Natural Gas Infrastructure: Enabling Energy Productivity

ALLIANCE TO SAVE ENERGY

Using less. Doing more.

Alliance Commission on National Energy Efficiency Policy

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PREAMBLE

The Alliance Commission on National Energy Efficiency Policy (the Commission) was organized to study energy-efficiency policies, programs, and opportunities to facilitate consensus recommendations on the next generation of domestic policies, programs, and practices on energy efficiency. The work of the Commission will include an assessment of the current state of energy efficiency in the U.S. economy and a review of the best local, state, and national practices. This work will culminate in a set of recommendations for the next administration and the 113^{th} Congress to ensure that the U.S. can double its energy productivity (twice as much gross domestic product [GDP] from each unit of energy) from 2011 to 2030.

This report, Natural Gas Infrastructure: Enabling Energy Productivity, is one of seven research reports that analyzes the current state of energy efficiency within the economy and reviews the best local, state, and national practices. These assessments will serve to provide the technical basis for the Commission's efforts to develop a set of recommendations for doubling the nation's energy productivity. The other reports will address the following areas: history and the business case of energy efficiency; transportation, land use, and accessibility; residential and commercial buildings, American manufacturing; power generation and system integration.

To provide a comprehensive assessment to the Commission, the last report identified as "system integration" will be a comprehensive analysis of the other research reports to identify common areas of consideration and areas of interdependency. It will also identify opportunities for the various sectors of the economy to work together.

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INTRODUCTION

This paper was prepared for the Alliance to Save Energy's Commission on National Energy Efficiency Policy (ACNEEP) to set forth the potential for the U.S. natural gas distribution infrastructure to support the goals of substantially increased energy productivity and to describe challenges to meeting those objectives that can be met by development of smart grid technologies and techniques for the gas grid.

DESCRIPTION AND SCOPE

This paper covers the gas transmission and distribution industries serving the continental U.S. from the point where natural gas has been processed to where it is delivered for use. It includes long distance transmission, storage, distribution, and direct end use by utility customers. It excludes any review of natural gas for use in generation facilities or as an industrial feedstock, as these issues are covered in other Commission reports. While this paper does not consider the potential improvements in exploration and production functions, it is necessary to understand the various sources and how changes in supply and gas composition can affect the gas grid, the Smart Grid, and customers.

SUPPLY RESOURCE BASE

Advances in American technology have opened the door to large new opportunities for extraction of natural gas in North America. Natural gas production from unconventional sources such as shale has grown considerably in recent years. In 2012, natural gas from shale accounted for a third of domestic production. While our proven reserves are significant, our potential supply may be even greater. [1]

Further technological developments will advance resource extraction efficiency, help mitigate some environmental and community impacts of natural gas production and delivery, and increase the efficiency of natural gas use in homes, businesses, and communities across the country. Prudent and responsible production and delivery of natural gas, supported by appropriate regulation and oversight, are vital to capturing the opportunity promised by these advances.

The natural gas market today is characterized by a strong supply and significant potential for expanding natural gas use for homes and businesses, electricity generation, and industrial plants. Investors are looking at the export of liquefied natural gas and the use of natural gas as a transportation fuel. Investments in these energy applications can provide benefits to our nation's economy, environment, and national security. The increase in demand also will support the long-term vitality of domestic natural gas production.

The country has experienced a transformational shift in the perceived role of natural gas from a resource often viewed as unreliable and scarce ten years ago to one that is now recognized as a foundation fuel for creating a clean, secure, and diverse U.S. energy portfolio.

Today's unusually low prices—a market response to excess supply—likely are not sustainable, but there is sufficient supply to allow for demand growth at reasonable prices. Domestic natural gas demand growth from 2012-2022 is needed to establish price levels that elicit a production response from gas producers. Many of the identified shale gas resource plays and more traditional production models become economically available to the market at a development cost of $5-6 per million British thermal units (MMBtu). This is precisely the foundation that accounts for the possibility of an additional 11 to 34 percent increase in domestic natural gas production during the next ten years.[2]

Even significant increases in demand could be supported by this large, dynamic, and diverse North American natural gas resource base. When coupled with expanding infrastructure and appropriate regulatory constructs, stable natural gas acquisition prices near $5-6 per MMBtu are envisioned during the next ten years and possibly beyond.[3]

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[1] American Gas Association, "Rethinking Natural Gas," 8.
[2] American Gas Association, "Rethinking Natural Gas," 23.
[3] Ibid.

NATURAL GAS VALUE CHAIN DESCRIPTION

The energy value chain is the process by which an energy source is produced and delivered to consumers. While each fuel has a unique value chain, there are many common elements. The energy value chain can be divided into six stages:

- Fuel extraction
- Processing
- Transportation
- Conversion
- Distribution (including electric long-distance transmission)
- End use

Through the analysis of a given fuel's energy value chain, we can better understand the energy consumed and the related emissions from energy choices. Each stage for each fuel has a unique physical process associated with it, and the energy efficiencies associated with this process can vary, even within an industry. Of the various forms of energy available to residential and commercial consumers, the natural gas value chain is one of the most energy efficient due to the lack of conversion needed and the relatively low losses during transmission and distribution.

FOCUS

Considering the rapidly changing resource base and the impact on the different value chains for the direct use of natural gas, effective and coordinated management of national electric and gas grids will become increasingly important but also provides near-term and long-term opportunities to support and sustain national goals to increase energy productivity in the US.

CURRENT OPPORTUNITIES TO ENHANCE OVERALL ENERGY EFFICIENCY THROUGH GREATER USE OF THE RESOURCE BASE

Energy efficiency remains one of the easiest and most effective ways to reduce energy consumption and mitigate greenhouse gas emissions. Direct use natural gas applications that capitalize on the efficiencies of the natural gas value chain coupled with use of high efficiency equipment options can help increase the productivity of the nation's energy supplies and increase economy-wide energy efficiency. In addition, in some areas of the country with electricity constraints, fueling more homes and businesses directly with natural gas could help ease demand on the electric power grid.[4]

Direct-use natural gas technology is an important segment within energy-service equipment and provides opportunities to reduce the environmental impact of the energy use that can be expected to vary by application and location.

A major opportunity to enhance overall energy efficiency exists in the end use application of combined heat and power (CHP) facilities fueled by natural gas, biomass, and so on. CHP systems use technology that reduces energy costs and emissions related to electricity and thermal generation and enhances grid reliability for individuals, companies, and localities that employ the systems in place of more conventional, separate electricity and thermal generation. Micro-CHP at the residential level is another option that could increase overall energy efficiency in homes across the country, offering 80-90% efficiencies.

Despite the benefits that CHP systems provide, the growth of CHP systems in the U.S. during the last ten years has been stagnant. In a recent Executive Order "Accelerating Industrial Energy Efficiency," President Obama stated,

> "Independent studies have pointed to under-investment in industrial energy efficiency and CHP as a result of numerous barriers. The Federal Government has limited but important authorities to overcome these barriers, and our efforts to support investment in industrial energy efficiency and CHP should involve coordinated engagement with a broad set of stakeholders, including States, manufacturers, utilities, and others. By working with all stakeholders to address these barriers, we have an opportunity to save industrial users tens of billions of dollars in energy costs over the next decade."[5]

President Obama has established a national goal of deploying 40 gigawatts (GW) of new cost-effective industrial CHP in the United States by the end of 2020. The Administration estimates that achieving this goal would save more than $100 billion in avoided energy costs and would spur between $40-80 billion in new capital investment.[6]

[4] American Gas Foundation, "Direct Use of Natural Gas."
[5] White House, "Accelerating Industrial."
[6] White House, "President Obama Signs."

FUTURE OPPORTUNITIES TO ENHANCE THE EFFICIENCY OF THE NATURAL GAS VALUE CHAIN

There are over 71 million customers across the country who use natural gas in their homes or businesses.[7] However, the level of gas-use saturation varies by geographic location from near zero in certain areas to as high as 90% in others. Hence, in many areas of the country, gas infrastructure is still growing due to new construction and adding gas infrastructure to previously underserved areas based solely on customer demand and utility economics. Smart Growth programs are being developed to optimize the expansion process through use of new technologies. Such investment programs can be integrated with, and managed in the context of, improved energy efficiency and environmental performance.

TODAY'S OPPORTUNITIES FOR INCREASED EFFICIENCY USING NATURAL GAS

Today, there are millions of homes and businesses that do not have access to natural gas service. Hence, these customers do not have the option of using efficient natural gas products to meet their energy needs and to reduce overall energy consumption. There is room for wise and efficient growth of natural gas consumption in today's domestic energy market, including significant potential in the residential, commercial, and transportation sectors using advanced technologies over the long-term. New and innovative approaches for extending natural gas infrastructure to underserved areas of the country will help reduce the nation's overall energy consumption by taking advantage of the efficient natural gas value chain and high efficiency natural gas energy applications.

In addition, new market dynamics created by abundant supply resources will spur additional technology development of efficient natural gas equipment so long as there is a healthy demand-pull.

GAS TRANSMISSION ENERGY USE

The North American natural gas transportation system is a complex network of inter- and intrastate pipelines designed to transport natural gas from producing regions to end-use markets. A report by the Interstate Natural Gas Association of America[8] states that the efficiency of interstate natural gas pipelines can be viewed from two main perspectives: *economic efficiency* and *transportation efficiency*. Economic efficiency measures the delivered cost to customers compared to the cost of the natural gas, taking into account both fuel cost and transportation rates. The transportation efficiency is an overall system measure of the fuel and/or electric energy used to transport natural gas and is a function of the overall system design (the hydraulic efficiency); how the system is operated; and the efficiency of individual components (such as the compressor units).

Pipeline companies strive to be as efficient as possible, yet this goal must be balanced with the need to provide reliable and flexible service to customers. For example, pipeline companies often guarantee a sufficiently high delivery pressure so that local distribution company customers do not need to install additional compression behind their city gates. While this can reduce the transportation efficiency of the interstate pipeline, it increases the overall efficiency of the wellhead-to-burner-tip value chain. This reduced efficiency, however, must be balanced with consideration of the economic, environmental, and public health benefits associated with the use of natural gas for power generation.

In short, the interstate natural gas pipeline industry provides a flexible transportation service that accommodates wide variations in the demand for delivery of natural gas to a diverse market of end-use consumers, and thereby enhances the efficiency of energy delivered in the US.

FUTURE OPPORTUNITIES FOR INCREASED EFFICIENCY THROUGH INCORPORATING NATURAL GAS IN SMART ENERGY GRIDS

For many years the natural gas infrastructure has met the needs of the consumer. However, it must evolve to support the level of operations necessary to achieve benefits of a smart energy future. Advanced gas infrastructure will enhance the value of investments made in the electric Smart Grid, will expand the goals of the current Smart Grid proposition, and will increase the safety of and reduce the environmental impacts associated with gas distribution. There also are opportunities to support emerging technologies and new markets such as alternative fuel vehicles and hydrogen for fuel cells and to develop even broader, holistic energy grids to the benefit of customers.

[7] Energy Information Administration, "Annual Report on Gas Operations", Form 176
[8] Interstate Natural Gas Association of America, "Interstate Natural Gas Pipeline Efficiency."

SUPPORT AND LEVERAGE INVESTMENTS IN ELECTRIC SMART GRID

For many years, natural gas and electric distribution systems have been planned and built separately to meet the forecast peak demands for each infrastructure; decisions typically are based on a thirty-year planning horizon. A smart energy future includes implementing broadened ways to be more efficient. One of the largest opportunities is to use the non-concurrent nature of the two U.S. energy grids serving customers. In many areas of the US, space heating drives gas energy use while air conditioning drives electric use. Continued demand information, new end-use technologies, and demand management strategies can be employed to flatten demand curves for both utilities and reduce the units cost of both infrastructures.

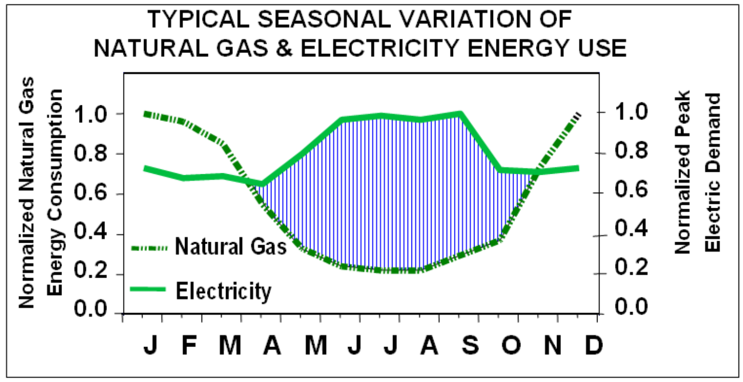

Figure 1: Typical seasonal variation in utility distribution networks in the northern U.S. Source: National Grid, "Track 'C' Networks of the Future."

GRID INTERDEPENDENCY

The fundamental driver of concern over interdependency between the electric and natural gas grids is the need to safeguard the reliable delivery of energy. Natural gas has become a strategic resource for electrical generation. Gas also is perceived to be an enabler of intermittent renewable resources such as solar and wind power, as well as a smart resource for direct use.

The Federal Energy Regulatory Commission and the North American Electric Reliability Corporation (FERC/NERC) Staff Report on the 2011 Southwest cold weather event included a discussion of the interdependency of the electric and natural gas industries.[9] The report stated that utilities are increasingly reliant on gas-fired generation, in large part because shale production has dramatically reduced the cost of gas. Likewise, the gas industry's use of electric-powered compression has increased in recent years. As a result, deficiencies in the supply of either electricity or natural gas affect not only the consumers of that commodity, but also of the other commodity as well. The report also explored some of the issues relating to the effects of shortages of one commodity on the other, including the question of whether gas production and processing facilities should be deemed "human needs" customers and thus exempted or given special consideration for purposes of electric load shedding. The report urged regulatory and industry bodies to explore solutions to the many interdependency problems that are likely to remain of concern in the future.

In 2006 the Gas-Electric Interdependency Working Group (GEIWG) completed a study for the New York City and New England areas.[10] The purpose of the GEIWG No. 1 study was to examine the effect of a loss of fuel to the specific generators in a region, and how it affected the electric power grid. The group recognized the gap in data exchange and effective communications, pointing out that "This is meant to be a significant first step in recognizing that the gas-pipeline grid and the electric transmission grid are two 'hard-connected,' highly interactive energy-delivery systems." This report notes that obtaining data on gas-delivery configurations was particularly problematic and multiple data issues needed to be resolved to get a clear picture of gas–electric interdependency. The report pointed out the gas–electric interaction in New England is extremely dynamic. It also indicated the importance of establishing an informal dialog with regional authorities such as Independent Systems Operator – New England (ISO-NE), so when a gas-driven emergency occurs, the nature of the emergency and possible remedial measures can be identified. Although the GEIWG study was focused on the New York City and New England regions, there is a high likelihood that the same or similar gas–electric interactions observed in this region occur in some other regions of the U.S. It will be important to consider how to anticipate challenges in other regions.

Natural gas is recognized by many as an enabler for intermittent renewable energy such as wind or solar. Natural gas also is recognized as a low-carbon alternative to coal-based generation, which will become increasingly important as federal carbon dioxide (CO_2) emission constraints come into effect. It is anticipated that some portion of the over 240 GW of coal-based power plants that are currently more than forty years of age will be retired during the next five to ten years due largely to the decreased cost of natural gas generation but also to costs associated with meeting various new and anticipated federal environmental rules.[11]

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[9] FERC/NERC, "Report on Outages and Curtailments."
[10] Gas-Electric Interdependency Working Group Study No. 1, Initial Report on Electric Exposure to Gas Disruption, New York City and New England, March 1, 2006
[11] Bradley et al., "Ensuring a Clean, Modern Electric Generating Fleet," 16.

Although the policies and regulatory response associated with greenhouse gases and CO_2 emissions are still in the formative stages, the likely impact is that there will be an increase in the emphasis on the use of natural gas to power electric generation and on increasing the efficiency of all combustion processes, and long-term emphasis on relying more on development of new energy storage technologies that could be coupled with intermittent renewable resources. As these issues are combined with the availability of unconventional gas, such as shale gas, the potential for regional changes in the energy supply mix and the delivery to the user is further complicated.

The recently released interim report from the Massachusetts Institute of Technology (MIT), "The Future of Natural Gas," states,

> The electricity sector is the principal growth area for natural gas under CO_2 emission constraints. The scale-up of intermittent electricity sources, wind and solar, significantly affects natural gas capacity and use in the electricity sector because of variability and uncertainty. . . . In the US, there are opportunities for more efficient use of natural gas (and other fuels), and for coal to gas fuel switching for power generation. Substitution of gas for coal could materially impact CO_2 emissions in the near term, since the US coal fleet includes a significant fraction of low-efficiency plants that are not credible candidates for carbon capture retrofit in response to carbon emissions prices, and since there is significant underutilized existing Natural Gas Combined Cycle (NGCC) capacity. [12]

The study focuses on the transmission/bulk-energy level. By contrast, the second draft of the U.S. Department of Energy (DOE) Smart Grid Research and Development Multi-Year Program Plan (The Plan) for 2010-14, released in March 2010, focuses on the electric distribution system. The Plan includes the integration of all generation and storage options with the milestone of having 20% (200 GW) of electricity capacity from distributed and renewable energy sources and the development of integrated distribution management systems for distribution automation. The plan also includes the demonstration of fast voltage protection and overvoltage protection solutions under high penetration of renewable energy. Although the DOE Plan is focused on distribution, it recognizes the need for modeling that includes fast computational algorithms and parallel computing capabilities that can be embedded in real-time controls and decision support tools. The plan also recognizes these tools need to be capable of modeling the effects on the entire grid, including developing reduced-order models of quasisteady state and dynamic response on the transmission and generation systems.

These studies indicate a need to improve, or in some instances establish, coordination between electric and natural gas systems. Enhanced nomination opportunities tailored to meet the needs of power generators, as offered by some natural gas pipeline operators, can enhance the efficiency of energy forecasting for power generators who hold firm capacity to purchase gas and schedule transportation. The vulnerabilities presented by an increasing reliance on natural gas in ensuring the reliability of the electric energy grid are the subject of analysis and efforts to identify strategies that optimize the delivery of energy are underway at Federal Energy Regulatory Commission (FERC), North American Electric Reliability Corporation (NERC), the DOE, and system operators across the U.S.

Moreover, by providing natural gas at the pressures and volumes required for fast ramping, natural gas generation facilities that are equipped with sensing and controlling technology are efficiently operated to provide real-time response. A fast response is critical to enhancing electric- and gas-grid interoperability by providing backup to renewables and for electric peak shaving. The enhancement of these same functions would allow distributed generation or combined heat and power facilities equipped with sensing and controlling technology to provide real-time response during peak demand periods, outage events, or as needed for system support.

VALUE OF SMART GAS GRID

The Smart Grid has been generally established by the DOE to be an "electric delivery network modernized using the latest digital/information technologies to meet key defining functions."[13] It can

- enable active participation by customers;
- accommodate all generation and storage options;
- enable new products, services, and markets;
- provide power quality for the digital economy;
- optimize asset utilization and operate efficiently;
- anticipate and respond to system disturbances; and
- operate resiliently against attack and natural disasters.

[12] MIT Energy Initiative, "The Future of Natural Gas," xiv.
[13] Lightner, "Smart Grid Activities," 3.

The U.S. natural gas infrastructure not only is a critical component to the U.S. electric grid but also serves the majority of the same customers directly and provides a supplement to the electric grid, where beneficial. In light of the need to increase the efficiency of all energy use at a time of expanding direct use of natural gas and diversifying supplies, many of the attributes of a Smart Grid are either directly relevant to the gas distribution system or have an analogous attribute. Therefore, a coordinated approach to design and implementation has substantial value.

For example, in order to optimize asset utilization and operate efficiently, electric grid managers in some regions of the U.S. employ a number of techniques, some of which include planned curtailment of services to customers across broad areas at peak times, which for most of the U.S. is driven by summer air conditioning loads. Some gas distribution utilities in colder climates have employed similar techniques in the peak winter season with far fewer but larger customers by automatically switching "temperature-controlled" customers temporarily to a back-up fuel solely on the basis of outside temperature.[14] The opportunity for a Smart Grid stems from the fact that it may well be the same customers that participate in the electric and gas programs.

The delivery system of the future will effectively use two-way communications and intelligent field devices to enhance safety and efficiency of the network and to effectively serve new end uses and supply sources.

A strong and flexible infrastructure will respond to consumer needs, and will enable pipeline and local distribution companies (LDCs) to safely and efficiently increase capacity and actively manage volume and pressure. This will be accomplished by using a network of sensors, two-way communications, and automation. This infrastructure readily accommodates diverse sources of supply.[15]

Optimized investment will be possible as better load forecasts, network monitoring, and demand-management techniques are employed to improve asset utilization, capital deployment, and increase useful life.[16]
Emerging technologies such as microgrids, thermal grids that manage loops of heated or chilled water, and alternatively fueled vehicles will create new uses for natural gas and electricity.[17]

ENABLE ENERGY EFFICIENCY THROUGH MORE COMPLETE INFORMATION TO CONSUMERS (DATA AND ANALYSIS, ETC.)

To optimize the use of natural gas, electricity, and other energy resources, accurate and comparable information must be available to consumers. This information must enable direct and fair comparisons of cost, reliability, carbon content, and other attributes of importance to consumers. Improved sensing and communications technologies, coupled with submetering options for residential, commercial, and industrial consumers, can provide tremendous insight on how individual appliances and equipment can be managed cost effectively. Armed with this information, consumers will be able to make choices about their energy use and reduce their energy cost.

ENHANCED MONITORING AND CONTROL (AMR, ETC.)

A smart energy future includes implementing ways to be more efficient. Better demand information, new end-use technologies, and demand-management strategies can be employed to flatten demand curves and reduce infrastructure costs.[18]

Emerging technologies such as microgrids, thermal grids, hybrid appliances, and alternatively fueled vehicles will create both opportunities for increased efficiency and new uses for natural gas and electricity. To respond to consumer needs, local distribution companies must be able to ensure that the infrastructure is capable of accommodating these new end uses while continuing to maintain the integrity and safe operation of their systems.[19]

New end-use technologies may also require enhanced delivery capability. Many of these technologies require further demonstration, and utilities working with developers will ensure the necessary accommodations are made so the full value of the new technologies can be realized. The gas distribution system also will be expected to deliver gas from new supply sources being developed.[20]

We have identified a wide variety of capabilities and functions that must be developed or enhanced in order to achieve the vision for delivery. The following discussion highlights a few that would be among those needing to be created or enhanced.[21]

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[14] EnerNOC, "Demand Response for Natural Gas," 8.
[15] Gas Technology Institute and Navigant Consulting Inc., "Natural Gas in a Smart Energy Future," 11.
[16] Ibid.
[17] Ibid.
[18] Gas Technology Institute and Navigant Consulting Inc., "Natural Gas in a Smart Energy Future," 14.
[19] Ibid.
[20] Ibid.
[21] Ibid.

Automated Flow Control and Volume/Pressure Management includes the development of sensing technology capable of monitoring and reporting volume and pressure that can be acted upon by artificial intelligence systems or system operators. The function of automated flow control and volume/pressure management would use communications technologies coupled with monitoring and control technologies. This approach uses real-time information on volume, pressure, and quality to maintain system operations. This broad area of functionality also could include smart gas metering and load monitoring devices at the consumer location that allow the LDC to monitor and manage the system to ensure the consumer load requirements are met safely and reliably. This can include real-time metering, remote disconnection, outage detection, and other features.[22]

Automated Shutoff includes the development and use of a combination of sensors and communications technologies located strategically throughout the gas network capable of detecting and reporting incidents. This requires activating one or more control devices and providing the data on a real-time basis to be acted upon by an artificial intelligence system and/or a system operator. The automated shutoff could be implemented in transmission pipelines, local distribution lines, or at the meter.[23]

Detection/Prediction of Third Party Damage would use a combination of visual and/or proximity sensing-based artificial intelligence to notify operations staff of a potential incident that could result in damage or of an occurrence of recent damage.[24]

Automated Leak Detection and Notification would include the development of sensors and communications for real-time monitoring and reporting of methane/ethane levels. A detection and notification system would also include a system capable of verifying consumer contacts and allowing operators to determine if action is required.[25]

Advanced sensors and communications could enable *Gas Quality Monitoring and Management*, and provide gas system operators the ability to obtain Btu, compositional, and trace constituent information from the gas throughout in the transmission and distribution system. Similarly, Btu Composition *Monitoring at the Customer Exchange (Billing)* would measure calorific data coupled with volume and pressure sensing to ensure the supplier and consumer that contract obligations are met. All of this support would allow system-wide efficiency and quality management, and facilitate the seamless integration of supplies including shale gas and renewable gas (biogas).[26]

ENABLE DIVERSE GAS SUPPLIES

Natural gas is not simply a fuel consisting of methane, nor is it homogenous in chemical and physical makeup. The specific properties and compositions of natural gas are complex and a function of many factors, including: 1) resource supply characteristics, 2) level of gas processing, and 3) degree of comingling prior to and during transportation.[27]

Conventional gas basins were the original source of most natural gas in North America because the gas was easily accessed and extracted. Unconventional gas sources historically were more difficult to obtain until recent technological breakthroughs in drilling and hydro-fracturing made their recovery economically favorable. Unconventional sources include: 1) shale gas, natural gas sourced from the original shale formations that has not permeated into another geologic formation; 2) tight sand gas, formed where gas migrates from the source rock into sandstone or carbonate formation; and 3) coal bed methane, generated during the transformation of organic material to coal.[28]

Another source of gas included in the grouping of gas referred to as "unconventional" that is increasingly being introduced to the natural gas delivery systems is known as renewable gas or biogas.[29]

Local gas distribution and transmission companies are progressively seeking to purchase and take delivery of fuel gas derived from this multitude of new sources. There is a need within the industry for information to compare these new sources with traditional natural gas supplies.[30]

[22] Ibid., 14-15.
[23] Gas Technology Institute and Navigant Consulting Inc., "Natural Gas in a Smart Energy Future," 15.
[24] Ibid.
[25] Ibid.
[26] Ibid.
[27] Ibid., 11.
[28] Ibid.
[29] Ibid., 11.
[30] Gas Technology Institute and Navigant Consulting Inc., "Natural Gas in a Smart Energy Future," PAGE.

The diversification of gas supplies and variations in methods to meet peak deliverability create unique challenges for the gas industry in that gas composition can vary substantially at the same time that the nature and material used in the distribution system is changing. The infrastructure also must serve a variety of both old and new appliances. The issue of interchangeability first became a concern when the U.S. was planning on imports of liquefied natural gas (LNG) a few years ago. *Interchangeability* is defined as *"*The ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety, efficiency, performance or materially increasing air pollutant emissions*.*" [31] The issue is now more significant. And, while it is being addressed to some degree, a more coordinated approach involving all participants along the natural gas value chain will be needed along with increased research and development (R&D) and greater corporate support. The opportunities to monitor and control gas composition through automation and smart energy grids may well ease the transition to diverse supplies as well as renewable gas sources.

RENEWABLE PIPELINE GAS FROM LOCAL WASTE

Renewable gas (RG) is pipeline-quality gas derived from biomass. The American Gas Foundation discussed the values of renewable gas in a study completed in 2011.[32] Under two practical long-term scenarios, renewable gas has the potential to meet between 4% and 10% of current (2010) natural gas usage in the U.S.[33] Renewable gas can be produced from a variety of biomass sources including wastewater treatment plants, animal manure, landfills, woody biomass, crop residuals, and energy crops. Renewable gas can have the same physical composition as natural gas but is produced from renewable, biomass resources by using technologies such as anaerobic digestion and thermal gasification.

Almost every state in the U.S. has the resources to participate in the production of renewable gas. And all the technology components to produce renewable gas from this variety of biomass sources exist today.

HYDROGEN INTEGRATION

The potential benefits of hydrogen as an energy carrier have been established for efficient use in fuel cells both in stationary energy use in heating and power generation as well as in vehicles. There are a variety of sources for hydrogen, including reformation of natural gas, electrolysis of water from electricity, and the gasification of dry waste material. If the benefits of hydrogen use are realized, there could be substantial effects for both gas and electric infrastructure. Hydrogen can be produced locally and used or dispensed locally, or it can be produced centrally and transported over roads or by pipeline. There are approximately 700 miles of hydrogen pipelines in the U.S.[34] However, greater use of hydrogen would require access to the natural gas pipeline networks. In the early years hydrogen would have to be blended according to the constituent limits that will vary by locality.[35] Due to the varied sources of hydrogen supply and variation in pipeline tolerances, monitoring and control of a diverse supply and users would need to be created and integrated into smarter gas and electric grids. In addition, hydrogen production also can be viewed as an option for sequestering carbon locally prior to combustion. There are technologies that can be used to remove solid carbon from methane prior to combustion or use in fuel cells.[36] Such technologies add a new dimension to the options for both customers and policy makers and should be allowed to compete with current technologies.

ENHANCED SAFETY (LEAK DETECTION, SEISMIC, SELF-HEALING, ETC.)

The natural gas transmission and distribution systems in the U.S. exhibit a very low rate of incidents that result in unsafe—or tragic—releases of natural gas. Pipeline systems are monitored by state utility commissions and the Pipeline and Hazardous Material Safety Administration (PHMSA) in the U.S. Department of Transportation Office of Pipeline Safety. Typically less than six incidents in transmission occur nationally each year.[37] This safety record is due to continuous maintenance and inspection programs as required by increasingly detailed regulations such as under the Pipeline Safety Improvement Act of 2002. Incidents involving natural gas transmission and distribution systems are primarily caused by damage to the systems from either human causes such as construction activity, or natural causes such as earthquakes. Estimates by the US Department of Transportation predict that the cost to the gas industry of complying with new integrity management requirements could approach $4.7 billion over the next 20 years. In addition, the cost of excavation to repair or replace pipelines grows quickly. As a result, gas utility R&D programs are supporting

[31] NGC+ Interchangeability Work Group, "White Paper on Natural Gas," 2.
[32] American Gas Foundation, "The Potential for Renewable Gas."
[33] This assumes a national usage of roughly 24 TCF of natural gas or 24 quadrillion BTU (for 2010). See U.S. Energy Information Administration's "U.S. Natural Gas Consumption by End Use."
[34] U.S. Department of Energy, "Fuel Cell Technologies."
[35] Mahnovski, "Robust Decisions."
[36] National Grid and Atlantic Hydrogen Inc, "Hydrogen-Enriched Natural Gas," 8.
[37] U.S. Department of Transportation, "Serious Pipeline Incidents."

the development of a number of techniques for inspection and repair of live gas lines that do not require excavation or even taking a line out of service. The integration of natural gas infrastructure into a smart energy grid has the potential to enable grid managers to more quickly identify, locate, and assess damage to the gas distribution system and to allow for quicker and more cost-effective repairs and safe return to service.

REDUCE METHANE EMISSIONS

The greater reliance on U.S. natural gas infrastructure to achieve national energy productivity goals also will result in added attention to the potential for unintended natural gas leakage from transmission and distribution systems. This leakage is a form of energy waste, but has a greater impact on greenhouse gas emissions. A ton of methane has a global warming impact that is twenty-one times greater than that of a ton of carbon dioxide, yet methane from all sources represents 10% of the U.S. greenhouse gas emissions. Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, by the decay of organic waste in municipal solid waste landfills, from sewer systems and from combustion in gasoline-powered vehicles. Methane leakage from the natural gas system today, wellhead to burner tip, is estimated to be under 2% of total throughput.[38]

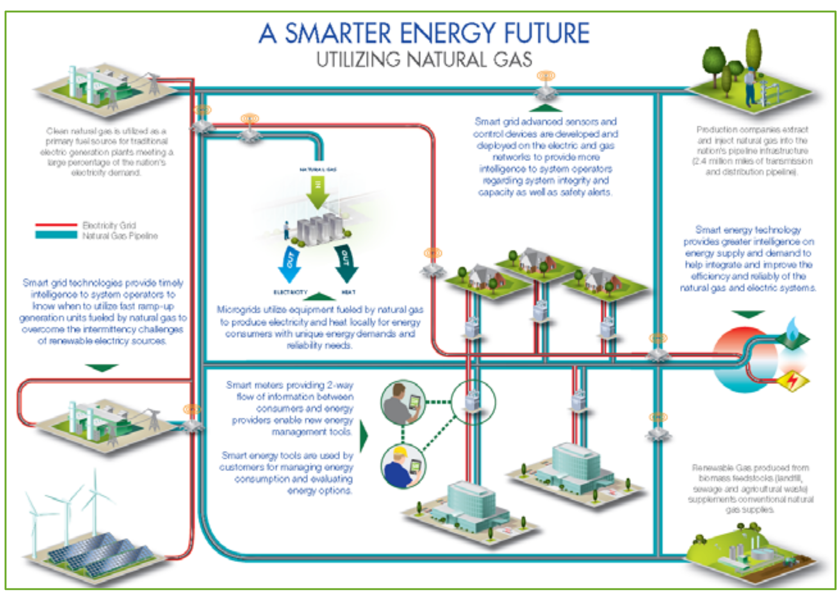
Low levels of methane emissions from pipeline natural gas can occur during production and throughout the delivery system, but emissions are decreasing. Leakage rates from the gas grid vary by location due to a variety of factors, such as the type and age of infrastructure. The methods to control methane emissions from transmission and distribution systems are well known through programs such as the U.S. Environmental Protection Agency's Natural Gas Star program. The use of new materials can reduce methane leakage by more than 90% in some cases, for example replacing cast iron or unprotected steel pipe with plastic pipe. As the use of gas infrastructure increases, either through direct use or for power generation, it will be necessary to make additional investments in modernizing existing gas infrastructure. A key means to justify the needed investments will be quicker and more accurate data on the specific causes and locations of natural gas leakage. Stopping or minimizing these leaks is a key element to improving the efficiency of the system.

HOLISTIC ENERGY GRIDS

Electricity and natural gas grids are the largest energy grids in the U.S., but there also are other energy grids using public rights of way, including fuel oil, steam and hot water, chilled water, and even hydrogen. Many of these are district energy systems that have long demonstrated efficiency, productivity, and environmental benefits. In the 21st century, such systems will be able to provide customers with far more choices and will enable real-time choices based on pricing, reliability, and environmental performance.

The "holistic energy grids" concept, illustrated in Figure 2, is being developed today in Europe, particularly in Denmark, and in Japan. With Japanese government's support, The Tokyo Gas Company has developed a "holonic" concept that proposes to use automation to operate flexible microgrids that include both centralized and decentralized heating, cooling, electric generation, and storage systems. The systems rely on both conventional feedstocks as well as a variety of steady and intermittent renewable energy supplies. The Tokyo Gas concept proposes to have district heating and cooling systems (DHC) work with microgrids to interchange electric and thermal energy simultaneously in metropolitan areas for higher efficiency.[40] Moreover, the microgrids will enhance energy security in case of emergencies by serving as an independent local grid.

Figure 2 – Illustration of a Holistic Energy Grid[39]



[38] National Risk Management Research Laboratory, "Methane Emissions from the Natural Gas Industry."
[39] Ibid.
[40] Tsukada, "Demonstration of Microgrid."

According to Tokyo Gas, “It is important to give energy-saving measures, including area-wide/networked energy usage, an important position in urban planning.” In the U.S., the realization of the investments needed to achieve the benefits of such systems will require some fundamental changes to energy regulation at all levels of government policies including:

- ensuring that smart grid implementation policies encourage the integration of natural gas and distributed energy applications;
- including natural gas and other energy transportation in advanced metering infrastructure development; and
- increasing governmental funding for expanded research in natural gas safety, reliability, and smart-energy infrastructure technology.[41]

CHALLENGES TO REALIZING BENEFITS

There are challenges to realizing the promise of a Smart Grid and primary among those is the investment needed and the regulatory support required. The gas distribution industry also is faced with the need to rehabilitate its oldest systems, such as cast-iron piping, while concurrently seeking funding to modernize and expand. As such, investments in new infrastructure and R&D to develop the cost-effective tools and techniques are essential to maintaining safety and modernizing the national and regional gas networks.

AGING INFRASTRUCTURE AND CAPACITY GROWTH

The increased demand for natural gas, both for power generation and for direct use, has been identified as possibly leading to constraints in delivery in some regions of the U.S. Those constraints are largely in the winter and rarely in the summer.[42] For example, the winter peak-day demand is projected to rise by 1.4% per year in New England, while firm demand overall is growing slower at a rate of 1.2% per year.[43] As such, peak deliverability concerns are rising at both the transmission and local level due to the difficulty in expanding infrastructure and the substantial increase in cost of pipeline reinforcements and replacements. These obstacles have not slowed demand or support for infrastructure expansion.[44] Optimization through smart-growth techniques can mitigate the challenges resulting from growth.

REGULATORY SCHEMES FOR CAPITAL INVESTMENTS

Achieving continued energy productivity gains by increasing the availability of natural gas infrastructure and the continued deployment of utility energy-efficiency programs in a changing energy landscape will require regulators, policy makers, stakeholders, and utilities to work together to develop innovative approaches for both system expansion and energy efficiency cost/benefits analyses. Some states are already taking the lead in developing new policies and regulatory schemes to ensure continued and aggressive advancement of energy productivity gains in their jurisdictions.

There is significant potential for natural gas to cost-effectively contribute to public goals such as reduced oil dependence, greater energy productivity, and reduced greenhouse gas emissions. However, economic constraints stand in the way of realizing the full potential of natural gas. Measured and prudent policy and regulatory approaches can help ease market constraints and provide a greater balance of long-term benefits and costs.

CONCLUSIONS

Natural gas infrastructure continues to grow in the U.S., and this growth provides opportunities to support aggressive goals for energy productivity while improving service and options for customers through the use of interactive smart electric and natural gas energy grids. The U.S. electric and gas grids are expected to become increasingly interdependent. Many attributes of a Smart Grid are equally valuable to both electric and gas grids, especially the ability to enable more efficiency measures and renewables based on the gathering of information and control. Energy grid management also is increasingly important as we begin to feel the effects of growing gas demand both for generation and direct use. A natural gas Smart Grid can be designed not only to meet these new needs efficiently, but also to do so in a way that enhances safety and reduces leakage on the distribution system.

Natural gas infrastructure has unique challenges, including the effects on the system of moving diverse gas supplies. Realization of smart gas growth and a natural gas Smart Grid requires coordinated new regulatory arrangements at the federal, state, and local levels, and increased support for R&D and infrastructure investment from governments and corporate entities along the entire value chain for both gas and electricity. Ultimately adoption of today’s Smart Grid concepts can lead to the development of a holistic energy grid that will offer customers and grid managers unprecedented tools to support high energy economic and environmental goals.

[41] American Gas Foundation, "Natural Gas in a Smart Energy Future,” 2.
[42] Charles River Associates, "The Ability to Meet Future Gas Demands.”
[43] ICF International, “Assessment of New England’s Natural Gas Pipeline Capacity.”
[44] Holland, Bill. "Bloomberg Doubles Down.”

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LIST OF ACRONYMS AND ABBREVIATIONS

ACNEEP – Alliance Commission on National Energy Efficiency Policy

Btu – British Thermal Units

CHP – Combined Heat and Power

CO_2 – Carbon Dioxide

DHC – District Heating and Cooling

DOE – Department of Energy

FERC – Federal Energy Regulatory Commission

GEIWG – Gas-Electric Interdependency Working Group

GW - Gigawatts

ISO-NE – Independent Systems Operator – New England

LCD – Local Distribution Companies

LNG – Liquefied Natural Gas

MIT – Massachusetts Institute of Technology

MMBtu – Million Btu

NERC – North American Electric Reliability Corporation

NGCC – Natural Gas Combined Cycle

PHMSA – Pipeline and Hazardous Material Safety Administration

R&D – Research and Development

RG – Renewable Gas

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