utilized by LDCs are extensive, with more than 2 million miles of main and individual service pipelines in 2011.[6]

Together these components of natural gas infrastructure comprise an important asset that provides access to energy for all sectors of the economy. However, it is a large, dispersed asset, that is often out of sight – either buried or in remote locations and often crossing state lines. Sometimes they exist within rights-of-way also occupied by other users, like roads or private property. These factors make monitoring and regulation of pipelines complex.

Pipelines are regulated by both the federal and state governments. In 2007, 81 percent of natural gas in the United States flowed through transmission pipelines that cross state boundaries. The Federal Energy Regulatory Commission (FERC) regulates the rates and services of these interstate pipelines, as well as the construction of new interstate pipelines. Other pipelines located within states (intrastate pipelines) are regulated by state regulatory commissions. State regulatory commissions regulate both transmission lines and local distribution companies for pipeline siting, construction, expansion, and rate structure.[7]

The federal government also regulates and enforces pipeline safety through the Department of Transportation, which works closely with state governments on pipeline inspection and safety protocols. Corrosion and defects can lead to leaks with serious safety and environmental implications. Visual inspection of natural gas infrastructure is difficult and complete replacements are nearly impossible given the extent of the network and the underground location. Instead, robotic inspection tools, often called "pigs," can be sent through pipelines to detect leaks, check pipeline conditions, and monitor for weaknesses.[8]

FIGURE 2: U.S. Natural Gas Supply Basins Relative to Major Natural Gas Pipeline Transportation Corridors, 2008



Source: Energy Information Administration 2012

REGIONAL DIFFERENCES IN INFRASTRUCTURE AND EXPANSION

Existing natural gas infrastructure reflects historical supply and demand for the fuel (explored in the other papers of this Initiative) and so varies across the country. Gathering line networks are most extensive from wellheads in traditional producing states like Texas, Oklahoma, and Louisiana, and most existing intrastate transmission lines are designed to take the fuel from those states to manufacturers and consumers in the Midwest and Northeast. The relative flow of natural gas through existing pipelines is illustrated in **Figure 2**.

Recent supply increases, lower prices and increased demand have all led to a need for expanded infrastructure, including gathering, transmission, and distribution pipelines, which can bring natural gas to users that may replace existing higher carbon fuel sources and achieve climate benefits. In a 2009 study, ICF International estimated that new changes in supply and demand will require that 28,000 to 61,900 miles of new pipelines be constructed in North America by 2030, and $108 to $163 billion worth of investment. ICF's analysis suggested additional storage capacity of 371 to 598 Bcf will be needed over the same time period, at a cost of $2 to $5 billion.[9] Current trends in natural gas supply and demand indicate that expansion is likely to fall on the higher ends of the ICF study.[10]

Much of this infrastructure expansion is due to the fact that a significant amount of the shale gas production is occurring in parts of the country like Ohio, Pennsylvania, and West Virginia that historically have not produced natural gas and instead have been traditional destinations for the gas. Likewise, new sources of biogas need infrastructure to collect, process, and either transport the gas to existing transmission infrastructure or utilize it on site. All new supply sources require new infrastructure and the farther these new sources are from existing transmission pipelines, the more extensive and expensive the new networks must be.

Similarly, new demand for natural gas appliances, industrial use, distributed generation and vehicle fueling in homes and businesses will also likely increase the need to expand local distribution networks. Investments are necessary in new mains, service lines, meters, and regulators that can service new customers. Indirect investments will also be required to enhance the capacity of the overall system, including for control rooms, main reinforcements, and improved flow design.[11]

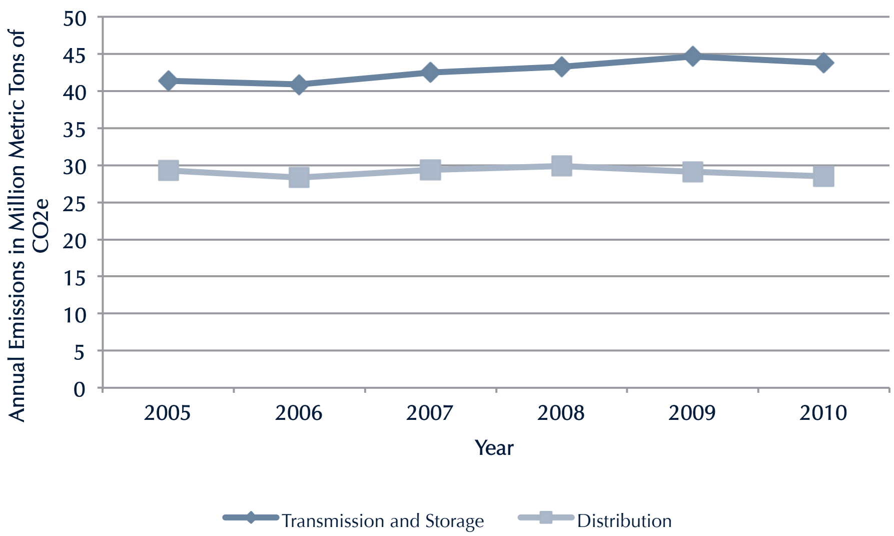
DIRECT EMISSIONS REDUCTIONS FROM NATURAL GAS INFRASTRUCTURE

Natural gas is primarily composed of methane, a highly flammable and very potent GHG. Throughout the transportation of the fuel from gathering at the well to distribution to end-use consumers, there is potential for methane to leak into the atmosphere from production wells, valves, compressor stations, faulty seals, pressure regulators and even broken pipes. While methane leakage and accumulation can be an important safety issue, unintentional leakage can also have significant implications for the climate and for the relative benefits of substituting natural gas for other fuel sources. The methane released into the atmosphere unintentionally in this fashion is referred to as a "fugitive emission." At natural gas storage facilities, emissions may come from compressors and even dehydrators. At the local distribution level, fugitive emissions escape at the city gate stations from valves, seals and pressure regulators.[12] While some CO_2, methane, and nitrogen oxides (NO_X) can also be emitted by compressors that often combust small amounts of natural gas for their energy, fugitive emissions make up the majority of all GHG emissions from natural gas infrastructure.[13]

In addition to fugitive emissions, methane can also be intentionally released or vented as part of the production process at the wellhead, or to reduce pipeline pressure. For safety and environmental reasons though, methane is often burned off in a process called "flaring," rather than venting. Flaring essentially combusts the methane on site forming CO_2, a less potent GHG.[14] Flaring of methane most often occurs when gas is found as a byproduct or co-product of other fossil fuels and insufficient gathering pipeline exist to take natural gas to market. In Texas, where gathering pipeline networks are well developed, in 2012 less than 1 percent of the natural gas produced is flared whereas in North Dakota, production of gas associated with the Bakken Shale formation results in almost 32 percent of the gas being flared, primarily due to a lack of infrastructure to transport the natural gas.[15] Venting and flaring at natural gas production sites were the subject of Environmental Protection Agency New Source Performance Standards for oil and gas wells in August 2012. The new regulations require that new wells utilize "green completion" technology that will allow excess natural gas from the well completion process to be taken to market, rather than flared.[16]

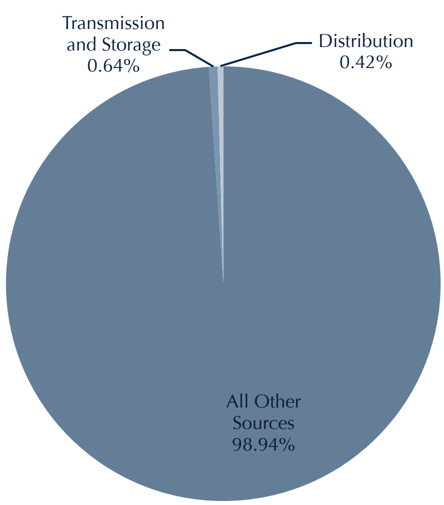
In 2010, methane emissions from transmission pipelines and storage totaled 43.8 million metric tons of CO_2e, while emissions from distribution networks totaled 28.5 million metric tons. These figures have been fairly consistent over time as network expansion has been offset by better system management (including leak detection), more energy efficient technology, and equipment replacement with new materials that are less subject to leakage. While methane emissions from natural gas infrastructure are a very small portion of the nation's total GHG emissions, (**Figure 3** and **Figure 4**), methane is a potent greenhouse gas, with 37 times the radiative forcing of CO_2, and an effective lifetime of 12 years. With these properties, reduction of leakage to the atmosphere is vital to ensuring that natural gas use has climate benefits when compared to other fossil fuels it may replace.[17]

FIGURE 3: Historical emissions from transmission, storage and distribution



Source: Environmental Protection Agency 2012

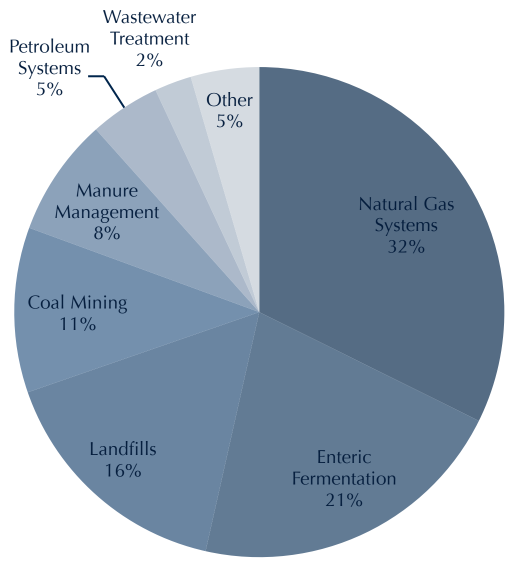
FIGURE 4: Natural Gas infrastructure as a percentage of total U.S. GHG emissions, 2010



Source: Environmental Protection Agency 2012

Despite the relatively small amount of emissions from natural gas infrastructure, compared to others sources of GHGs, the production and distribution of natural gas is a large component of total U.S. methane emissions. In 2009, natural gas systems accounted for 32 percent of total methane emission, as illustrated in **Figure 5**.[18]

FIGURE 5: U.S. Methane Emission Sources, 2010



Source: Environmental Protection Agency 2012

Fortunately, there are many technologies and process improvements that can reduce the methane emissions from natural gas infrastructure. The federal Natural Gas Star program, for example, has worked with industry to identify technical and engineering solutions to fugitive and combustion-related emissions from infrastructure equipment including zero bleed pneumatic controllers, improved valves, corrosion-resistant coatings, dry seal compressors, as well as improved leak detection and repair strategies. The solutions identified by this voluntary program often have payback periods of less than three years, depending on the price of natural gas. Infrastructure sector participants in Natural Gas Star have reported that methane emission were reduced by 15.9 Bcf in 2010 and over all, a total of 276.5 Bcf of GHG have been reduced since the program began in 1993.[19] For local distribution companies, the increased use of inexpensive and durable plastic pipes has also reduced emissions from these low-pressure networks, although the material is not strong enough to be used in high-pressure transmission lines.[20]

BARRIERS TO INFRASTRUCTURE DEVELOPMENT

Other papers in our C2ES-UT Natural Gas series have examined how natural gas may be used to reduce emissions in the power, industrial, and transportation sectors, as well as in commercial and residential buildings. Expanded uses of natural gas require an expanded infrastructure and an expansion faces significant hurdles. Like many other types of infrastructure, pipelines are long-lived capital assets with complicated financing and economics. Interstate transmission pipelines have rates of return that are regulated by FERC. Large transmission pipelines must also line up project finance or debt to fund construction, which may be complicated by intricacies of individual projects, including the contracts for supply and demand of the carried natural gas as well as the specific physical needs of pipeline construction.[21]

For local distribution networks, the costs of expansion and upgrades vary considerably depending on whether the network is being expanded to new or existing communities, the density of the neighborhood, and the terrain. For new distribution pipelines to be built in urban areas, they must contend with a variety of challenges, including costly repairs of overlaying roads and landscaping, negotiations with surface and other subsurface rights-of-way holders, and public inconveniences. Accordingly, new urban pipelines can cost five times as much as rural ones.[22] Costs can be lowered when buildings are designed and constructed ready for natural gas access. Retrofitting buildings is more expensive when preparations are not made for internal building piping and hook-ups to natural gas supplies, should they be added later.

At the same time, the financing of these LDC investments holds its own challenges. Traditionally, expansion costs are based on a regulated ratemaking where the costs are only recovered after the investment is made. This situation creates a lag between when investments are made and when they can be paid for. State-level innovation has provided some policy options to overcome financing challenges. Some states, like Colorado, authorize tracker mechanisms allowing rates to change in response to operating costs and conditions. Others, like Georgia, permit surcharges for cost recovery., Some, like Nevada, allow the use of a deferred accounting mechanism so that costs can be better aligned with ratemaking cases before state regulatory commissions. Seven southern states, like Texas, have decoupled gas consumption and cost recovery to create what is known as a "rate stabilization method."[23]

Pipelines are also impacted by a number of other project-specific requirements and regulations at the federal, state, and local levels. These requirements pertain to route selection, siting, and project approval by regulatory agencies that may all be affected by environmental, safety, community, operation, construction timing, and cost concerns. The size of the challenge for any individual project may vary significantly depending on the pipeline and the jurisdictions it crosses. For natural gas to realize its climate benefits, these barriers to expanding our gas infrastructure must be overcome.[24]

ENDNOTES

1 Beyond U.S. borders, the national network is tightly connected to Canada and Mexico via many land connections and more loosely to global liquified natural gas markets via a few terminals on the coasts. However, for the purposes of this paper, it will be referred to as the national or U.S. network.

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