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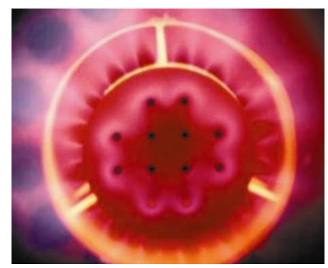
WHITE PAPER

Natural Gas in a Smart Energy Future





A strategic resource for electricity and a smart resource for homes and businesses

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Legal Notice

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GTI and Navigant wish to thank the sponsors and the many people who contributed to this paper. The vision for natural gas in a smart energy future described herein incorporates the knowledge and opinions of the sponsors and over 60 interviewed individuals, in addition to direct feedback from organizations across the natural gas industry.

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Foreword

This white paper is the result of industry-wide support for the development of a compelling vision of a smart energy infrastructure integrating natural gas with electricity from multiple sources, including renewables, resulting in what we describe as a "smart energy future." Our sponsoring organizations recognized the value that abundant, domestic, low-carbon natural gas provides for establishing a secure and affordable energy source compatible with North America's environmental, economic, and societal goals. This white paper promotes the thesis that natural gas' importance to electric smart grid implementation is critical and should be viewed as part of a broader smart energy future. Various energy resources must be utilized to provide reliable, safe, affordable, clean, and efficient energy to North America's homes and businesses.

The development of the vision for *Natural Gas in a Smart Energy Future* included interviews with over 60 individuals and groups representing the entire natural gas industry. Each interviewee was challenged with a set of questions focused on identifying the problems and opportunities, needs and gaps, hurdles and obstacles where action is required now to achieve the vision they could foresee for the industry. To further encourage long range thinking each interviewee was asked to envision the natural gas industry at a point that would be at least 20 years into the future such as 2030 and beyond. Over 470 observations from these interviews were summarized into a vision statement which was then reviewed with a wide variety of industry stakeholders representing federal, provincial, and state regulatory bodies and codes and standards organizations, as well as industry experts and stakeholders.

The vision includes seamless communication and data management between the electric and natural gas infrastructures expanding the concept of a smart electric grid to an energy infrastructure that can enable a smart energy future. This paper also identifies key tools and steps needed in order to achieve the vision in view of policy, regulatory, and technology challenges and proposes a framework to support discussions between natural gas companies, electric companies, regulators, policy makers and other stakeholders.

Executive Summary

This white paper presents a compelling vision of how natural gas can provide the key to a smart energy future through its efficient, safe, and reliable delivery and use as an abundant, domestic, affordable, low-carbon energy source for all segments of the economy. It also anticipates integrating the natural gas infrastructure with an increasingly "smart" electricity grid and supporting increased levels of renewable energy.

A smart energy future in which natural gas is effectively integrated has the potential to deliver several important advantages:

- Improved safety, energy security, and environmental performance;
- A more efficient infrastructure, with the ability to provide demand response, accommodate emerging technologies, and new sources of supply;
- Improved demand response for electric distribution through switching heating and cooling loads to natural gas and through the use of distributed generation;
- Greater consumer choice resulting in maximum energy value; and
- More optimized energy value from renewable wind and solar through the use of fast ramping dispatchable generation.

Failing to realize a smart energy future in which natural gas is not effectively integrated could create or exacerbate a number of problems:

- The delivery infrastructure will not be at an optimal level for society;
- Higher energy costs for consumers;
- Consumer options for efficient energy use will be limited;
- Greenhouse gas emissions will increase and be more costly to manage;
- The increased use of intermittent renewable energy sources will create performance issues for the electric grid that could have been effectively addressed; and
- Demand response options for the electric distribution system will be limited and more costly.

A Smart Energy Future

The term "smart grid" is widely used to describe a more advanced network of electricity generation, delivery, and end use applications. A smarter energy infrastructure including natural gas would also provide consumers with more timely information for making energy decisions. Action is required now to get to the smart energy future of 2030 and beyond. Available energy sources and infrastructure will need to be optimized to meet North America's overall energy needs in a manner that is:

- Clean and sustainable;
- Reliable and secure;
- Affordable and efficient; and
- Robust and flexible.

A smarter energy future assumes diverse and lower-carbon energy resources are combined with an energy delivery infrastructure that is more reliable and secure than what we have today. This will require technological advances to enhance the efficiency of energy use and reduce greenhouse gas emissions, as well as energy efficiency improvements to reduce consumers' carbon footprint. All of this must be accomplished with a focus on cost in order to maintain the global competitiveness of North America and maintain affordability for energy users.

The Vision for Natural Gas

Natural gas in North America is a critical energy resource, representing a quarter of the total energy consumed in the United States and Canada. New shale gas discoveries have significantly increased supply estimates for the United States and Canada, as well as globally. North American natural gas is efficiently distributed to and used for home and building heating, water heating, and in industrial processes. Natural gas also is a significant fuel for electric power generation and is the fuel of choice for new electric power plants. The U.S. Department of Energy (DOE) forecasts that 900 of the next 1,000 power plants built will be fueled with natural gas.[1]

Therefore, the vision for natural gas in a smart energy future presented here acknowledges the value of natural gas as a strategic resource for electricity, and a smart resource for homes and businesses. Some of the technology included in the vision does not yet exist or is not fully implemented. With further development however, these technologies could be made available as we progress toward the 2030 vision.

For purposes of simplicity within this white paper, the natural gas industry will be discussed as being represented by three broad sectors.

Supply: Exploration and production, natural gas processing, gathering pipelines, compressor stations, and storage.

Delivery: Transmission and distribution piping, compressor stations, and storage facilities used to deliver natural gas.

End Use: Full economic spectrum of consumers from industrial, power generation, residential, commercial, and other uses including transportation.

The supply, delivery, and end-use sectors each must address key challenges in order to fully realize the vision for natural gas in a smart energy future *(Figure 1)*.

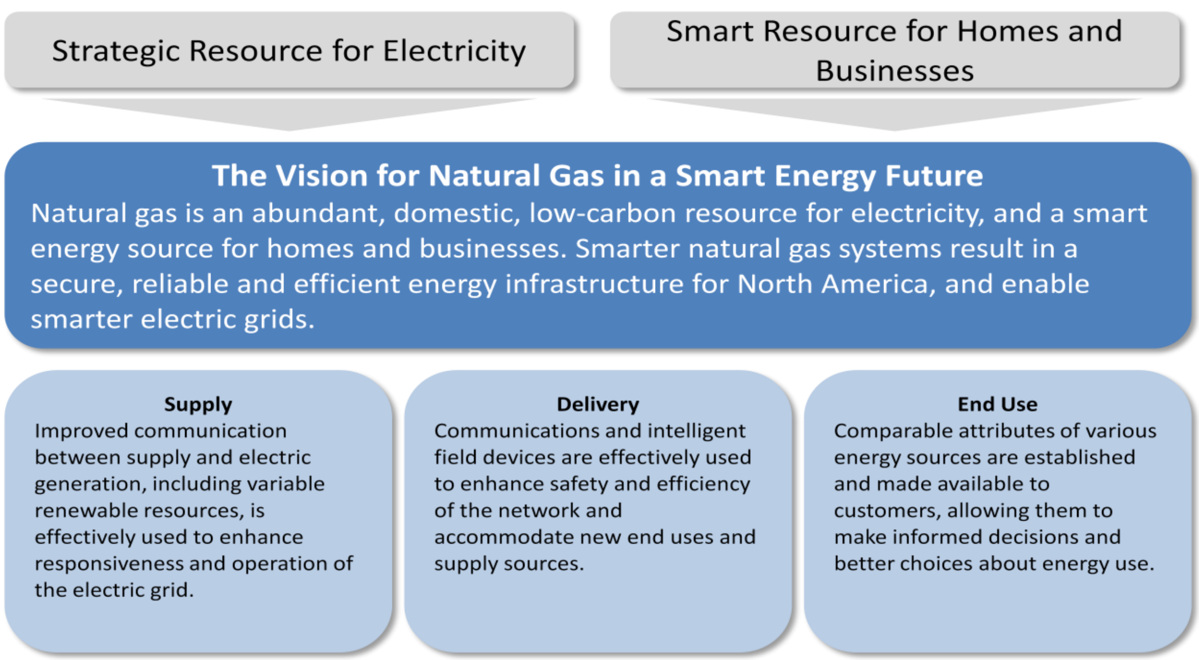

Figure 1. The Vision for Natural Gas in a Smart Energy Future

1 *http://www.energy.gov/energysources/naturalgas.htm (Last visited 11/17/2010)*

Achieving the Vision

Pursuing the vision for natural gas in a smart energy future by 2030 must begin now. By enhancing the energy resource mix and infrastructure that is in place, and by fully implementing existing and emerging technologies and business models, achieving the vision is possible in the 2030 timeframe. However, achieving the vision requires action to create or enhance key capabilities within each of the major sectors as follows.

Supply:* *Within the Supply sector, establish tighter coordination of natural gas supply and natural gas-fired electricity generation to complement variable renewable resources, thereby enhancing responsiveness and operation of the electric grid.

Natural gas currently fuels a large portion of the electricity generation portfolio, and this is increasing as compliance with environmental regulations reduces the number of power plants with high greenhouse gas emissions and/or prohibitive regulatory requirements and lead times. Because renewable energy availability varies due to normal daily and even hourly fluctuations in wind and sunlight, fast-acting generators fueled with natural gas can balance power fluctuations. These generators can also regulate grid voltage and frequency, which is necessary to tap the full potential of renewable energy. Tighter coordination and information sharing between electric grid operators and gas suppliers, and technology advancements are key factors to ensure adequate gas supply to generators. Specific capabilities include:

- Automated high ramping supply response;
- Wide area monitoring, visualization, and control;
- Predictive load modeling and forecasting;
- Real time inter-grid communications (gas and electric);
- Automated/dispatchable market area storage; and
- Peak electric demand management assistance.

Delivery:* *Within the Delivery sector, create or improve sensing, monitoring and controlling technologies to effectively enhance the safety and efficiency of the network and accommodate new end uses and emerging supply sources.

The design and construction of the natural gas delivery system of today is typically based on satisfying the requirements of the existing and reasonably foreseeable peak load for a 30-year period. The system of the future will be expected to accommodate emerging technologies and electric demand response programs that have the potential to increase natural gas load. The system also will be expected to accommodate energy efficiency programs that have the potential to decrease peak load. Finally, the system of the future will be expected to accommodate emerging local or regional sources of supply that will differ in quality and composition from those of today. By creating or enhancing the ability to estimate and control load and supply, as well as volume and pressure on a real time basis, the utilization of the infrastructure can be significantly improved. The delivery sector needs improved technologies to provide:

- Detection/prediction of third party damage;
- Automated leak detection and notification;
- Automated flow control and volume/pressure management;
- Automated shut-off;
- Gas quality monitoring and management; and
- Btu composition monitoring at the customer exchange (billing).

Natural gas fueled microgrids comprised of one or more interconnected distributed generation and combined heat and power (DG/CHP) units are one example of an end use that is anticipated to be part of the smart energy future and supported by the natural gas delivery infrastructure. A microgrid incorporates groups of small power and/or combined heat and power generators and loads in systems interconnected to the utility grid, or operated independently as islands. These systems are well suited to applications where there are concentrations of energy consumers needing both electricity and heat, such as industrial facilities, hospital complexes, college campuses, and other facilities with similar construction. Microgrids can help improve the utilization of the energy delivery infrastructure, defer electric generation and delivery upgrades, reduce electric transmission losses, improve energy service reliability, and reduce overall energy costs for consumers within the microgrid. Microgrids will require adequate local natural gas and electricity infrastructures, and the ability to manage energy production and consumption actively and locally.

End Use:* *Within the End-Use sector, implement technology to help consumers make well informed energy choices.

Energy supply is becoming more complex, with new resources such as wind, solar, and biofuels providing a host of new choices for consumers. The problem is consumers do not have a clear picture of where their energy comes from, what it really costs to produce and deliver it, and what impacts it has on the environment and society. Moreover, it is not possible to make consistent comparisons among energy sources. Customers need to have information about the energy they use, better tools to manage their energy use, and access to pricing programs that allow them to value their energy choices properly. Specific capabilities needed include:

- Adoption of full-fuel-cycle analysis in codes, standards and energy labeling;
- Moderating peak electricity demand by using natural gas powered cooling solutions in the commercial applications and natural gas powered DG/CHP systems on an aggregated basis or as part of a microgrid for residential and/or commercial consumers;
- Advocating the use of CHP systems to supply power, heat and cooling at industrial and commercial applications;
- Plain language educational programs for consumers;
- Suite of tools allowing consumers to make smart energy usage choices;
- Consumer energy optimization;
- Hybrid electric/renewable energy/natural gas appliances capable of providing space conditioning, water heating, cooking, and clothes drying; and
- Measurement and verification of energy efficiency program participation.

These capabilities listed above are explained in more detail in the Appendix.

Benefits

Achieving the vision requires a long term commitment to transforming our energy systems, but we must take action now. Some benefits, like increasing asset utilization and lowering energy costs, will be most noticeable as technologies are deployed fully across the energy infrastructure over many years. Others, like increasing reliability or equipment life, will be more localized, and will yield benefits incrementally.

In the smart energy future, consumers will have a clearer picture of their energy usage and will be able to monitor, manage and conserve energy while protecting the environment. New technology platforms will be provided allowing for the introduction of new products and services. A coordinated network of sensors and control technologies will help consumers utilize energy resources according to individual preferences and value criteria.

The delivery infrastructure also will benefit from additional information from a network of sensors and control technologies to provide transmission and distribution companies with real-time information about customer load, and network volume and pressure. This will enable improved asset utilization, diversification of supply sources, system reliability, service quality, and safety.

Recommendations for Action

Achieving the vision in the long term will require a number of near term actions related to policy, technology development, and implementation of key capabilities in each of the industry sectors.

FOR POLICYMAKERS:

Research and Development/Budget

- Include natural gas in advanced metering infrastructure development to optimize common infrastructure, interoperability and cross-compensation among all utility infrastructures including electricity and water;
- Ensure that future federal funding programs including Smart Grid encourage and allow the use of funding for dedicated natural gas projects and combined electric/natural gas projects;
- Develop a technology roadmap for natural gas in a smart energy future, including critical input from a broad group of stakeholders and the energy technology R&D community;
- Increase governmental funding for basic as well as applied research in natural gas safety and reliability and smart energy infrastructure technology; and
- Establish a governmental public-private research, development and deployment program for natural gas similar in size to the electric Smart Grid programs that includes component and system suppliers.

Regulatory

- Expand the use of source energy standards to recognize the value of full-fuel-cycle energy efficiency and carbon emission benefits and incorporate full-fuel-cycle analysis in all conservation and energy efficiency standards, including common measures of energy and greenhouse gas emissions;
- Expand ongoing Smart Grid standards development efforts to include natural gas;
- Provide consumers information about energy usage and energy appliance selections so they can make educated decisions.
- Modify the International Green Construction Code to ensure that every new building has access to natural gas service where available;
- Modify market rules to facilitate and create procedures for direct communications between pipeline and electric grid operators to fully optimize the usage of energy.
- Promote real-time communications between the gas and electricity grids;
- Approve projects in a timely manner to ensure natural gas infrastructure can meet the needs of all current and future end-uses; and
- Make energy efficiency programs neutral with respect to energy sources, and encourage collaboration among all energy providers.

FOR INDUSTRY:

Enhance or Create Capabilities for Supply

- Create and expand real-time communications between the gas and electricity grids;
- Enhance systems to manage natural gas supply for fast-ramping generation to complement variable renewable resources and provide ancillary services; and
- Actively engage federal, provincial, and state regulators to help resolve the issues related to developing shale gas as a long-term energy source.

Enhance or Create Capabilities for Delivery

- Ensure the natural gas infrastructure can meet the needs of all current and future end-uses;
- Enhance the system capability to accept and distribute a wide range of renewable gas sources;
- Ensure current and future natural gas infrastructure can accommodate emerging technologies, peak demand, energy efficiency programs, and new sources of supply; and
- Create or enhance capabilities to improve natural gas asset utilization on a real-time basis.

Enhance or Create Capabilities for End Use

- Develop cost effective systems to be used to moderate peak electricity demand by using natural gas powered cooling solutions in the commercial applications and natural gas powered DG/CHP systems on an aggregated basis or as part of a microgrid for residential and/or commercial consumers;
- Advocate the use of DG/CHP systems to supply power, heat and cooling at industrial and commercial applications;
- Develop hybrid electric/natural gas appliances capable of providing space conditioning, water heating, cooking, and clothes drying; and
- Provide customers the information to make educated choices about their energy usage and energy appliance selections.

Defining a Smart Energy Future

In recent years, the term "smart" has come to signify capability and quality in numerous products and services. In the energy industry, the term "smart grid" is now widely used to describe a more advanced network of electricity generation, delivery, and end uses. While the smart grid has many different meanings depending on one's point of view, it is generally accepted that a smarter grid is more reliable, operationally efficient, and cost-effective. In addition, a smarter grid can better accommodate renewable energy resources such as wind and solar, and power cleaner vehicles and more efficient appliances.

This paper describes natural gas' role in the actions required now to get to a smart energy future in the timeframe of 2030 and beyond. The smart energy future includes natural gas and electricity optimally coordinated in an energy value chain to power homes and businesses, keep us comfortable, and drive our economy while preserving our environment and national security. The smart energy future includes four characteristics *(Figure 2).*

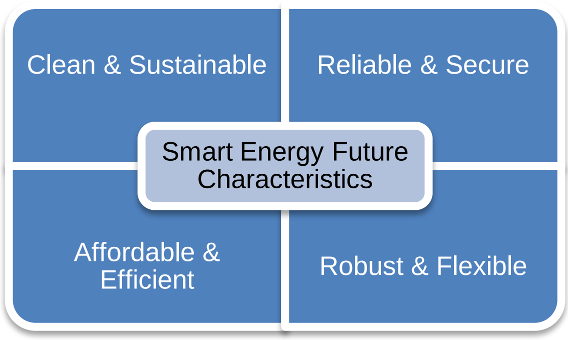

Figure 2. Characteristics of a Smart Energy Future

While these characteristics do not exist fully with the energy resource mix and infrastructure currently in place, a full implementation of existing and emerging technologies and business models, will make it possible. Because of its qualities, natural gas can play a critical role in making a smart energy future a reality.

In the smart energy future a diverse and lower carbon energy resource mix will be implemented within a delivery infrastructure that is more reliable and secure than what we have today. This will require an increasing share of renewable energy resources and other technologies to reduce carbon emissions. It also will require improving energy efficiency and reducing the carbon footprint of all energy consumers. Finally, this all must be accomplished while containing the cost of energy by ensuring investments in smart technologies to demonstrate value for energy users.

Natural Gas is Clean and Sustainable

Analysis by Gas Technology Institute (GTI) suggests an increase of natural gas use in electricity production from central generation and distributed generation, transportation, and residential, commercial and industrial applications can be a major component in reaching a 42 percent reduction in U.S. carbon emissions by 2030. Natural gas provides the most direct means for immediate and sustainable carbon dioxide (CO_2) reduction because:

- Natural gas-fired power generation emits the least CO_2 per BTU of any fossil fuel, with 56 percent lower CO_2 emissions than coal, the dominant electricity generation fuel in the United States;
- The direct use of natural gas in applications where heat is required such as for space conditioning or water heating is much less carbon intensive than using electricity for the same application, particularly when the electricity is generated with high-carbon fuels;

- As part of the electric smart grid, natural gas generation can be quickly ramped to complement variable renewable electricity generation such as wind and solar, enabling these carbon-free generation technologies to enter the resource mix;
- The expanded development of renewable gas (biogas) will further reduce the carbon intensity of the energy resource mix in North America; and
- The development and commercial deployment of carbon capture and storage for natural gas power plants will allow gas generation to operate at near zero GHG emissions.

Natural Gas is Reliable and Secure

The North American natural gas infrastructure is an interconnected system of producing wells, gathering lines, processors, transmission and distribution pipelines, compressor stations, and storage facilities serving over 75 million customers with a history of close to 100 percent reliability. When the reliability of the natural gas delivery system is paired with natural gas-fired electric power generation, the combination results in a proven, conventional technology that is highly dependable compared with other technologies. The integration of natural gas with electricity into a highly reliable energy delivery infrastructure would provide an extraordinary combined level of reliability, especially when coupled with applications interconnected with this integrated grid such as backup electricity generation, microgrids, and loops of heated or chilled water managed as thermal grids.

New shale gas discoveries have significantly increased supply estimates for the United States and Canada, as well as globally. A recently released report on natural gas by Massachusetts Institute of Technology (MIT)[2] summarized resource estimates from a variety of sources and concluded the mean remaining natural gas resource base is around 2,100 (trillion cubic feet) Tcf or about 92 times the annual U.S. consumption of 22.8 Tcf in 2009. With deployment of technologies that can cost-effectively extract natural gas, North America has enough natural gas resources for at least the next 100 years.

Natural Gas is Affordable and Efficient

Natural gas can be delivered from the wellhead to consumers at 91percent efficiency utilizing the delivery system throughout North America[3]. No other energy delivery system, from source of energy production to end-use, is comparable. Almost all natural gas used in North America originates in North America, and is delivered cost effectively and efficiently through an extensive transmission and distribution system. When the future cost of plant construction, fuel price, and CO_2 are considered, natural gas generation has a lower levelized cost of electricity than nuclear or coal-fired generation. Natural gas fired electricity generation also is not subject to a number of environmental issues related to plant-siting and waste associated with other forms of electricity generation. When the source energy attributes noted above, determined through full-fuel-cycle analysis from production to end use, are compared to any other major energy source for consumers a favorable advantage for overall energy efficiency and carbon emissions is shown to be available to consumers as they make their energy choices. Whether those choices are to include natural gas service as part of new construction, which type of energy to use for space conditioning, water heating, cooking, or clothes drying or when they are deciding which appliance to purchasing as a replacement natural gas provides an efficient cost effective energy source.

2 "The Future of Natural Gas, an Interdisciplinary MIT Study, Interim Report," MIT Energy Initiative, Massachusetts Institute of Technology, 2010.

3 American Gas Association, "Source Energy and Emission Factors for Residential Energy Consumption," August 2000

Natural Gas is Robust and Flexible

In 2009, approximately 22.8 Tcf[4] and 2.6 Tcf[5] of natural gas was delivered to U.S. and Canadian consumers, respectively, through an intricate infrastructure including gathering systems, processing facilities, market centers, compressor stations, and pipelines. Along the way there are options to store natural gas in underground facilities and to transfer natural gas between pipeline systems. Added flexibility is provided by infrastructure to import or export natural gas.

4 http://www.eia.doe.gov/energyexplained/index.cfm?page=natural_gas_home#tab2 (Last visited 11/17/2010)

5 http://www.cga.ca/publications/documents/Chart7-SalesandExports.pdf (Last visited 11/17/2010)

The Vision for Natural Gas

The Source of the Vision

The vision for *"Natural Gas in a Smart Energy Future"* is the product of extensive discussions among leaders from across the natural gas industry. During a series of interviews, workshops, and forums, these experts were challenged to think about the natural gas industry in 2030 and beyond. They talked about opportunities to improve our energy infrastructure, and achieve the four *(Figure 2)* characteristics of the smart energy future.

This vision expresses a consensus of the industry participants; some of the technology included in the vision does not exist or is not fully implemented today, but the industry participants believe it is important to start now to achieve this vision. With development and application, these technologies could be made available within the 2030 timeframe.

The Vision

In North America natural gas is a critical energy resource, representing a quarter of the total energy consumed in the U.S. and Canada. Consumption is well distributed among industrial processes, power generation, commercial, residential, and other uses including transportation *(Figure 3).*

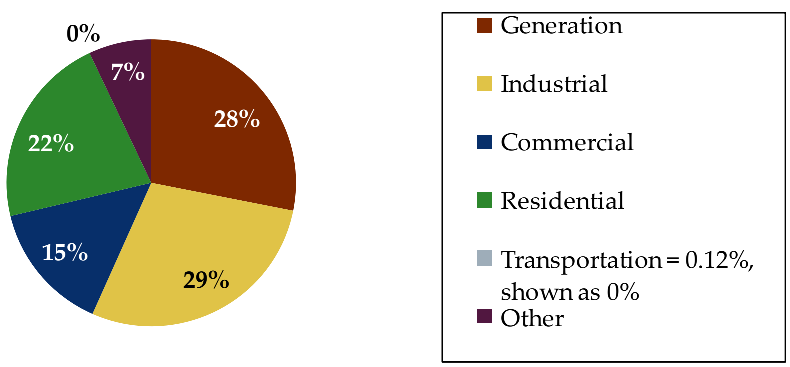

Figure 3. Breakdown of North American Natural Gas Consumption by Sector in 2009

Therefore, the vision for natural gas in a smart energy future *(Figure 4)* acknowledges the value of natural gas as a strategic resource for electricity production in central power plants and distributed generation. It also is a smart resource for homes, businesses, and as a fuel for medium and heavy duty vehicles. The supply, delivery, and end-use sectors are three major sectors involved in achieving the vision for natural gas in a smart energy future.

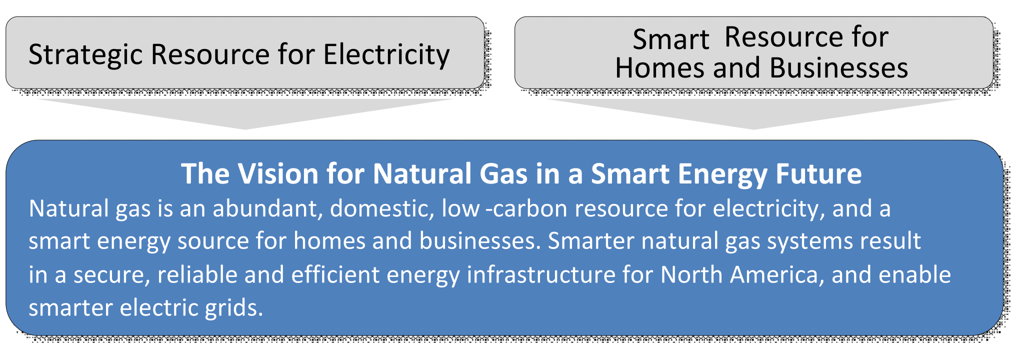

Figure 4. Vision for Natural Gas

The Vision for Supply

The responsiveness and operation of the electric grid is improved through increased levels of direct and timely communication among wholesale gas producers and marketers, transporters and electric generators, including communications from variable renewable resources.

- *Direct communication* allows natural gas suppliers to respond to fluctuations in electricity production more quickly and efficiently.
- *Fast-ramping gas-fired power generation* complements variable renewable resources to provide reliable and secure electricity.
- *Demand forecasts* for electricity are available to gas suppliers, helping ensure fuel is available when and where it is needed. Energy market information is available, allowing tighter coordination between pipeline and grid operators.
- *Real-time information* about weather, demand, infrastructure, and operating conditions is shared among all parties.

Natural Gas – Now and in the Future

Natural gas is not simply 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.

Conventional gas basins were the original source of most natural gas in North America because the gas was easily accessible and extracted. Unconventional gas sources historically were more difficult to induce production of gas until recent technological breakthroughs in drilling and hydro-fracturing made it 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 a sandstone or carbonate formation); and (3) Coal bed methane (generated during the transformation of organic material to coal).

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.

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

The Vision for Delivery

Delivery effectively uses two-way communications and intelligent field devices to enhance safety and efficiency of the network and effectively serve new end uses and supply sources.

- *Robust and flexible infrastructure* responds to consumer needs and enables pipelines and local distribution companies (LDCs) to safely and efficiently increase capacity and actively manage volume and pressure using a network of sensors, two-way communications, and automation. This infrastructure readily accommodates diverse sources of supply.
- *Optimized investment* is possible as better load forecasts, network monitoring and demand management techniques are employed to improve asset utilization, capital deployment, and increase useful life.
- *Emerging technologies* such as microgrids, thermal grids that manage loops of heated or chilled water, and alternatively-fueled vehicles create new uses for natural gas and electricity.

The Vision for End-Use

Comparable attributes of various energy sources have been established and made available to consumers, allowing them to make informed decisions about energy use.

- *Transparent, repeatable analyses* are done for multiple energy sources to directly compare attributes such as energy content, price, and environmental quality on a full-fuel-cycle basis.
- *Comparable energy attribute information* is available to consumers in a simple and convenient form.
- *Energy management tools* provide timely intelligence aiding consumers in making energy choices.

Achieving the Vision

For many years the natural gas infrastructure has met the needs of the consumer. However, it must evolve further to support the level of operations necessary to achieve the vision and associated benefits of a smart energy future. *Figure 5* summarizes where work is required in order to fully capture the benefits of natural gas in a smart energy future. These challenges cannot be met today with the energy resource mix and infrastructure that is in place; however, by fully implementing existing and emerging technologies and business models, it is possible. Because of its qualities, natural gas can play a foundational role in achieving each of these objectives, and making the smart energy future a reality. The following sections describe in more detail the steps to achieve the vision for 2030, and present some key capabilities/functions/technologies. These capabilities are highlighted based on GTI/Navigant's review of the information collected from extensive interviews and dialogue with industry experts and stakeholders as well as their own in-depth understanding of the natural gas industry.

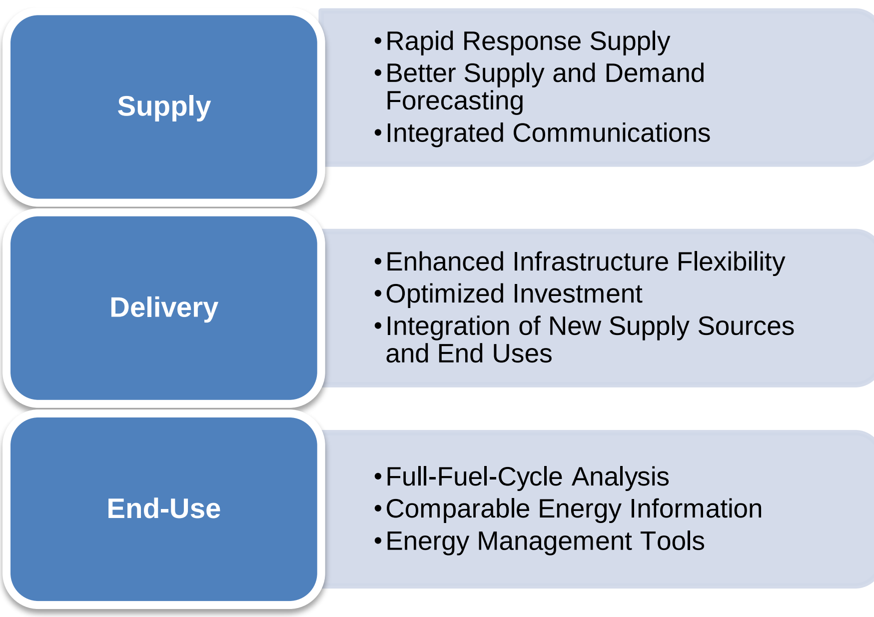

Figure 5. Key challenges by sector

Capabilities for Supply

The demand for natural gas can change dramatically. Weather significantly affects heating load for direct use, and can also affect the electricity demand served by natural gas generators specifically as variable renewable resources play an increasing role in the energy supply mix. Wind and solar generation are variable by nature, and in some instances grid operators and electric system planners have struggled to maintain grid reliability as a result. In the past, the availability of natural gas for generation may have been taken for granted. However, as more variable resources are utilized, more fast-ramping generation will be required to balance them. Where gas generation is used for this purpose, pipeline pressure and volume must be actively managed through tighter communications and information sharing to respond to variable electricity production in conjunction with storage facilities and pipeline service offerings.

Unfortunately, the time horizons for planning and operating the electric and gas grids differ due to physics and markets. Tighter integration of gas and electricity in a smart energy future means the alignment of demand forecasts must improve to ensure supply is made available to meet demand. This will also require better information sharing between pipeline operators and electricity grid operators.

When actual conditions deviate from forecasts, pipeline operators and electricity grid operators must still maintain system reliability. An electric grid operator may call on a generator with little notice, and it must be ready to deliver. This requires a ready fuel supply, and the pipeline operator must have requested and delivered it – before the generator was called upon. A more fully integrated smart energy grid requires direct communication between suppliers, pipeline operators and electricity grid operators. This may require modifications to market rules.

To achieve the vision for supply, a wide variety of capabilities will need to be developed or enhanced. Several are highlighted below.

Real Time Inter-grid Communications (Gas/Electric) will need to be provided, including two-way, secure, redundant path communications between pipeline operators and generators. Redundant paths allow the signals to travel via either wireless or wired paths, perhaps using radio, satellite, cable, power-line, or telephone to ensure two-way communication is maintained. This approach leverages the high speed communications linkage connecting the central office with each individual sensor, controller or any other information gathering point within the gas/electric infrastructure, commonly referred to in the communications industry as backhaul. An approach of this type would provide real-time data which can be acted upon by automated intelligence systems and/or system operators, resulting in coordinated operations between the electric and gas grids.

Wide Area Monitoring, Visualization, and Control includes the use of two-way communication technologies to collect, analyze, and interpret data from sensors and monitoring locations along the transmission pipelines. The data collected would be analyzed by system operators with the help of computer programs to provide beneficial information allowing the real-time status of the system to be visualized and controlled. A system with these capabilities will provide proactive response for predicted events and real-time reactive responses for any unforeseen events.

Coordinated Operation of Natural Gas and Electricity Infrastructures

Today the natural gas and electricity infrastructures are largely controlled independently, with little cross-communications which is primarily the result of sizable differences in time constants and system dynamics. Electric loads have major daily and seasonal fluctuations but smaller annual fluctuations, whereas natural gas loads have smaller daily variations but major annual fluctuations. Gas storage can exceed 20% of the annual consumption, with the storage capability varying significantly by region. Due to the system dynamics it is often assumed the gas system will be able to instantly respond to demands from the electric system, however, both theoretical as well as real-life experiences have shown these assumptions are false. A new model could be developed to accurately anticipate the impacts of substituting high ramp rate gas generation for other resources such as intermittent wind resources over broad geographic areas. The targeted use of the model could improve long range planning, contingency analysis, and risk mitigation for the two energy grids.

Joint modeling could account for dependencies including weather, changes in supply and demand, and emergencies, and account for the differences in operational time constants between the infrastructures.

Developing an integrated operational capability would involve:

- Piloting an operational model in a single region or control area;
- Extending operations to multiple control areas in a wide-area demonstration; and
- Finalizing a national-scale operational framework.

Technology capable of providing *Automated High Ramping Supply Response* results in delivering natural gas at the pressures and volumes required to operate fast-ramping generation facilities efficiently. This would work by connecting electric and natural gas transmission through an infrastructure equipped with sensing and controlling technology to allow real-time response.

Novel methods for *Automated/Dispatchable Bulk Market Area Storage* need to be developed for every market area to provide large volume storage available for immediate response to support the continued operations of the natural gas system. Storage of this type needs to be automatic and flexible with response rates comparable to those provided by today’s salt dome storage facilities which are geologically restricted to certain regions of North America.

Predictive Load Modeling and Forecasting needs to be developed allowing the use of current consumer load data in combination with historical load data, current and historic weather data and current and historic major consumer use patterns. The resulting modeling and forecasting software would provide trend analysis to allow accurate load prediction and forecasting.

Peak Electric Demand Management Assistance includes the direct communications to the natural gas grid through the use of technologies to monitor and proactively provide appropriate peak electric load reduction and/or demand response in support of the needs of the electric infrastructure.

Capabilities for Delivery

Emerging technologies such as microgrids, thermal grids, hybrid appliances, and alternatively fueled vehicles will create new uses for natural gas and electricity. To respond to consumer needs, LDCs must be able to ensure the infrastructure is capable of accommodating these new end uses while continuing to ensure the integrity and safe operation of their gas systems.

For many years, natural gas distribution systems and electric distribution systems have been planned and built separately to meet the forecast peak demands of each infrastructure typically based on a 30-year planning horizon. 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 cost.

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 will also be expected to deliver gas from new supply sources being developed.

Similar to the approach we used for supply, we have identified a wide variety of capabilities and functions that must be developed or enhanced in order to achieve the vision for delivery. We have highlighted a few that would be among those needing to be created or enhanced.

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 could also include smart gas metering and load monitoring devices at the

Enabling New Energy Technologies

The full scale demonstration of technologies can be key to their commercialization. Regional demonstrations of a microgrid (a localized grouping of power and/or combined heat and power generation, energy storage, and loads that normally operate connected to a traditional grid that are coupled and connected through a single point or disconnected and function autonomously) should be considered addressing the wide variety of possible applications. For example, there are areas in North America where economic development is an imperative. The use of a microgrid to provide premium power could be offered to attract manufacturing and high tech industries. With the pressure being placed on older coal generating power plant to meet emissions limitations, it may be appropriate to evaluate the long standing strategy of a single large central generating facility versus smaller combined cycle natural gas generating stations located throughout the same area being served. These smaller natural gas units would be interdependent and have sufficient redundancy to back each other up should an unplanned outage occur at any one location. This configuration would also have the ability to seamlessly incorporate intermittent renewable power. Using a microgrid for communities that are susceptible to outages, an approach known as “islanding” may be another attractive use of this technology. Islanding may be an effective tool as part of a peak demand response where the natural gas unit is used as a backup to the electric grid or it may be preferred to use the natural gas unit as the prime source of power and the electric grid as the backup. One final example of the use of microgrid is to optimize the performance of renewable technology. Renewable resources are often criticized due to their intermittency and low capacity factors. Combined installations that directly link renewable energy with natural gas generation and possibly energy storage may be key in moving both technologies forward.

consumer location that allow the LDC to monitor and manage the system to ensure the consumer load requirements are met safely and reliably. This may include real-time metering, remote disconnection, outage detection, and other features.

Automated Shut-off 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 warrants 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 shut off could be implemented in transmission pipelines, local distribution lines, or at the meter.

Detection/Prediction of Third Party Damage would utilize 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.

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.

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 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 quality management, and facilitate the seamless integration of supplies including shale gas and renewable gas (biogas).

Capabilities for End-Use

The supply of energy is becoming more complex. New energy resources such as wind, solar, and biofuels will provide a host of new choices for consumers. The problem is most consumers do not have a clear picture of where the energy comes from, what it really costs, and what impacts it has on the environment and society. Consumers need to have information about the energy they use, better tools to manage their energy use, and access to pricing programs that allow them to value their energy choices properly. Factual, repeatable analyses of the full-fuel-cycle efficiency and cost of multiple fuels must be conducted and directly compared so consumers can make energy choices that best meet their needs. This should include accounting for regional variations in fuel mix and availability.

Full-Fuel-Cycle Analysis in Codes, Standards and Energy Labeling should be adopted for buildings and appliances to include source energy or what is referred to as full-fuel-cycle analysis as the basis for energy efficiency and emissions standards. A requirement should also be established for the consumer to have access to available natural gas wherever natural gas distribution occurs.

Codes and Standards for Buildings and Appliances

One way to directly and quickly influence the energy choices being made is to ensure the codes and standards for buildings and appliances are up-to-date. Quick examples to be addressed are the use of Full-Fuel-Cycle Analysis in the building codes and the standards across North America and updating home energy rating systems such as HERS and the Energuide Rating System. Full-Fuel-Cycle analysis is also referred to as source energy and should not be confused with site energy. Source energy is the comprehensive measurement of the amount of energy consumed at the site, plus the energy that is consumed during the extraction, transportation, processing, and distribution of the energy to the point of use. This is in contrast to site energy that is simply the amount of energy consumed at the point of use. Home energy rating system guidelines establish a systematic process for the delivery of whole-house home energy ratings. The ratings also provide evaluation of the cost-effectiveness of options to achieve greater energy efficiency in those homes.

Information about the source, composition, quality, and price of various energy sources must be made available to consumers in an easy to understand and compare format. These attributes should incorporate more comprehensive information, and account for regional differences in resource availability and market options.

Armed with consistent and comparable energy information, consumers should be provided a *Suite of Tools Allowing Consumers to Make Smart Energy Choices* about their energy supply and how they ought to use it. Such tools help consumers distinguish between important factors such as carbon intensity, reliability, price, and other factors.

Consumer Energy Optimization can be provided through the development and use of a simple, easy to use, and convenient in-home display and/or a smart thermostat connected with every major energy-consuming appliance. The in-home display and/or smart thermostat would also be capable of two-way communications with utilities to receive demand response requests or time-of-use information. This simple yet sophisticated approach coupled with consumer education will provide the consumer with plain language, site-specific choices for energy use and carbon footprint. The full-fuel-cycle efficiency of end use appliances could be provided to consumers for their end use decisions and full-fuel-cycle could be used by regulators when producing energy efficiency and air emission/carbon regulations.

Plain Language Education Programs for Consumers coupled with straight-forward easily understood messaging will allow each consumer to make the energy choices that are right for their situation. Whether those choices are to include natural gas service as part of new construction or which type of energy to use for space conditioning, water heating, cooking, or clothes drying or when they are deciding which appliance to purchasing as a replacement, clear and concise information on energy cost and emissions based on factual, repeatable analysis is essential for a smart energy future.

Measurement and Verification of Energy Efficiency is an important function that needs to be fully developed and simplified. It would use sensing and communicating technology to provide a method for determining the energy efficiency impacts of actions taken by the consumer. Improved sensing and communications technologies can also be coupled with sub-metering options for residential, commercial, and industrial consumers to cost effectively monitor individual appliances and equipment.

Benefits of a Smarter Gas Infrastructure

By beginning now, the capabilities and technologies described in the preceding section will have a significant positive impact for consumers and our economy and will significantly improve the configuration and operation of the energy infrastructure in North America from now to the year 2030 and beyond.

Consumers will have a clearer picture of their energy usage and will be able to monitor, manage, and conserve energy while protecting the environment. New technology platforms will be provided allowing for the introduction of new products and services. Benefits from a coordinated network of sensors and controlling technologies will also be realized for each of the direct use options such as space conditioning, water heating, and cooking. This network of sensors and controlling technologies will recognize the energy needs of the consumer and coordinate these needs with the available information on price and carbon content of the energy options available. With such real-time information, consumers will have simple, easy to understand information to make a smart energy choice.

The increased level of performance of the infrastructure will yield benefits to energy consumers and society in five fundamental categories:

- *Safety* – reductions in injuries, loss of life, and property damage
- *Economic* – reduced costs, or increased production at the same cost, resulting from improved utility efficiency and asset utilization, and better-informed and empowered consumers
- *Reliability and Service Quality* – reduction in interruptions and service quality events
- *Environmental* – reduced impacts of climate change and effects on human health and ecosystems
- *Energy Security* – improved energy security (i.e., dependence on foreign sources)

Safety Benefits

A smarter gas infrastructure will be equipped with sensors, communications, information processors, and control devices to detect and respond to conditions compromising the safety of utility workers and the public. In addition to reducing incidents directly related to the gas infrastructure, automation and remote control can also reduce the need for service workers to perform manual operations in the field. This reduces the chance of traffic incidents and work-related hazards.

Safety related technologies to be created or enhanced include those to reduce or eliminate damage, improve leak detection and location, and detect unauthorized access or changes in condition that may require immediate response. The development and use of advanced global positioning and geographic information systems in conjunction with mobile and/or hand-held devices is another safety related area of technology advancement that complements all aspects of field construction, operations and maintenance.

Economic Benefits

Improved Asset Utilization

Transmission and distribution pipelines make up a significant proportion of the natural gas infrastructure; the usage of these assets to their full capacity is among the top priorities of the industry. Pipeline capacity is the ability to move natural gas from the point of supply to the point of use and is based on a combination of pipe size and operating pressure. Whether a pipeline system achieves optimal performance is affected by the utilization rate, (which may be influenced by scheduled or unscheduled maintenance), changing market demands, or weather related events impacting operations. A system peak-day usage rate generally reflects peak system deliveries relative to estimated system capacity. Capacity can be influenced by secondary compression and/or line packing or storage.

Technology areas potentially influencing the ability to improve capacity usage include predictive maintenance, improved weather forecasting, and more accurate advanced warning from major consumers of increased load requirements (such as improved communications with electric generators) and real-time stress measurement sensors (versus predictive calculations) for use during line-packing and improved communications with local/regional storage.

Better forecasting and monitoring of load and grid performance will enable grid operators to dispatch a more efficient mix of generation that could be optimized for societal needs while reducing cost. This will include ensuring the base load units are operating at their peak efficiency, renewable resources are fully utilized, and units designed to provide rapid ramping, ancillary services, and system support are coordinated in a manner to address system variability, with the entire operation occurring at the lowest cost.

Gas Transmission and Distribution Capital Savings

The construction of new infrastructure requires a tremendous amount of time and expense to work through the design, engineering, and permitting. The need for new construction may be driven by projections of new load from new construction or from projections that the load for existing consumers will increase. Connecting new consumers, specifically residential consumers, can be a major expense to be cost-justified before it occurs.

Having an improved understanding of peak requirements and real-time load information will enable the designs for new transmission and distribution systems to be optimized for societal needs and capable of accommodating system peaks without being over-built.

Potential Benefits of Gas Theft Reduction

Over the last three years, one mid-sized utility has investigated between three and five thousand gas theft incidents annually; one notable case involved $1.4M in stolen natural gas. Assume the average case takes one employee one day to investigate and document and decide if further action is required and that only 10% of the investigations result in prosecutions with each taking one week of a lawyer's time, Using this utility as an example, the following typical cost is calculated - 4,000 cases/year X 8 hours/ investigation X $30/hour = $960,000 to investigate. 400 cases/year to prosecute X 40 hours/case X $50/hour = $800,000 to prosecute. This results in a total cost per year for 4,000 theft cases of $1,760,000 or $440/case. Assuming the value of each theft averages $10,000, 400 thefts per year results in $4 million in value each year for a utility of this size. For every 10% reduction in case load and theft the savings equates to $400,000 in gas that is not stolen and $176,000 in reduced investigation and prosecution costs. The result is an annual savings of $576,000 for every 400 cases eliminated by the use of a smart system.

Extrapolating this result: There were 70,761,000 users of natural gas across the U.S. per AGA in 2008, for an average number of thefts per year of 127,370. Following the logic and the assumptions of cost shown above this number of thefts would result in an investigative cost of $30.6M, legal costs to prosecute of $254.7M and an estimated value of the stolen gas of $127.4M for a total industry estimated cost of $412.7M per year.

http://articles.chicagotribune.com/2010-07-28/news/ct-x-n-nicor-gas-theft-20100728_1_nicor-gas-natural-gas-nicor-spokesman-richard-caragol

Optimizing the use of existing assets and deferring capital investments through the use of real-time pressure and volume sensors coupled with real-time load data is another benefit resulting from an integrated communications system. As consumers are provided with educational programs and tools and techniques to make smarter decisions about their energy use, it is reasonable to assume changes will occur in daily, seasonal, and annual load. Energy efficiency programs result in improved end use technology, increased consumer awareness, and/or the ability to provide energy when it is needed either through direct use, load shifting or energy storage on a regional basis are all possible outcomes of a smart energy future.

Operations and Maintenance Cost Savings

Operating and maintaining the extensive natural gas transmission and distribution network costs nearly a billion dollars per year. Implementing intelligence and automation in natural gas systems could yield significant cost savings in operations and maintenance. *Table 1* provides a summary of typical operating and maintenance activities as quantified in an industry report from 2000 for natural gas distribution companies across the United States. Every one percent improvement in operational efficiency contributes over $5 million per year savings in 2010 dollars.

Table 1. Estimated Annual Gas Distribution Operations and Maintenance Cost [6]

Activity	Annual Cost (2010 $MM)
Distribution Maintenance	
Plastic Pipe Locating	106
Plastic Pipe Main Repair	46
Plastic Pipe Service Repair	64
Cast Iron Joint Repair	9
Distribution Operations	
Leak Pinpointing	93
Logging Pressure Readings	147
Re-lighting	4
Meter Reading	58
Total	**527**

Theft Reduction

Gas theft results when the meter is circumvented allowing unauthorized access to the natural gas delivery system with no record of the use. Alternative piping and/or valving are typical methods of meter tampering that have occurred resulting in a low level of usage or no record of usage. In addition to the improvements in public safety resulting from reducing unauthorized access, there are also potential economic benefits associated with reducing gas theft as described in the adjacent call out box.

Energy Efficiency and Cost Savings to Consumers

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 the consumers. Improving sensing and communications technologies coupled with sub-metering 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 usage and reduce their energy cost.

6 Sources: Nicholas Biederman, Gas Technology Institute, September 2002, GRI-02/0183, and GTI analysis. Assuming a 2.5% annual escalation rate from 2000 to 2010.

A GTI study[7], completed in 2009, focused specifically on these two issues by analyzing the benefits of increased direct use of natural gas achieved through a cost-effective mechanism to increase the full-fuel-cycle efficiency and reduce greenhouse gas emissions. The GTI study found subsidies provided to increase the direct use of natural gas will provide greater benefits than comparable subsidies to electric end-use technologies with respect to reducing primary energy consumption, consumer energy costs and CO_2 emissions.

The study also identified the following benefits could be achieved by 2030, if consumer education and research and development were combined with subsidies to encourage direct use of natural gas:

- 1.9 Quads/2.9 Exajoules energy savings per year
- 96 million metric tons CO_2 emission reduction per year
- U.S. $213 billion cumulative consumer savings
- 200,000 GWh electricity savings per year
- 50 GW cumulative power generation capacity additions avoided, with avoided capital expenditures of $110 billion at $2,200/kW.

The summary of energy savings for both natural gas and electricity, financial savings for consumers, and the emissions reductions shown above is a compelling reason to increase the direct use of natural gas through education of consumers and increased funding of research and development activities. Moreover, by providing natural gas at the pressures and volumes required for fast-ramping, natural gas generation facilities equipped with sensing and controlling technology can be efficiently operated providing real-time response. The enhancement of these same functions would allow one or more distributed generation or combined heat and power (CHP) facilities equipped with sensing and controlling technology to provide real-time response during peak demand periods, outage events or as needed for system support. Finally, the same system coordinating the needs of the electric and gas distribution system could readily use distributed generation units to balance the energy needs to support electric vehicle deployment. This use of natural gas technologies would avoid the need for large scale electric distribution infrastructure upgrades as well as a wide variety of other alternate vehicle transportation interests such as those from fleet, municipal, and marine vehicles.

Job Creation and Economic Impact

A study completed in 2009[8], prepared by IHS Global Insight for America's Natural Gas Alliance (ANGA), used U.S. Bureau of Labor Statistics data to estimate the number of workers involved in the production and transportation of natural gas. This in-depth economic analysis concluded in 2008, approximately 622,000 jobs were directly related to natural gas in the United States and the natural gas industry was responsible for supporting an additional 2.2 million jobs. The ANGA study also defined the jobs supported by natural gas including:

- Upstream exploration and production companies
- Midstream processing and pipeline transportation companies
- Downstream LDCs
- Suppliers and onsite construction service providers
- Natural gas pipeline construction
- Manufacturers of field machinery and equipment

7 Neil Leslie, P.E., Validation of Direct Natural Gas Use to Reduce CO_2 Emissions, June 26, 2009, Gas Technology Institute.
8 America's Natural Gas Alliance, The Contributions of the Natural Gas Industry to the U.S. National and State Economies, September 2009.

Job creation and overall economic improvement will result from the significant capital investment in the wide variety of sensing, communicating, data managing, and controlling technologies needed to achieve a smart energy future. Electric utility capital investment in generation, transmission, and distribution in the U.S. over the next 20 years has been estimated to be between $1.5 to $2 trillion dollars[9]. Included in those estimates for electric system upgrades are those associated with smart grid infrastructure which has been estimated to cost a minimum of $165 billion[10] by 2030. It is reasonable to assume the corresponding investments for the natural gas industry would be proportionately scaled. Much of this investment will depend on the technology development enabling each of the capabilities and functions identified here and others to be enhanced or created. Job types will include those in research and development, design and engineering, construction and installation, operations and maintenance, and marketing and sales, as well as all the associated supporting roles.

The ability to fuel a wide variety of direct uses as described above in the section on energy efficiency and cost savings is another beneficial economic outcome of the enhancement or creation of selected capabilities.

Reliability and Service Quality Benefits

While unusual, a gas service interruption can occur in two ways: 1) the consumer discontinues gas consumption to comply with a specific order by the LDC or pipeline company or 2) the loss of pressure and/or volume from the delivery system results in insufficient natural gas to maintain safe and reliable operations and causes an outage for one or more consumers on a local or regional basis.

In both cases, there is an impact to the consumer. There may be an impact to the utility depending on the cause of the interruption and the time and complexity involved in restoring service. Therefore, improving service reliability can provide a significant benefit to consumers and utilities, and in the case of large-scale service interruptions, there may also be a benefit to society. The benefit to consumers is typically determined by the value of service, which can vary by consumer class and geography. Commercial and industrial consumers typically place a higher value on service due to the impact an interruption can have on business operations. The benefit to utilities will depend on the cost of restoring service, including capital equipment replacement and service operations.

Modeling, forecasting, and market area storage could help gas companies provide more consistent supply for consumers as conditions change. This can be particularly important for the supply sector to ensure the supply of natural gas matches the demand. A variety of economic and reliability benefits can result if this can be done in a more precise and real-time fashion.

Tighter integration of natural gas with electricity could also have an important effect on the reliability of electricity service to consumers. By implementing gas-fueled distributed generation, either in stand-alone configurations or in microgrids, electricity outages could be dramatically reduced.

Another area in which natural gas can increase the reliability of energy supply is in connection with variable resources. The increase in variable renewable resources such as wind and solar will alter traditional dispatch practices and operation of the electric grid. In order to maintain reliability, grid operators will come to rely on flexible and efficient resources to complement variable renewable resources. Fast ramping generators could provide capacity, energy, and ancillary services at competitive costs.

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9 http://www.infrastructurereportcard.org/fact-sheet/energy (Last visited 11/17/2010)
10 Electric Power Research Institute, Palo Alto, California, Power Delivery System of the Future, A Preliminary Estimate of Costs and Benefits, 1011001, July 2004.

Environmental Benefits

CO_2 emissions result from burning carbon based fuels. Reducing the use of carbon-based fuels or increasing their efficiency through improved appliances or more direct use by the consumer leads to reduced CO_2 emissions. The greatest opportunities for natural gas to contribute to carbon-reduction benefits are in power generation and expanded direct use. The largest carbon reductions per unit of natural gas consumed are from CHP systems and direct gas use assuming these uses will be in lieu of electricity consumption by end users.

In 2010 the MIT published an interim report on "The Future of Natural Gas."[11] The report summarized the environmental benefits of natural gas well by stating that:

> *"In a carbon-constrained world, a level playing field — a CO_2 emissions price for all fuels without subsidies or other preferential policy treatment — maximizes the value to society of the large U.S. natural gas resource. Even under the pressure of an assumed CO_2 emissions policy, total U.S. natural gas use is projected to increase in magnitude up to 2050. Under a scenario with 50 percent CO_2 reductions to 2050, using an established model of the global economy and natural gas cost curves that include uncertainty, the principal effects of the associated CO_2 emissions price are to lower energy demand and displace coal with natural gas in the electricity sector. In effect, gas-fired power sets a competitive benchmark against which other technologies must compete in a lower carbon environment."*

The study also shows displacing inefficient electric generating plants (heat rate greater than 10,000) with natural gas combined cycle units has the potential to reduce CO_2 emissions by a factor of three while cautioning new pipelines and natural gas storage would likely be needed to supply fuel to these plants. If natural gas generation can be used to complement variable renewable generation, environmental benefits are also obtainable.

Energy Security Benefits

Today, there is growing interest in achieving security of our energy infrastructure. Oil provides a significant proportion of the energy used in North America, the majority of which comes from foreign sources. The domestic supply of natural gas has been recognized as being in excess of 100 years of the current usage in North America resulting in the forecasting of stable prices for the foreseeable future; whereas, the world oil prices are rising, in part due to the devaluation of U.S. currency. This has resulted in a decoupling of the relative pricing between natural gas and oil in recent years; the decoupling is expected to continue. One of the favorable outcomes anticipated from this trend is an increase in the use of natural gas in new markets that have traditionally been served by liquid fuels.

11 "The Future of Natural Gas, an Interdisciplinary MIT Study, Interim Report," MIT Energy Initiative, Massachusetts Institute of Technology, 2010.

Recommendations for Action

Achieving the vision in the long term will require a number of near term actions related to policy, technology development, and implementation of key capabilities in each of the industry sectors.

FOR POLICYMAKERS:

Research and Development/Budget

- Include natural gas in advanced metering infrastructure development to optimize common infrastructure, interoperability and cross-compensation among all utility infrastructures including electricity and water;
- Ensure that future federal funding programs including Smart Grid encourage and allow the use of funding for dedicated natural gas projects and combined electric/natural gas projects;
- Develop a technology roadmap for natural gas in a smart energy future, including critical input from a broad group of stakeholders and the energy technology R&D community;
- Increase governmental funding for basic as well as applied research in natural gas safety and reliability and smart energy infrastructure technology; and
- Establish a governmental public-private research, development and deployment program for natural gas similar in size to the electric Smart Grid programs that includes component and system suppliers.

Regulatory

- Expand the use of source energy standards to recognize the value of full-fuel-cycle energy efficiency and carbon emission benefits and incorporate full-fuel-cycle analysis in all conservation and energy efficiency standards, including common measures of energy and greenhouse gas emissions;
- Expand ongoing Smart Grid standards development efforts to include natural gas;
- Provide consumers information about energy usage and energy appliance selections so they can make educated decisions.
- Modify the International Green Construction Code to ensure that every new building has access to natural gas service where available;
- Modify market rules to facilitate and create procedures for direct communications between pipeline and electric grid operators to fully optimize the usage of energy.
- Promote real-time communications between the gas and electricity grids;
- Approve projects in a timely manner to ensure natural gas infrastructure can meet the needs of all current and future end-uses; and
- Make energy efficiency programs neutral with respect to energy sources, and encourage collaboration among all energy providers.

FOR INDUSTRY:

Enhance or Create Capabilities for Supply

- Create and expand real-time communications between the gas and electricity grids;

- Enhance systems to manage natural gas supply for fast-ramping generation to complement variable renewable resources and provide ancillary services; and
- Actively engage federal, provincial, and state regulators to help resolve the issues related to developing shale gas as a long-term energy source.

Enhance or Create Capabilities for Delivery

- Ensure the natural gas infrastructure can meet the needs of all current and future end-uses;
- Enhance the system capability to accept and distribute a wide range of renewable gas sources;
- Ensure current and future natural gas infrastructure can accommodate emerging technologies, peak demand, energy efficiency programs, and new sources of supply; and
- Create or enhance capabilities to improve natural gas asset utilization on a real-time basis.

Enhance or Create Capabilities for End Use

- Develop cost effective systems to be used to moderate peak electricity demand by using natural gas powered cooling solutions in the commercial applications and natural gas powered DG/CHP systems on an aggregated basis or as part of a microgrid for residential and/or commercial consumers;
- Advocate the use of DG/CHP systems to supply power, heat and cooling at industrial and commercial applications;
- Develop hybrid electric/natural gas appliances capable of providing space conditioning, water heating, cooking, and clothes drying; and
- Provide customers the information to make educated choices about their energy usage and energy appliance selections.

Appendix: A Framework for Assessing the Benefits of Integrating Natural Gas with the Smart Grid

Context

The vision for natural gas in a smart energy future assumes the natural gas can be utilized as a smart energy resource for homes and businesses, and as a strategic resource for electricity. This means:

- Natural gas must be available where it is needed in sufficient quantity and quality, even as new end uses increase, including electricity production;
- The natural gas infrastructure must continue to be safe, highly reliable and secure;
- The natural gas infrastructure must continue to support the production and delivery of natural gas efficiently and cost effectively, even as the system is expanded and becomes more complex; and
- Natural gas will play an increasingly important role as a resource for reducing CO_2 emissions.

Achieving all of this will require a level of capability and functionality that does not exist today, but can be implemented in the coming years. The following framework has been developed to illustrate which capabilities are most important to achieving the benefits.

Approach

The approach used to develop this framework is similar to the approach used in similar benefits assessment work conducted by Navigant for the electric Smart Grid.[12] This is:

- Clarify the objectives or needs for enhancing the capability of the infrastructure;
- Identify the basic functionality that would support this capability;
- Determine the benefits that could result from implementing this functionality, and to whom the benefits accrue; and
- Define the relationships between the functions and the benefits.

In developing this framework for natural gas in a smart energy future, the GTI-Navigant team conducted numerous in-depth interviews with staff from natural gas companies around North America. The goal of these interviews was to identify important issues and challenges for the natural gas infrastructure in the future. Conversations during these interviews ranged from ensuring the safety and reliability of the gas system, to enhancing the overall efficiency of the energy value chain, to increasing operational efficiency, to enabling the use of renewable forms of energy. The information obtained during these interviews, along with information from GTI-Navigant subject matter experts, was organized and distilled into the framework presented here.

12 Similar approaches were used for supporting the US Department of Energy and the California Energy Commission in assessing the benefits of electric smart grid systems and technology.

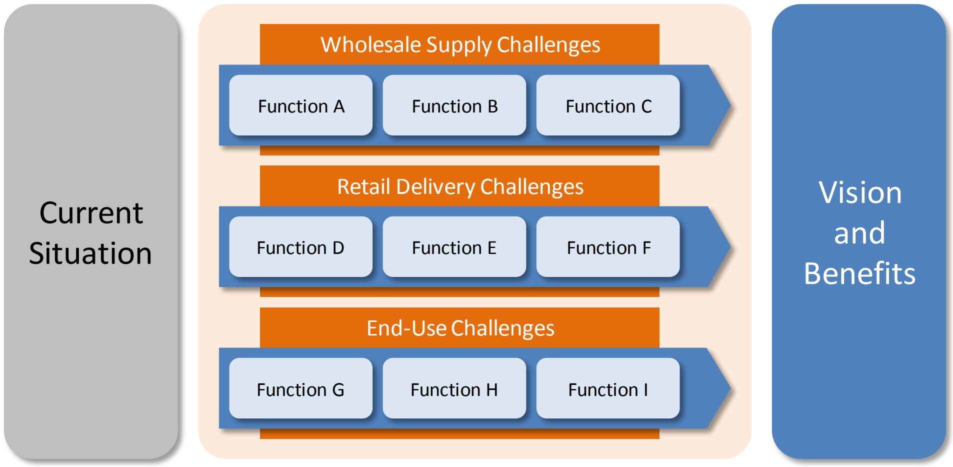

Figure A-1. Functions enable the vision and its associated benefits.

Framework

Objectives

The objectives for the enhancing the capability of the natural gas infrastructure come from the objectives of the smart energy future described in the white paper. Our energy resources and infrastructure in North America should be:

- Clean and sustainable;
- Reliable and secure;
- Affordable and efficient; and
- Robust and flexible.

Functions

Functions, as used in this framework, are desired actions or capabilities. A function can be implemented in different ways depending on the way it is utilized. Functions are not technologies or systems, although they are related to them. Functions can remain relevant as technology evolves.

Twenty functions were developed that describe specific natural gas system capabilities that would contribute to achieving the objectives identified previously.

Table A-2. Definitions of Natural Gas Functions.

FUNCTIONS	DESCRIPTION
Automated High Ramp Rate Supply Response	Provide natural gas at the pressures and volumes required to efficiently operate fast ramp rate generating facilities connected to electric and natural gas transmission through an infrastructure equipped with sensing and controlling technology to allow real-time response.
Wide Area Monitoring, Visualization, and Control	Use 2-way communications technologies to collect, analyze and interpret transmission supply data resulting in information that is then used by visualization and control technology providing proactive responses for predicated events and real-time reactive response for unforeseen events.
Peak Electric Demand Management	Monitor and proactively provide appropriate peak load reduction and/or demand response through direct use, the use of dual fuel appliances or local generation measures to requests triggered by the events on the electric grid.
Predictive Load Modeling and Forecasting	Use of current customer load data in combination with historical load data, current and historic weather data and current and historic major customer use patterns to provide trend analysis that allows accurate load prediction and forecasting by modeling software.
Real Time Inter-grid Communications (Gas/Electric)	Two-way, secure, redundant path communications that leverage backhaul options to provide real-time data that can be acted upon by artificial intelligence system and/or system operators resulting in coordinated operations between the electric and gas grids.
Automated/Dispatchable Market Area Storage	Large volume storage available for immediate response to support the continued operations of the natural gas system.
Gas Supply Quality Monitoring and Management	Sensors and other real-time monitoring devices that provide BTU, compositional and trace constituent analysis to allow system-wide quality management.
BTU Composition Monitoring at Custody Exchange (Billing)	Calorific monitoring coupled with volume and pressure sensing to ensure the supplier and customer that contract obligations are met.
Remote Cathodic Protection Monitoring and Reporting	Real-time system monitoring of cathodic protection installations that report changes or the loss of capability, eliminating or significantly reducing site visit obligations.
Automated Leak Detection and Notification	Real-time monitoring and reporting of methane/ethane levels to a system capable of verifying customer contacts and allowing operators to determine if action is required.
Detection/Predictive Third Party Damage	A system that uses a combination of visual and/or proximity sensing based artificial intelligence to proactively notify operations staff of a potential incident that could result in damage or of an occurrence of recent damage.
Automated Flow Control and Volume/Pressure Mgmt and Real-Time Load Balancing (Re-routing)	Sensing technology capable of monitoring and reporting volume and pressure that can be acted upon by artificial intelligence systems or system operators. This includes communications technologies coupled with monitoring and control technologies that use real-time information on volume, pressure and quality to maintain system operations. This includes opening and closing valves.
Automated Meter Reading (AMR)	Advanced meters coupled with communications capability to record and report use data. This includes turn-on/turn-off cost, and collections.
Real-time Load Measurement and Management	Smart gas metering and load management devices in the customer premise that allow the LDC to monitor and manage customer load and end use appliances. This may include real-time metering, remote disconnection, outage detection and other features.

Remote Meter Shut-off	Use of 2-way communications to stop flow through a meter to improve safety, reduce the need for site visits or to assist with non-payment.
Remote Meter Turn-on	Use of 2-way communications to re-establish flow through a meter following a proper response to a safety related event, to reduce the need for site visits or to re-establish service for a customer.
Automated Distribution Shut-off	The use of a combination of sensors and communications technologies located strategically throughout the distribution network capable of detecting and reporting incidents that would warrant 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.
Automated Transmission Shut-off	The use of a combination of sensors and communications technologies located strategically throughout the transmission network capable of detecting and reporting incidents that would warrant 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.
Customer Premise Energy Use Optimization	A simple, easy to use and convenient in-home display and/or a smart thermostat capable of 2-way communications with utilities to receive demand response requests or TOU rate information as well as every major energy using device that provides the customer with plain language site specific choices for energy use and carbon footprint.
Measurement and Verification of Energy Efficiency	The use of sensing and communicating technology to provide a positive method of indicating an energy efficient request was responded to by one or more measurable actions on the part of the customer.

Benefits

Implementing the functions described above will have a significant impact on the configuration and operation of the energy infrastructure in North America. The increased level of performance will yield benefits in four fundamental categories:

- Economic – reduced costs, or increased production at the same cost, that result from improved utility system efficiency and asset utilization;
- Reliability and Service Quality – reduction in interruptions and service quality events;
- Environmental – reduced impacts of climate change and effects on human health and ecosystems; and
- Energy Security and Safety – improved energy security (i.e., dependence on foreign sources), and reductions in injuries, loss of life and property damage.

Within each category are several sub-categories and specific benefits, and each benefit can be derived from multiple sources. While the same, or similar, benefit can be realized within multiple industry sectors, most specific benefits are focused primarily in one sector (supply, delivery, or end use).

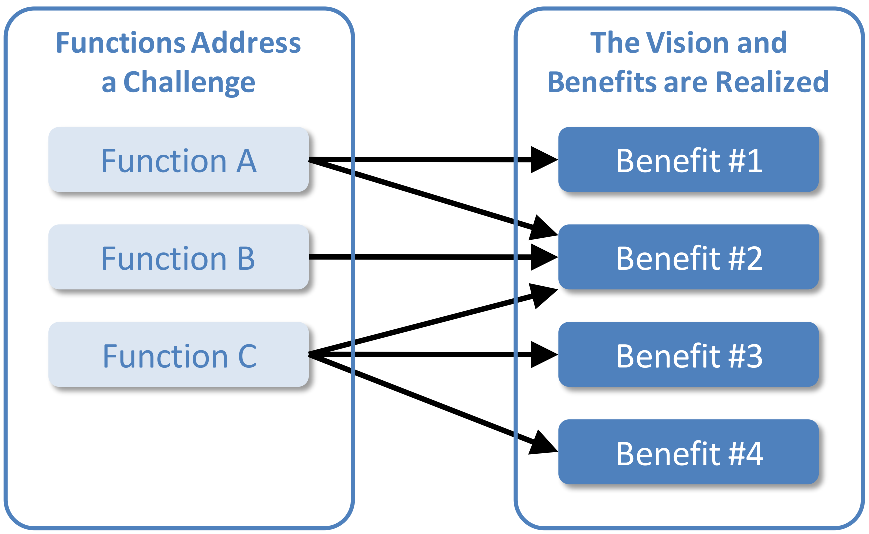

Figure A-2. Functions lead to benefits.

Recall from *Figure A-1* that functions enable achieving the vision and its associated benefits. Depending on the function, it can contribute to more than one benefit (*Figure A-2*). For example, implementing Remote Meter Turn-off can lead to multiple benefits including reduced operations cost, reduced CO_2 emissions from fewer utility vehicle miles being required for daily operations and maintenance, and improved public and utility worker safety. It is also possible for one benefit to be supported by multiple functions. For example, several functions, including Automated Leak Detection and Notification, Detection/Prediction of Third Party Damage, and Automated Distribution Shut-off, all contribute to the benefit of improved public safety.

Table A-3. Benefit Categories and Benefits.

Economic Benefits	
Improved Asset Utilization	Optimized Electricity Generation Operation
	Deferred Electricity Generation Capacity Investments
	Improved Pipeline Capacity Usage
Gas Transmission and Distribution (T&D) Capital Savings	Deferred Transmission Capacity Investments
	Deferred Distribution Capacity Investments
	Reduced Equipment Failures
Gas T&D O&M Savings	Reduced T&D Maintenance Cost
	Reduced T&D Operations Cost
	Reduced Meter Reading Cost
Theft Reduction	Reduced Gas Theft
Energy Efficiency	Reduced Lost and Unaccounted For Gas
Energy Cost Savings	Reduced Energy Costs (to consumers)
Reliability Benefits	
Service Interruptions	Reduced Gas Interruptions to Consumers
	Reduced Electric Interruptions to Consumers
Service Quality	Reduced Pressure Drops
Safety Benefits	
Safety	Reduced Public Safety Incidents
	Reduced Utility Worker Incidents
Environmental Benefits	
Air Emissions	Reduced CO_2 Emissions
	Reduced SO_x, NO_x, and PM-2.5 Emissions
T&D Gas Emissions	Reduced Gas Leakage
Security Benefits	
Energy Security	Reduced Oil Usage
	Stabilized Energy Price
	Reduced Wide-scale Blackouts

Table A-4. Definitions of Benefits.

Benefit	Definition
Optimized Electricity Generation Operation	Better forecasting and monitoring of load and grid performance would enable grid operators to dispatch a more efficient mix of generation that could be optimized to reduce cost. The coordinated operation of energy storage or plug-in electric vehicle assets could also result in completely avoiding central generation dispatch.
Deferred Electricity Generation Capacity Investments	Utilities and grid operators ensure that generation capacity can serve the maximum amount of load that planning and operations forecasts indicate. However, this capacity is only required for very short periods each year, when demand peaks. Reducing peak electricity demand and flattening the load curve should reduce the generation capacity required to service load, and lead to cheaper electricity for customers.
Improved Pipeline Capacity Usage	Improved forecasting and communications between suppliers and consumers will allow pipeline companies to better match nominations and deliveries, increasing the throughput and value of every pipeline.
Deferred Transmission Capacity Investments	Reducing the load and stress on transmission pipelines increases asset utilization and reduces the potential need for upgrades. Closer monitoring, rerouting gas flow, and reducing pressure could enable utilities to defer upgrades on lines and transformers.
Deferred Distribution Capacity Investments	As with the transmission system, reducing the load and stress on distribution elements increases asset utilization and reduces the potential need for upgrades. Closer monitoring and load management on distribution feeders could potentially extend the time before upgrades or capacity additions are required.
Reduced Equipment Failures	Reducing mechanical stresses and deterioration on equipment increases service life and reduces the probability of premature failure. This can be accomplished though enhanced monitoring and detection, enhanced pressure management, or loading limits based on real-time equipment or environmental factors.
Reduced T&D Maintenance Cost	The cost of sending technicians into the field to check equipment condition is high. Moreover, to ensure they maintain equipment sufficiently, and identify failure precursors, some LDCs may conduct equipment testing and maintenance more often than is necessary. Online diagnosis and reporting of equipment condition would reduce or eliminate the need to send people out to check equipment resulting in a cost savings.
Reduced T&D Operations Cost	Automated or remote controlled operation of valves and other distribution equipment eliminates the need to send a line worker or crew to the switch location in order to operate it. This reduces the cost associated with the field service worker(s) and service vehicle.
Reduced Meter Reading Cost	Minimizing the time spent reading meters manually leading to reduced meter operations costs. Some technologies can also reduce costs associated with other meter operations such as connect/disconnect, outage investigations, and maintenance.
Reduced Gas Theft	Smart meters can typically detect tampering. Moreover, a meter data management system can analyze customer usage to identify patterns that could indicate diversion. These new capabilities can lead to a reduction in gas theft through earlier identification and prevention of theft.
Reduced Lost and Unaccounted For Gas	Better sensors and control technology will reduce the amount of gas that is lost.
Reduced Gas Interruptions to Consumers	The monetary benefit of reducing sustained outages is based on the value of service (VOS) of each customer class. The VOS parameter represents the total cost of a power outage per MWh. This cost includes the value of unserved energy, lost productivity, collateral damage, administrative costs, the value of penalties and performance based rates. Functions that lead to this benefit can reduce the likelihood that there will be an outage, allow the system to be reconfigured on the fly to help restore service to as many customers as possible; and, enable a quicker response in the restoration effort.

Reduced Electric Interruptions to Consumers	A sustained outage is one lasting > 5 minutes, excluding major outages and wide-scale outages. The monetary benefit of reducing sustained outages is based on the VOS of each customer class. The VOS parameter represents the total cost of a power outage per MWh. This cost includes the value of unserved energy, lost productivity, collateral damage, administrative costs, the value of penalties and performance based rates. Functions that lead to this benefit can reduce the likelihood that there will be an outage, allow the system to be reconfigured on the fly to help restore service to as many customers as possible, enable a quicker response in the restoration effort, or mitigate the impact of an outage through islanding or alternative power supply.
Reduced Pressure Drops	Better managing gas volume and pressure will help reduce incidents of low pressure that may affect consumer service levels. For some sensitive consumers, a pressure drop can be as disruptive as an interruption of service.
Reduced Public Safety Incidents	Sensors, communications, information processors and control devices can detect and respond to conditions compromising the safety of utility workers and the public.
Reduced Utility Worker Incidents	Automation and remote control can reduce the need for service workers to perform manual operations in the field, reducing the chance of traffic incidents and work-related hazards.
Reduced CO_2 Emissions	Functions providing this benefit can lead to avoided vehicle miles, decrease the amount of central generation needed to their serve load (through reduced electricity consumption, reduced electricity losses, more optimal generation dispatch), and or reduce peak generation. These impacts translate into a reduction in CO_2 emissions produced by fossil-based electricity generators and vehicles.
Reduced SO_x, NO_x, and PM-2.5 Emissions	Functions providing this benefit can lead to avoided vehicle miles, decrease the amount of central generation needed to their serve load (through reduced electricity consumption, reduced electricity losses, more optimal generation dispatch), and or reduce peak generation. These impacts translate into a reduction in pollutant emissions produced by fossil-based electricity generators and vehicles.
Reduced Gas Leakage	By ensuring the integrity of the gas infrastructure, and by avoiding over-pressure, less gas will leak. This reduces the amount of gas lost, but also reduces the emission of methane, a potent greenhouse gas.
Reduced Oil Usage	The functions that provide this benefit eliminate the need to send a service worker or crew to the valve or compressor locations in order to operate them, eliminate the need for truck rolls to perform diagnosis of equipment condition, and reduce truck rolls for meter reading and measurement purposes. This reduces the fuel consumed by a service vehicle or line truck. The use of natural gas vehicles (NGVs) can also lead to this benefit since the electrical energy used by NGVs displaces the equivalent amount of oil.
Stabilized Energy Price	Integrating natural gas for use by homes and businesses, and also for electricity generation will tend to reduce volatility in energy supply, and thereby reduce price volatility and increase energy options.
Reduced Wide-scale Blackouts	The functions that lead to this benefit will give grid operators a better picture of the bulk power system, and allow them to better coordinate resources and operations between regions. This will reduce the probability of wide-scale regional blackouts.

Relationships between Natural Gas Functions, Benefits and the Vision

As described above, functions lead to benefits and enable the vision. The tables on the following pages illustrate these relationships.

Table A-5. Mapping of Relationships between Natural Gas Infrastructure Functions and Benefits
Table A-6. Mapping of Relationships between Natural Gas Infrastructure Functions and the Vision

Table A-5. Mapping of Relationships between Natural Gas Infrastructure Functions and Benefits

Benefits Derived from Implementing Functions			Natural Gas Infrastructure Functions																			
			Automated High Ramp Rate Supply Response	Wide Area Monitoring, Visualization, and Control	Peak Electric Demand Management	Predictive Load Modeling and Forecasting	Real Time Inter-grid Communications (Gas/Electric)	Automated/Dispatchable Market Area Storage	Gas Supply Quality Monitoring and Management	BTU Composition Monitoring at Custody Exchange (Billing)	Remote Cathodic Protection Monitoring and Reporting	Automated Leak Detection and Notification	Detection/Prediction of Third Party Damage	Automated Flow Control and Volume/Pressure Mgmt and Real-Time Load Balancing (Re-routing)	Automated Meter Reading (AMR)	Real-time Load Measurement and Management	Remote Meter Shut-off	Remote Meter Turn-on	Automated Distribution Shut-off	Automated Transmission Shut-off	Customer Premise Energy Use Optimization	Measurement and Verification of Energy Efficiency
Economic	Improved Asset Utilization	Optimized Electricity Generation Operation	●				●	●						●								
		Deferred Electricity Generation Capacity Investments	●				●															
		Improved Pipeline Capacity Usage				●																
	Gas T&D Capital Savings	Deferred Transmission Capacity Investments		●			●	●														
		Deferred Distribution Capacity Investments			●	●								●		●						
		Reduced Equipment Failures							●													
	Gas T&D O&M Savings	Reduced T&D Maintenance Cost							●			●							●	●		
		Reduced T&D Operations Cost								●				●			●	●	●	●		
		Reduced Meter Reading Cost													●		●	●				
	Theft Reduction	Reduced Gas Theft														●	●					
	Energy Efficiency	Reduced Lost and Unaccounted For Gas										●							●	●		
	Energy Cost Savings	Reduced Energy Costs (to customers)			●																●	
Reliability	Service Interruptions	Reduced Gas Interruptions to Customers		●				●						●					●	●		
		Reduced Electric Interruptions to Customers																				
	Service Quality	Reduced Pressure Drops					●	●														
Safety	Safety	Reduce Public Safety Incidents	●								●	●	●				●		●	●		
		Reduce Utility Worker Incidents									●	●	●		●		●	●	●	●		
Environmental	Air Emissions	Reduced CO_2 Emissions																				
		Reduced SO_x, NO_x, and PM-2.5 Emissions																				
	T&D Gas Emissions	Reduced Gas Leakage										●										
Security	Energy Security (not monetized)	Reduced Oil Usage																				
		Stabilized Energy Price	●		●																	
		Reduced Wide-scale Blackouts	●				●	●														

● *signifies that the Function contributes a benefit*

Table A-6. Mapping of Relationships between Natural Gas Infrastructure Functions and the Vision

The Vision for Natural Gas in a Smart Energy Future Natural gas is an abundant, domestic, low-carbon resource for electricity, and a smart energy source for homes and businesses. Smarter natural gas systems result in a secure, reliable and efficient energy infrastructure for North America, and enable smarter electric grids.		**Natural Gas Infrastructure Functions:** Automated High Ramp Rate Supply Response	Wide Area Monitoring, Visualization, and Control	Peak Electric Demand Management	Predictive Load Modeling and Forecasting	Real Time Inter-grid Communications (Gas/Electric)	Automated/Dispatchable Market Area Storage	Gas Supply Quality Monitoring and Management	BTU Composition Monitoring at Custody Exchange (Billing)	Remote Cathodic Protection Monitoring and Reporting	Automated Leak Detection and Notification	Detection/Predictive Third Party Damage	Automated Flow Control and Volume/Pressure Mgmt and Real-Time Load Balancing (Re-routing)	Automated Meter Reading (AMR)	Real-time Load Measurement and Management	Remote Meter Shut-off	Remote Meter Turn-on	Automated Distribution Shut-off	Automated Transmission Shut-off	Customer Premise Energy Use Optimization	Measurement and Verification of Energy Efficiency
Supply Improved communication between supply and electric generation, including variable renewable resources, is effectively used to enhance responsiveness and operation of the electric grid.	Actively managed natural gas supply responds to fluctuations in electricity production. Fast-ramping gas fired power generation is integrated with variable renewable resources to ensure a reliable and secure electricity supply.	●				●	●						●								
	Demand forecasts for electricity are available to gas suppliers, helping ensure that fuel is available when and where it is needed. Energy market information is available, allowing tighter coordination between pipeline and grid operators.		●		●																
	Direct communications between pipeline and grid operators is possible, and real-time information about weather, demand, infrastructure and operating conditions is shared.					●															
Delivery Communications and intelligent field devices are effectively used to enhance safety and efficiency of the network and accommodate new end uses and supply sources.	Robust and flexible infrastructure responds to consumer needs and enables local distribution companies (LDCs) to safely and efficiently increase capacity and actively manage volume and pressure using a network of sensors, two-way communications, and automation. This infrastructure readily accommodates diverse sources of supply such as renewable and shale gas.						●	●	●				●		●	●	●	●	●		
	Optimized investment is possible as better load forecasts, network monitoring and demand management techniques are employed to improve asset utilization, capital deployment and increase useful life.				●		●			●	●	●	●		●						●
	Emerging technologies such as distributed generation, microgrids, thermal grids and alternatively-fueled vehicles are creating new uses for natural gas and electricity.			●																●	
End Use Comparable attributes of various energy sources are established and made available to consumers, allowing them to make informed decisions and better choices about energy use.	Transparent, repeatable analyses are done for multiple energy sources that directly compare attributes such as energy content, price, and environmental quality on a full fuel cycle basis.																			●	
	Comparable energy attribute information is available to customers in a form that is simple and convenient.								●											●	
	Energy management tools provide timely intelligence that aids consumers in making energy choices.			●																●	●

● signifies that the Function supports the Vision

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