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The Economic Benefits of Natural Gas Pipeline Development on the Manufacturing Sector

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CHAPTER ONE: A DESCRIPTION OF THE NATURAL GAS PIPELINE SYSTEM

Introduction and Overview

The rapid increase in domestic natural gas (NG) production continues to reshape the U.S. economy and redefine America's competitive advantages within the global economy, especially within the manufacturing sector. In the continuing effort to understand how a resurgent oil and gas industry impacts broad-based manufacturing, IHS examined how the expansion of NG pipeline infrastructure benefits the U.S. manufacturing sector. Beyond exploration and production companies, many firms across a diverse set of industry sectors are beneficiaries of tens of billions of dollars in capital expenditures and operating and maintenance (O&M) expenditures made annually across the hydrocarbon value chain. Going forward, lower natural gas prices will result in benefits to consumer purchasing power and confidence, higher profits among businesses, and improvements in cost-competitiveness for domestic manufacturers relative to their international competitors. The U.S. economy experienced significant gains in 2015: IHS estimates that economic benefits from increased domestic shale gas production and the accompanying lower NG prices include contributions of $190 billion to real gross domestic product (GDP), 1.4 million additional jobs, and $156 billion to real disposable income.

IHS Energy expects that the ongoing development of conventional and unconventional NG plays in the U.S. Lower 48 will keep supply growth steady between 2016 and 2025, enabling it to meet domestic demand. The rapid growth of NG production in some of the major shale plays has created bottlenecks in some parts of the U.S. where there is insufficient transmission pipeline capacity to move the NG to market. IHS estimates that approximately $25.8 billion was spent in the U.S. in 2015 to construct 6,028 miles of new natural gas transmission pipelines, resulting in a temporary increase in employment of 347,788 jobs, with 59,874 in the manufacturing sector. Similarly, the construction spending is expected to have contributed $34 billion to GDP and $21.9 billion to labor income in 2015. This study presents current unit cost estimates, in dollars per mile, for constructing and operating three types of NG pipelines: gathering, transmission, and local distribution. The focus of this study is on the economic impacts of constructing and operating new NG transmission lines, as they are the means by which pipeline-ready NG is transported from the wellhead to local markets; the effects of the other two other types of NG pipelines will also be considered as appropriate.

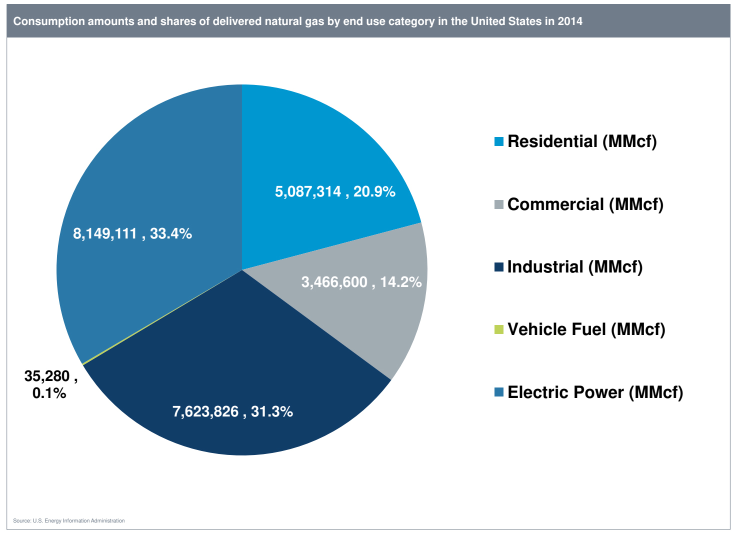
Well-understood economic contributions are derived from midstream and downstream energy capital and O&M expenditures across a diverse supply chain. Recent IHS analyses on the U.S. 'manufacturing renaissance' identified clear competitive advantages that have emerged for manufacturing in America as a result of the increased supply of competitively priced natural gas. For energy-intensive industries such as chemicals, metals, food, and refining, production costs have been reduced as a result of the increase in natural gas supply, and IHS expects these industries to outperform the U.S. economy as a whole through 2025.

The improved competitive positioning of industries in the manufacturing sector is shaping state and local economic development strategies across the country. Increased supplies of NG, especially at lower delivered prices, enhances the competitiveness of economies by making them more attractive to manufacturing activities that are large, and intensive users of NG such as chemicals, food, paper, and metals. The close proximity of existing clusters of manufacturing establishments to increased NG supplies can generate new pipeline-related economic development, often because of the availability of direct connections to a new or expanded NG pipeline. In a recent IHS manufacturing strategy study for the City of Philadelphia Industrial Development Corporation, core recommendations included expansion of NG pipeline capacity from the Marcellus Shale region to the Greater Philadelphia area as an enabler for expanding the regional manufacturing sector. Recent IHS research indicates that sectors such as food, cement, wood, paper, chemicals, and primary and fabricated metal products will be the largest beneficiaries of increased supplies and lower NG prices, as they both use it intensively (i.e., consume a high number of British Thermal Units (Btu) per unit of output) and require large amounts of it, especially in chemicals subsectors, where it is used as a feedstock. Expansions of NG pipeline capacity are also needed to enable the construction of new NG-fired electric generating plants. In addition to providing key inputs for the construction of NG pipelines, the manufacturing sector will also benefit economically from the capital expenditures for new electric generating plants and for facilities used to process and store NG and natural gas liquids (NGLs).

In a nutshell, the combination of increased access to shale gas and the transmission lines that move that affordable energy to manufacturers across America meant 1.9 million jobs in 2015 alone. In the following sections, IHS will identify the major sources of demand for NG by the manufacturing subsector and describe the key components of the gathering, transmission, and distribution system. The focus of this analysis will be on the effects of increased NG supply and the construction and operation of NG transmission pipelines on the manufacturing sector.

Natural Gas Users

According to the U.S. Energy Information Administration (EIA), over 24.4 trillion cubic feet of NG was delivered to consumers in 2014.[1] Natural gas consumption is typically classified into five main categories of end users, as described below.



Electric Power

The electric power sector uses large amounts of NG as a fuel in producing electricity. The electric power sector consumed 8,100,000 million cubic feet (MMcf) of natural gas in 2014, the largest end user share at 34%. In addition, the electric power sector has had the second-highest growth rate in demand for NG among major end-user categories, with a compound annual growth rate (CAGR) of 4.1% from 2004 through 2014.[2]

Industrial

Many industries use NG as a fuel or a feedstock for production, with approximately 80% of total industrial demand for NG coming from the manufacturing sector. The remaining 20% comes from other industrial activities, such as agriculture, construction and mining.[3] Our U.S. Industrial Gas Demand report identified four ways that NG is used by the manufacturing sector:

- As a fuel for direct process uses, such as drying, melting, process cooling and refrigeration
- As a fuel for direct non-process uses in manufacturing establishments, such as heating, ventilation, and air conditioning (HVAC), lighting, and other uses
- As a fuel for indirect purposes, primarily in boilers that are used to produce electricity and steam
- As a feedstock, with almost 93% occurring in the petroleum refining, chemical, and primary metals sectors

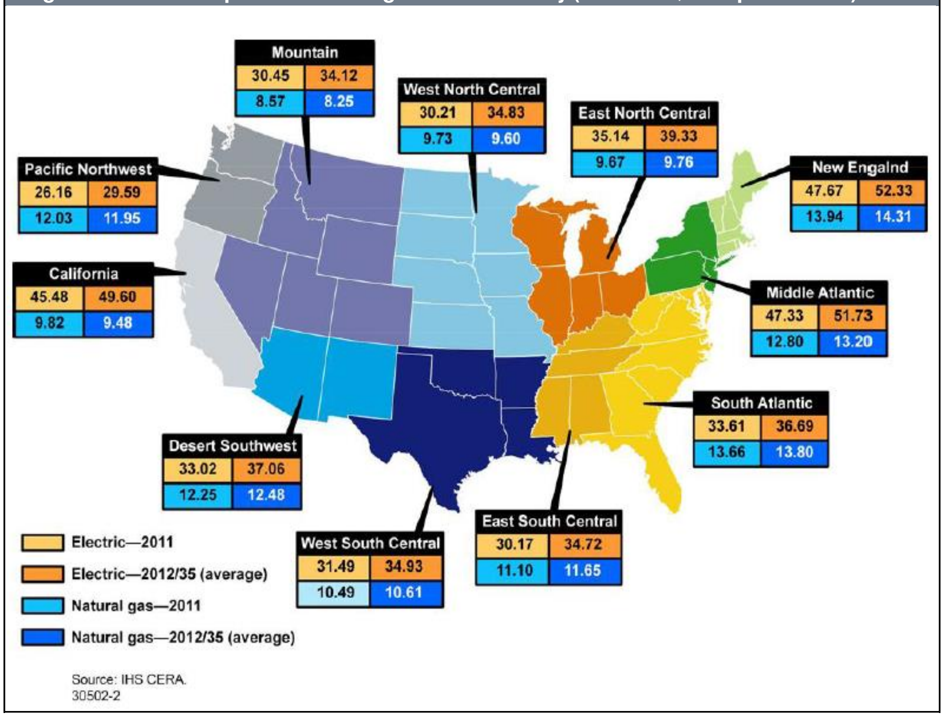
The three fuel uses account for 91% of total demand for NG by the manufacturing sector, while the remaining 9% is for feedstock.

Industrial end users of NG are the second-largest consumers of natural gas, using 7.6 million MMcf in 2014. The industrial sector accounted for 31% of consumption of delivered NG in the US in 2014. Growth in industrial use of NG has been slower than most other end-use categories, with a CAGR of 0.5% from 2004 through 2014. Industrial gas consumption had declined over two decades as a result of increasing energy efficiency, high gas prices in the years before the shale gas revolution, and slow growth in industrial production for the most gas-intensive industries, many of which were hit hard by the Great Recession,[4] but are currently showing signs of stabilization.

[1] U.S. Energy Information Administration. “Natural Gas Consumption by End Use.” Accessed July 2015. http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.
[2] U.S. Energy Information Administration. Total consumption. 30 June 2015 release.
[3] IHS CERA, March 2014, U.S. Industrial Gas Demand. mil
[4] IHS CERA *Fueling the Future with Natural Gas: Bringing It Home,* page VII-1.

Residential

Regional residential prices - natural gas and electricity (constant $2012 per MMBtu)



Residential consumption of NG natural gas typically includes household uses, such as heating, cooling, cooking, and other similar activities. Residential consumption growth is relatively slow, at CAGR of 0.5% from 2004 through 2014, to 5 million MMcf. While there has been a 31% increase in residential customers served between 1990 and 2011, residential gas customers reduced their consumption of gas by approximately 1.2% a year, in part, through the use of more energy-efficient homes and appliances. When normalized for weather, NG consumption has been relatively flat in that time period.[5]

Commercial

Commercial businesses use NG for non-manufacturing purposes, such as for heating, cooling, and so on. Typical commercial users include leisure sectors, wholesale and retail trade, and government agencies. Commercial consumption of NG is relatively low, as compared with other end users, at around 3.5 MMcf in 2014, and growing at a CAGR of 1% from 2004 through 2014.

Recently, vehicles powered by NG have increased in popularity. While use as a vehicle fuel is a small proportion of overall consumption, about 0.1% of total delivered NG consumption in 2013 and 2014, it is the fastest growing consumer of natural gas, with a compound annual growth rate (CAGR) of 4.8% from 2004 through 2014. On-road vehicles account for 79% of total demand for transportation fuels.[6] Given recent declines in the price of NG fuels, there is significant growth potential in natural gas vehicles.

The Natural Gas Pipeline System

The on-shore NG pipeline system is a complex network that transports NG from the wellhead to the end user, and in 2014, it was composed of over 1.52 million miles of pipeline[7] that are located in every state in the country. The NG pipeline system is composed of three major subsystems:

- Gathering pipelines
- Transmission pipelines
- Distribution pipelines

Each of the three pipeline segments performs different functions in the NG system and has varying requirements for materials, construction, and operations. In this section, we will describe the NG logistics system, which includes major pipelines segments, facilities, and basic components that are required on those segments and their relative size in mileage.

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[5] IHS CERA *Fueling the Future with Natural Gas: Bringing It Home,* page 81.
[6] IHS CERA *Fueling the Future with Natural Gas: Bringing It Home,* page 209.
[7] Mileage includes pipelines that are active, inactive/idle, and temporarily abandoned.

The largest clusters of natural gas pipeline are located in natural gas production areas the South, which includes pipeline from NG–rich Texas, Louisiana, and the Gulf Coast. Pennsylvania, Wyoming, Oklahoma, and Colorado also have significant clustering of natural gas pipeline systems. The rise of unconventional technologies has expanded the U.S. production base sufficiently that domestic gas resource production could supply current U.S. consumption for 88 to 154 years.[8]

According to the U.S. Department of Transportation,[9] in 2014 the length of on-shore natural gas pipeline system was 1,573,477 miles and comprised the following components:

- Gathering pipelines: 11,390 miles in 26 states, 0.7% of the total
- Transmission pipelines: 297,800 miles in 50 states, none in the District of Columbia, 18.9% of the total
- Distribution pipelines: 1,264,287 miles in all 50 states and the District of Columbia, 80.4% of the total

Natural Gas Gross Well Withdrawals by State, 2013 (MMcf)

State	2013
Alabama	271,986
Alaska	3,215,358
Arizona	72
Arkansas	1,139,654
California	252,310
Colorado	1,604,860
Florida	18,011
Illinois	2,887
Indiana	7,938
Kansas	292,467
Kentucky	94,665
Louisiana	2,413,575
Maryland	32
Michigan	123,622
Mississippi	413,329
Missouri	-
Montana	63,242
Nebraska	1,032
Nevada	3
New Mexico	1,271,185
New York	23,458
North Dakota	345,787
Ohio	186,181
Oklahoma	2,143,999
Oregon	770
Pennsylvania	3,259,042
South Dakota	16,205
Tennessee	5,400
Texas	8,211,255
Utah	470,863
Virginia	139,382
West Virginia	717,892
Wyoming	2,047,757
U.S. Natural Gas Gross Withdrawals (MMcf)	30,005,254

Source: EIA

Natural Gas Gathering Pipelines

The gathering pipeline system is the first step in the NG delivery system, linking together small branches of pipeline to push NG collected from the wells in the NG and oil fields into larger pipelines to move NG through the system. The gathering pipeline systems is composed of small, low-pressure pipelines that sometimes travel through multiple leaseholder fields and occasionally require the help of compressors to generate additional pressure to push the NG on its way. Operating pressure in gathering pipeline systems varies considerably based upon pressure produced from wells. The first stop in the gathering pipeline system is a leasing facility, where the volume of NG is metered, or measured, to assess royalties owed to leaseholders.

Typically, when NG is pumped from the ground, it contains constituents that could damage the pipeline system that must be removed before it can be put into a transmission line (i.e., pipeline-ready NG). Each pipeline has a rating for the quality of NG, pressure, and quantity it can handle. Gathering pipeline systems are smaller in diameter, as they handle smaller quantities of NG. Gathering pipeline systems are located mainly in NG-producing states. There were 11,390 miles of gathering pipelines in the United States in 2014 with about 56% of the total in Texas, Louisiana, and Oklahoma; however, more gathering pipe is being installed in Pennsylvania, Ohio, Colorado, and West Virginia.

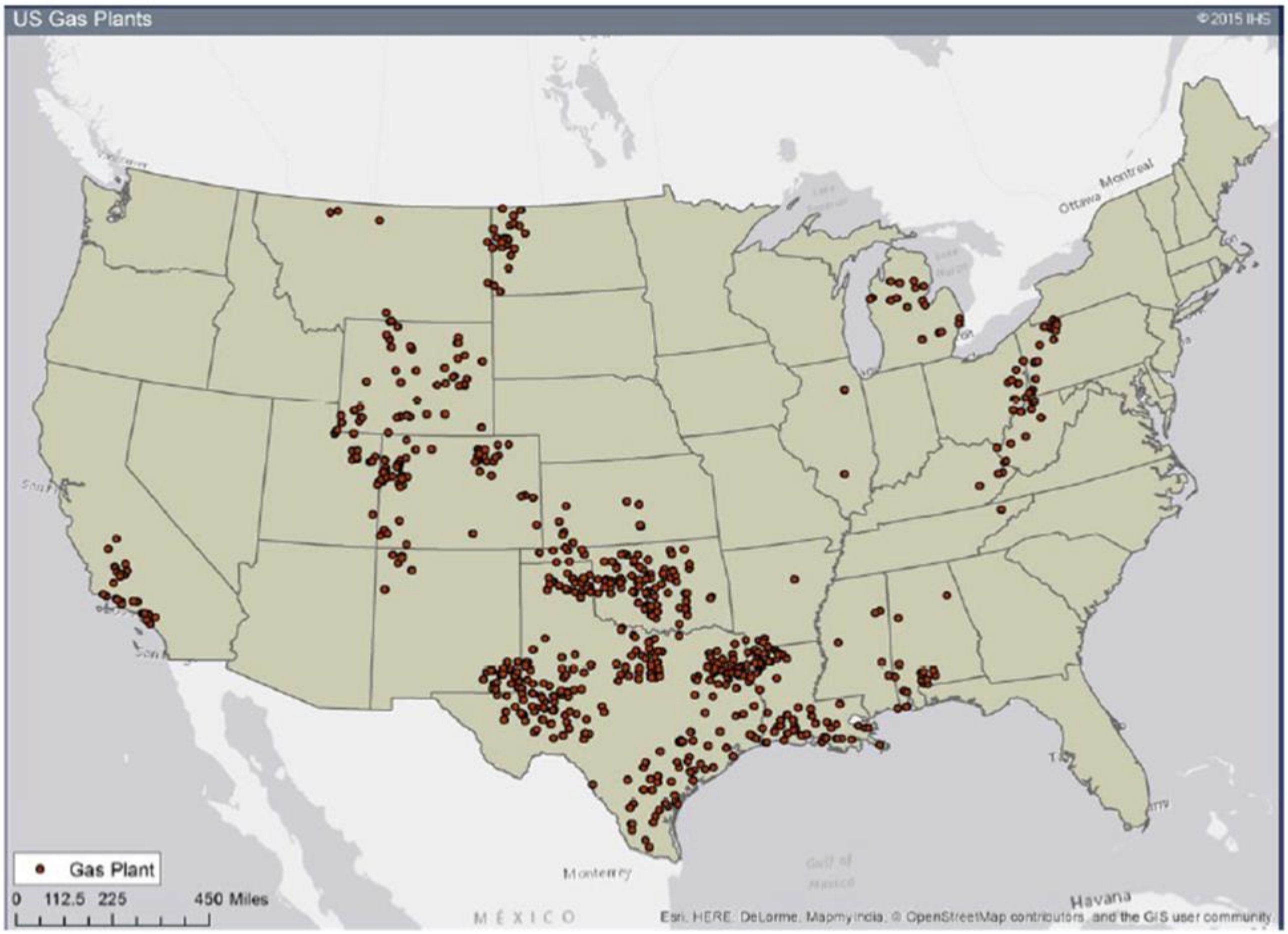
Natural Gas Processing Plants

Natural gas processing facilities are the next point in the system, where impurities and marketable gas and liquids by-products are separated, based on future pipeline standards for these materials. Natural gas, especially "wet" gas, often has

[8] IHS CERA *Fueling the Future with Natural Gas: Bringing It Home,* page ES-5.
[9] U.S. Department of Transportation, Pipeline and Hazardous Materials and Safety Administration. http://phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print.

valuable by-products that are processed and resold. Primarily, the various types of NG liquids (NGL themselves have a variety of uses, including as petrochemical feedstock (e.g., ethane, butane, and isobutene) and fuel (e.g., propane).

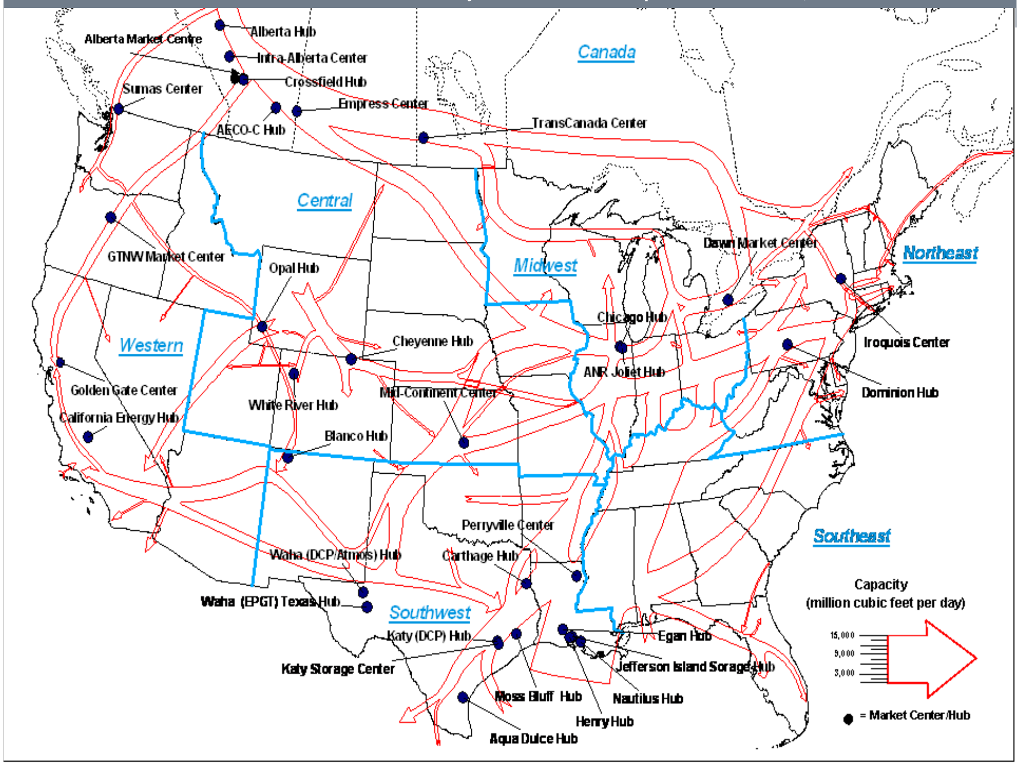
Other by-products of NG processing that may be extracted and sold include: sulphur, carbon dioxide, nitrogen, and condensate (heavier liquids). Compressors then help push NG toward transmission line inlets. According to IHS,[10] as of June 2015, there were a total 728 operating NG processing plants in the United States, with a combined capacity of 83,955 million cubic feet per day (MMcf/d). The accompanying map shows the current spatial distribution of gas processing plants in the United States. The map clearly shows they are located in the major gas-producing formations in the United States, such as the Marcellus in western Pennsylvania, the Bakken in western North Dakota, and the formations concentrated in Louisiana, Oklahoma, and Texas. Some of the plants along the Louisiana and Texas coasts also process NG produced off shore in the Gulf of Mexico.



[10] IHS Energy, June 2015. Second Quarter – North American NGL Markets Infrastructure Update.

Natural Gas Transmission Pipelines

Natural Gas Market Centers and Hubs in Relation to Major Natural Gas Transportation Corridors, 2009



Source: U.S. Energy Information Administration

The transmission pipeline system is composed of much larger pipelines that move NG within (intrastate) and across (interstate) states. Typically, interstate lines are owned by large holding companies. Transmission lines are constructed of high-strength steel that is 0.25 to 0.75 inches thick and typically range from 20 to 42 inches in diameter. The transmission system can operate at a pressure of 200 to 1,500 pounds per square inch (psi),[11] based on the maximum allowable operating pressure rating of the pipe. The pipelines are also coated with epoxy to protect them from corrosion. The volume of NG and its speed of movement, up to 30 miles per hour through the transmission system depend upon the diameter of the pipe and its pressure, which is dictated by several factors: 1) ambient conditions, such as elevation and temperature; 2) proximity to compressor stations; and 3) the amount of pressure generated by the compressor station. As NG moves along the transmission lines, it generates friction, and as pressure falls, NG speeds slow down. Generally, compressor stations are located between 50 to 100 miles apart[12] on transmission lines, but in regions where NG must move through large elevation changes and/or temperature changes, they are located closer together to give NG a boost. Compressor stations typically also contain filtering and scrubbing systems to capture any contaminants that the NG may have picked up along its journey.

Compressors: A compressor is a machine driven by an internal combustion engine or turbine that creates pressure to "push" the gas through the lines

Condensate: A gas that becomes a liquid when exposed to atmospheric pressure

Supervisory Control and Data Acquisition (SCADA): Systems that monitor transmission pipelines automatically, transmitting data on pipeline operation points, such as volume, pressure, and temperature

Given the importance of NG pressure and volume within the transmission pipeline, valves, safety monitoring systems, and pipeline redundancy around compressor stations are crucial to the transmission system. Control centers and operators constantly monitor and adjust the pressure and volume in lines. Valves that can be operated remotely are used to shut off the flow of NG to pipelines that are undergoing maintenance or have been flagged for safety reasons.

Natural gas moving through the transmission pipeline system generally follows 11 distinct transportation route corridors, from producing regions to consumer regions. Five major routes originate from the Texas/Louisiana/Gulf Coast area,

[11] American Gas Association website. Accessed July 2015. < https://www.aga.org/how-does-natural-gas-delivery-system-work>
[12] Shively, B. and Ferrare, J. "Understanding Today's Natural Gas Business." Enerdynamics Corps. 2007

four originate from Canada, and two originate from the Rocky Mountain area. On these routes, there are multiple points, referred to as hubs/market centers, where transmission pipelines intersect. Hubs provide services such as wheeling between pipelines, exchanges, title transfers, price discovery, electronic trading, parking (temporary storage), and lending. Distribution hubs are privately owned and are often used as price points for trading and contracts. Large end-user clients will often purchase titles for NG, as well as futures from hubs, which will be delivered through the transmission and distribution systems.

The end point of the transmission line is located at the city gate, also referred to as the gate station, where transmission mainlines meet the local distribution system, and is typically operated by the local distribution company (LDC). Most NG end users are located past the city gate, on the distribution pipeline system. Almost all residential and commercial gas users rely on gas LDCs for their gas purchases and/or deliveries.[13]

Few power utilities and industrial manufacturers, that consume a large volume of NG, will be located along the main transmission. Smaller transmission line pipe offshoots of 6- to 16-inch-diameter pipe provide service to local distribution companies or directly to large end-user customers.[14] The frequency in which end-user clients are located along transmission lines, rather than along the distribution lines, is regional in nature.

Storage Facilities

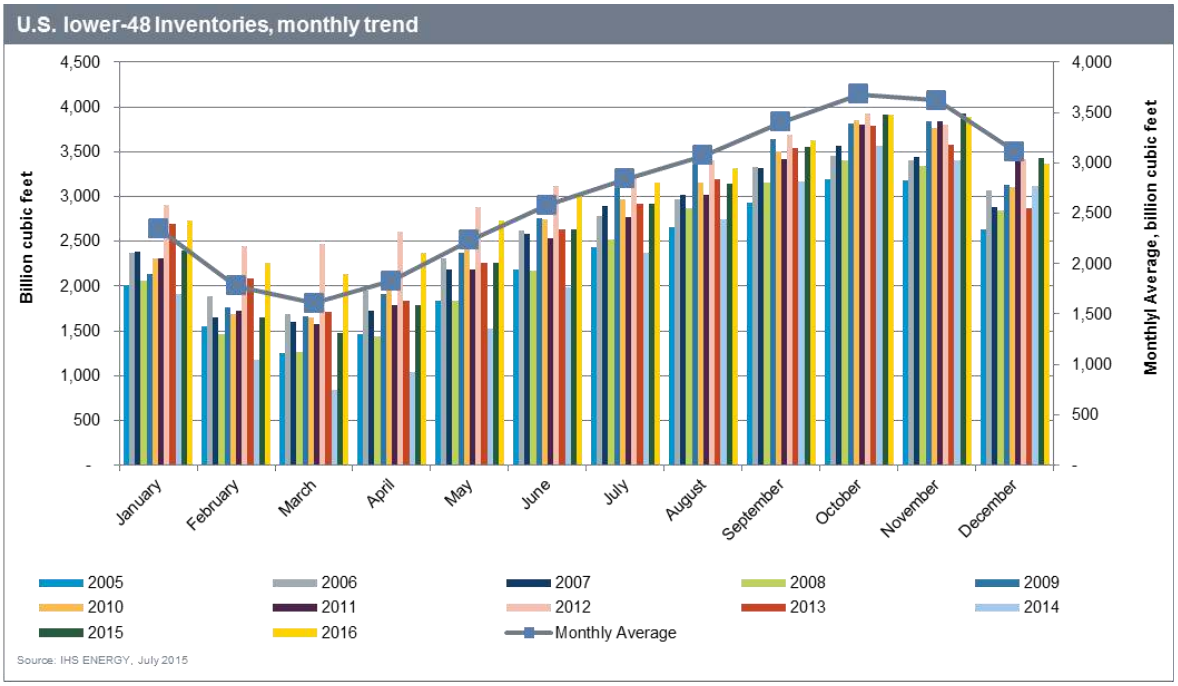
Transmission lines move NG away from the gathering lines, toward end users that receive their gas via local distribution systems. A number of NG demand factors, which will be described in Chapter Two, determine where and when NG is in demand. Surplus NG will be sent to storage facilities. Cost-efficient availability of storage and inventory near the consumer play a significant role in NG pricing. Geographic circumstances, pipeline availability, and demand fluctuation affect the kind of storage that is available and the potential inventory flow.

Underground storage facilities are used for longer-term storage, and there are three main types that may be located near the production region or the end-user region:

- Depleted NG or oil fields, which are typically located either in producing regions or in formally producing regions that are closers to consumption areas. Depleted fields are optimal storage locations, as much of the necessary infrastructure for withdrawal is already in place, keeping conversion costs low. Additionally, they account for more than 80% of capacity.
- Salt caverns, which are located primarily in Gulf Coast states, but also in the Northeast, Midwest, and Southwest, allow for high rates of withdrawal and injection, but the conversion costs are higher than depleted field conversion.
- Saline aquifers, which are also located primarily in the Midwest, can be suitable for underground storage, based on their geological qualities. Converted aquifers require a larger "cushion" of gas and greater monitoring of performance to maintain safe injection and withdrawal performance.

Monthly underground storage, including inventories, withdrawals, and injections, are monitored and reported by the EIA on a monthly basis. According to EIA, there are approximately 400 active underground storage facilities in the Lower 48 states with inventories that fluctuate on a monthly basis, following seasonal patterns for heating and cooling.

[13] IHS CERA *Fueling the Future with Natural Gas: Bringing It Home,* page 79.
[14] Shively, B. and Ferrare, J. "Understanding Today's Natural Gas Business." Enerdynamics Corps. 2007.



Natural Gas Distribution Pipelines

The distribution pipeline system is the final pipeline system in the delivery system from wellhead to consumer. Local distribution companies deliver gas supply within market areas to customers using 1,264,287 miles of smaller-diameter, low-pressure mains and approximately 880,000 miles of customer service lines that deliver gas from a street connection to the customer's meter.[15] Distribution pipelines are smaller than transmission pipelines, ranging from 24 inches to 2 inches in diameter. Pressure ranges from 60 psi, in pipelines located nearest to the transmission line, to 0.25 psi near, near homes and small businesses. The distribution system consists of pipes (mains and lines), small compressors, regulators to reduce pressure, valves to control flow, metering to measure the flow, and supervisory, control, and data acquisition systems (SCADA) to monitor and remotely control flow. Older distribution lines have been made of various types of material, but newer distribution lines are often constructed with PVC piping, which is less corrosive than metals.

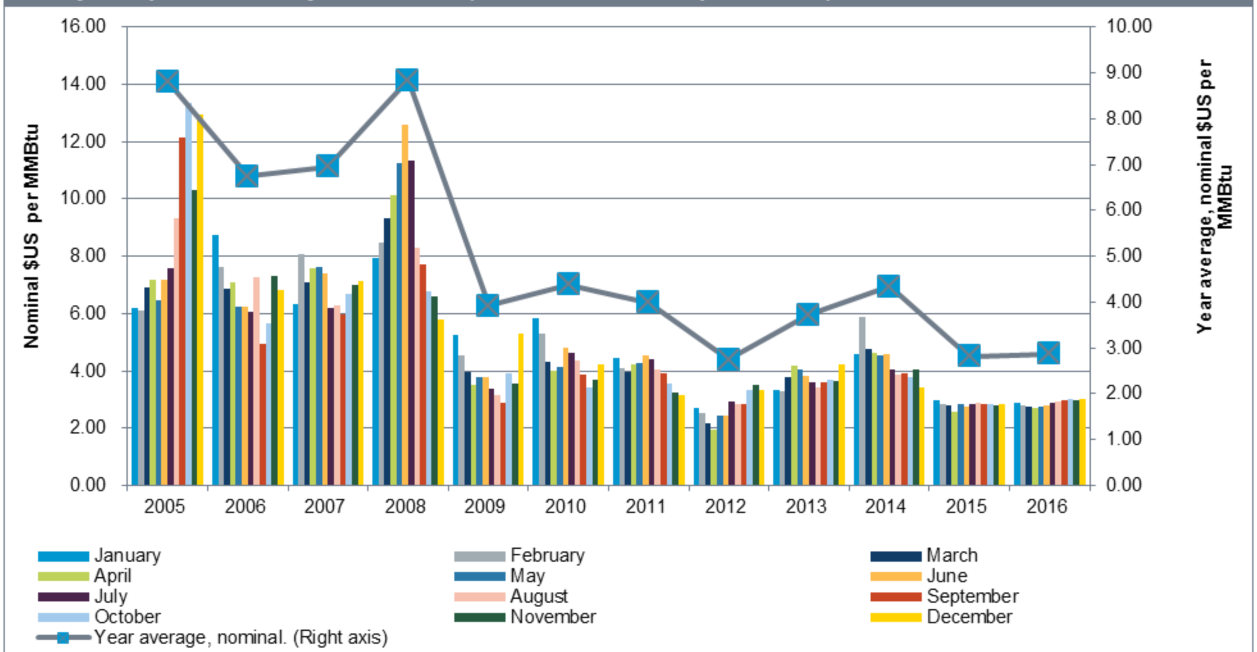
As NG flows through the city gate from the transmission line, interconnects (local distribution companies or local utilities) meter the gas, regulate the pressure (depressurize), and scrub and filter the gas to ensure it is clean and free of water vapor. Natural gas is odorless until mercaptan, the familiar rotten-egg-smelling odorant, is added as an additional safety measure at this point. Local distribution companies or local utilities transport and distribute NG from this point onward to end users. Industries and commercial machinery operators often require higher pressure to operate, and regulators along the distribution system are used to adjust pressure to meet end users' needs. Large end users often hold title to their own gas through market transactions and pay local distribution companies for transportation services. Gas LDCs serve more than 65 million residential customers, more than 5 million commercial customers, and more than 190,000 industrial and power-generation customers.[16] The local NG distribution system is very complex, with service areas ranging from very large to quite small.

[15] American Gas Foundation "Gas Distribution Infrastructure: Pipeline Replacement and Upgrades," page 1.
[16] IHS CERA *Fueling the Future with Natural Gas: Bringing It Home,* page 79.

Natural Gas Liquids (NGLs) and Liquefied Petroleum Gas (LPG) Pipelines

NGLs are produced primarily by NG processing plants and usually contain some or all of the following five types of liquids: ethane, butane, isobutene, propane, and pentane. About 71% of NGLs in the United States are produced by NG processing, the remaining 29% are generated during refining, consisting primarily of propane and butane, and a small volume of ethane. According to IHS, only about 60% of U.S. natural gas production requires processing; the rest is too dry (i.e., low liquid content). The shale plays with the wettest NG are the largest sources of NG liquids, including the Eagle Ford in Texas, and the Utica and Marcellus formations in western Pennsylvania, southeast Ohio, and West Virginia.

Henry Hub prices: History and outlook (nominal US dollars per MMBtu)



Source: IHS ENERGY, released July 2015

IHS estimates that total production of NGLs in the United States in 2014 averaged just over 3.7 million barrels per day. (mmb/d). The seasonal fluctuation in production levels is clearly evident. The production and transportation of NGLs requires the use of NGL storage facilities. IHS recently estimated that the major companies involved in NGL production and transportation currently have a total NGL storage capacity of 328.5 million barrels. Liquefied petroleum gas (LPG) is produced from crude oil refining or NG processing. It consists primarily of propane, normal butane, and isobutene, and current definitions exclude ethane and olefins. According to the U.S. Department of Energy,[17] LPG can be liquefied through pressurization (without requiring cryogenic refrigeration) for convenience of transportation or storage. Both NGLs and LPG are sent via pipelines from processing location, which are usually located in or adjacent to the major NG fields, to locations where they can be processed into other products. According to IHS,[18] there are currently 66,443 miles of NGL pipelines in the United States operated by major companies with a combined capacity of 14,757,802 barrels per day (b/d).

NGLs and LPG Marine Terminals

Marine terminals are used to transfer NGLs and LPG from land transportation modes, such as pipelines and rail, to ships for export or the reverse when they are imported. The map below shows the location of the currently operating LPG marine terminals in the United States.

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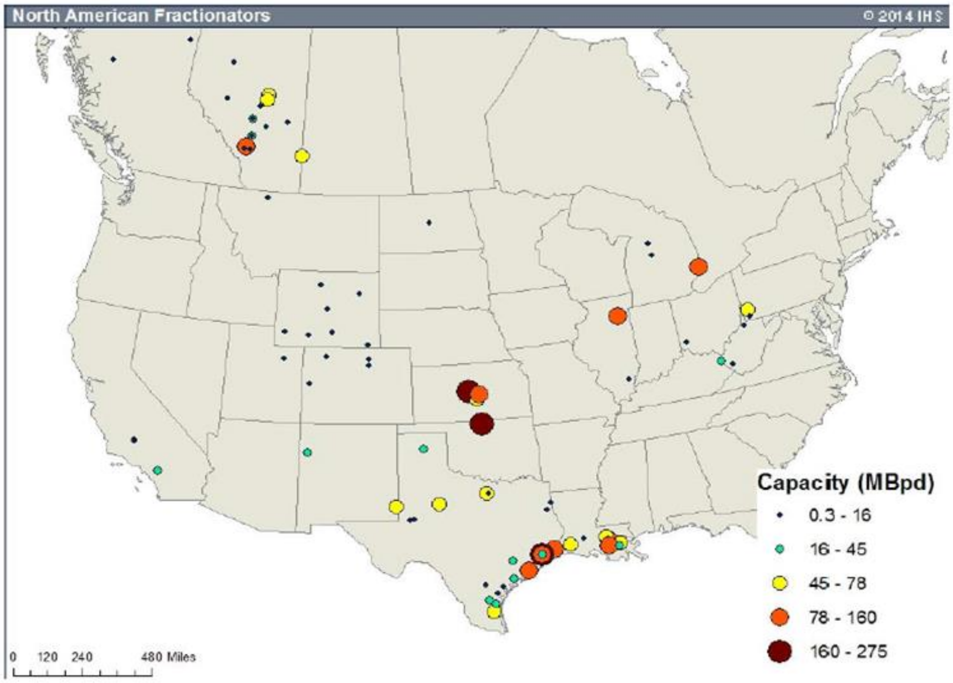
[17] U.S. Department of Energy, Energy Information Administration, July 2015. Glossary. http://www.eia.gov/tools/glossary/index.cfm?id=L.
[18] IHS Energy, June 2015. Second Quarter – North American NG Markets Infrastructure Update

Natural Gas Fractionators

Natural gas liquids fractionation facilities process NGLs into other products that are then used as inputs into petrochemical productions. For example, a fractionator may use several different processes to separate ethane from the NGL stream. According to IHS,[19] in 2013 there were a total of 93 NGL fractionators located in the United States with a combined processing capacity of 4,423 thousand barrels per day (mbd). The map below shows the spatial distribution and capacities of the major clusters of NG fractionators in the United States and Canada. While fractionators are usually located in major NG producing regions, they can also be located at the end of pipelines carrying NGLs and LPG, for example. Sunoco Logistics has recently started construction of a 35,000 bpd fractionation plant at its Marcus Hook Industrial Complex, located on the Delaware River about 25 miles south of Philadelphia.

[19] IHS Energy, June 2015. Second Quarter – North American NGL Markets Infrastructure Update.



Liquefied Natural Gas Facilities

Liquefied natural gas (LNG) is produced by cooling to a temperature of approximately -260 degrees Fahrenheit. The primary reasons for liquefying NG are to store it for future use (i.e., in a peak shaving facility) and re-gasifying it when it is needed and putting it back into a pipeline to transport it, such as in an LNG tanker, or for direct use, such as a fuel in NG vehicles. Natural gas in liquid form takes up about 1/600th of its volume when in gaseous form. The major types of LNG facilities include:

- Liquefaction plants that convert pipeline ready gas to liquid form prior to storage, transport, or other use.
- Regasification facilities.
- Storage facilities, including peak shaving plants.
- Marine terminals through which LNG can be either exported or imported.

As described by the Department of Energy,[20] LNGs can be liquefied through pressurization (without requiring cryogenic refrigeration) for convenience of transportation or storage. Both NGLs and LNG are sent via pipelines from processing locations, which are usually located in or adjacent to the major NG fields, to locations where they can be processed into other products. According to IHS,[21] there are currently 66,443 miles of NGL pipelines in the United States operated by major companies with a combined capacity of 14,757,802 b\d.

According to the Federal Energy Regulatory Commission (FERC),[22] there are currently 11 operating LNG export/import terminals in the United States with a combined capacity of 18.5 billion cubic feet per day (Bcfd). All of them are located along the Atlantic Ocean and Gulf of Mexico coasts, with 12.9 Bcfd of capacity present along the Gulf of Mexico coast.

Peak shaving facilities store LNG and re-gasify it to meet peak demands for NG. According to FERC, there are 13 peak shaving plants located in the United States, primarily in the Middle Atlantic and Northeast states. The role of supply and demand in NG availability and pricing are described in the next chapter.

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[20] U.S. Department of Energy, Energy Information Administration, July 2015. Glossary. http://www.eia.gov/tools/glossary/index.cfm?id=L
[21] IHS Energy, June 2015. Second Quarter – North American NG Markets Infrastructure Update.
[22] Federal Energy Regulatory Commission, July 2015. http://www.ferc.gov/industries/gas/indus-act/lng/lng-existing.pdf.

CHAPTER TWO: DRIVERS OF PIPELINE GROWTH – NATURAL GAS SUPPLY AND DEMAND

The NG resource base in North America is plentiful and low cost. A geological assessment of 17 unconventional NG plays in North America published by IHS Energy in 2010 indicated that many years of growing gas demand could be supplied at a breakeven wellhead price of $3.75 to 4.50/btu. Recent technological advances and price moves suggest that the reserve base is even larger and the current break-even prices are even lower.

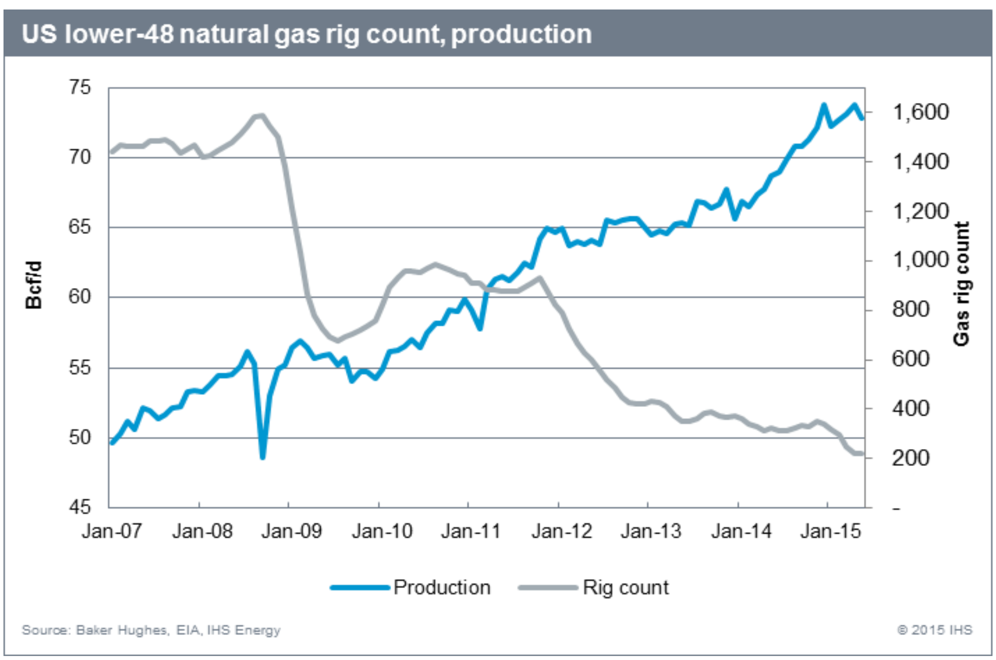
Nevertheless, supply does not generally grow at a steady rate. Investment decisions are made in consideration of the prevailing and expected market environment. There is often a lag of several months, as rigs are hired and wells are drilled, completed, and hooked up to gathering lines and other infrastructure before new production begins to flow. As a result, supply responds to market changes with a lag. Operators' responses to price changes will be further delayed if they have placed corporate hedges against adverse changes in the market.

The unexpected growth of Appalachian production has upended traditional gas flows and created new infrastructure needs.

Supply Growth

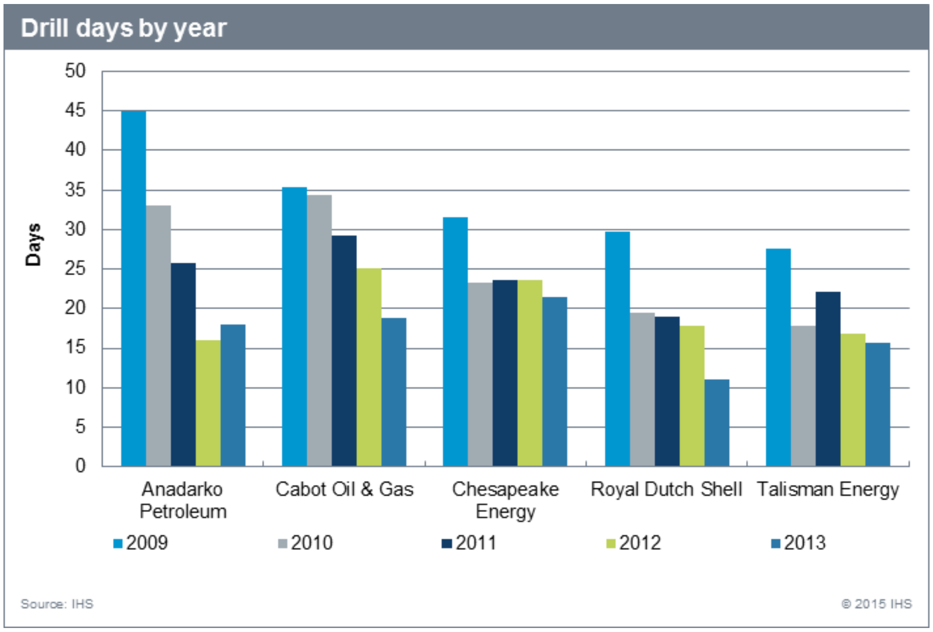
Supply growth continues at a strong pace, despite obstacles. With the widespread adoption of unconventional gas production techniques, the U.S. Lower 48 gas resource base has become a juggernaut of supply growth.[23] Between 2007 and 2014 U.S. Lower 48 gas production grew by approximately 2.5 billion cubic feet per day (Bcfd), or 4% of total production, every year.[24] In one 12-month period ending December 2011, production grew by about 5.6 Bcfd. In 2014, the year-over-year increase was 3.8 Bcfd on an annual average basis.

Growth has persisted despite falling prices for both gas and oil and significantly lower rig activity. The industry has fueled growth, despite these obstacles, by improving drilling and completion technology and increasing productivity in dry gas plays. Additionally, producers have focused their drilling activities on the most productive areas of each play to maximize production and minimize cost.



Rig counts have fallen while production continues to grow The U.S. Lower 48 gas-directed rig count averaged 332 in 2014, a more than 75% decline since 2008 when there were almost 1,500 gas-directed rigs operating. Gas-directed drilling has declined further in 2015, averaging 250 through July.

[23] U.S. Lower 48 excludes the non-contiguous states of Alaska and Hawaii.
[24] In this section, natural gas refers to dry natural gas.

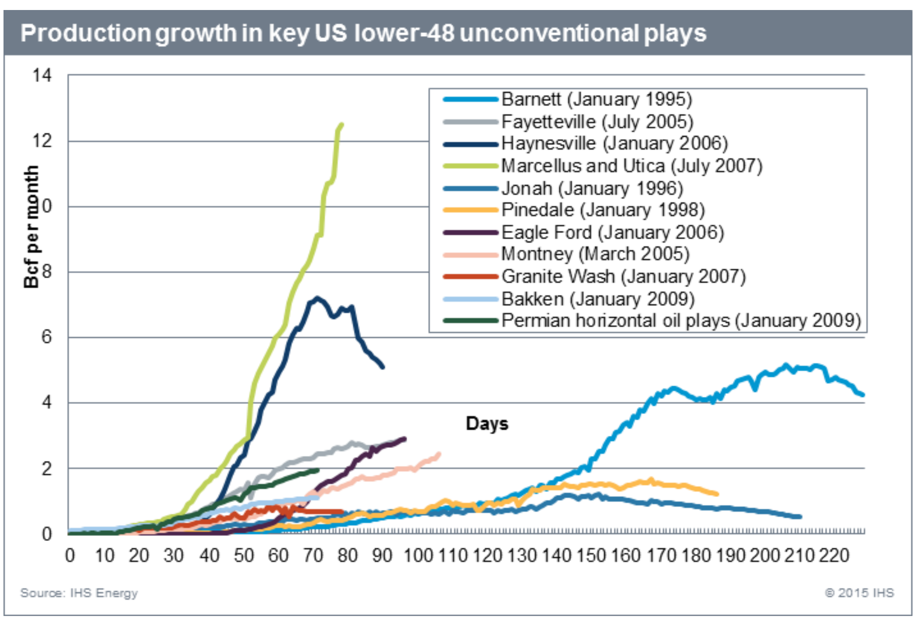


Oil-directed drilling is also a significant contributor to NG production in the U.S. Lower 48 because in many oil plays, NG is intermixed with the oil and gets produced via the same well. While in some cases, where infrastructure does not exist, this gas is burned off in a process called flaring, in most cases, the gas is collected and brought to market on the pipeline system. This is called associated gas, and in 2014 it represented approximately one-fifth of all U.S. Lower 48 NG production. Because gas is produced as a byproduct of oil in these areas, well economics are tied to the price of oil and not gas. As a result, associated gas production depends on the amount of oil-directed drilling that occurs. Oil prices, namely West Texas Intermediate (WTI) Crude, have fallen dramatically over the past year, from over $100/bbl in July 2014 to approximately $46/bbl in October 2015. While the impact on oil-directed drilling did lag behind the fall in oil prices, the oil rig count fell from 1,602 in early October 2014 to 578 by the end of October 2015, a decline of 64 %.

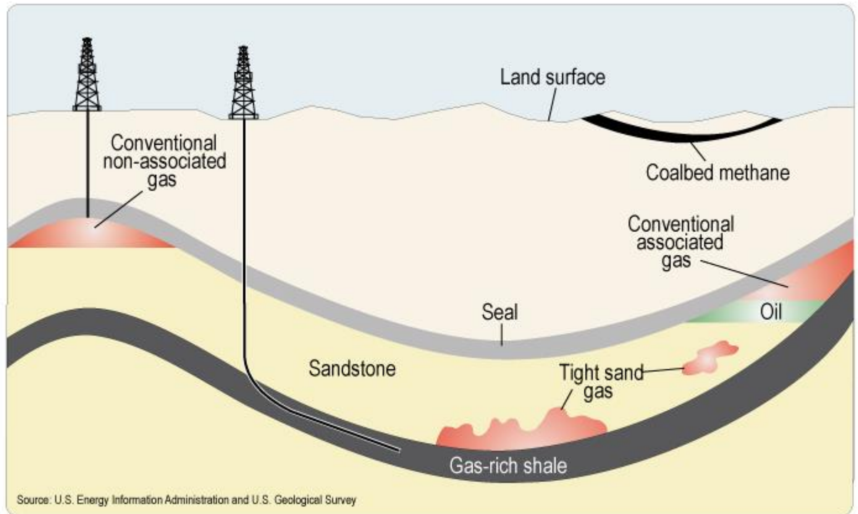
Despite declining drilling activity for both gas and oil, gas production continues to grow as rig efficiency and well productivity both increase. Drillers are focusing on the most productive areas of plays, and rigs are drilling more complex wells with longer horizontal segments and more hydraulic fracturing stages to increase productivity. At the same time, the practice of drilling multiple wells on a single pad along with other innovations has significantly reduced the time required to drill a well. In the Marcellus, for example, average drill days have declined significantly for many operators since 2009, indicating the learning trends among operators in the play.

Well Productivity

Well productivity is steadily increasing in many plays. As operators become more familiar with the geological structure of plays and sub-plays, they are able to target the most productive areas for drilling. They are also making steady incremental gains in extending laterals and reducing well costs via drilling and completion efficiencies. Additional technological developments in drilling technique are expected to improve productivity over the next five years. Such technological innovations, together with new connections to the interstate pipeline network, have allowed a much quicker ramp-up of plays brought into development in recent years. The Marcellus and Utica plays have been leaders in production growth; with production exceeding 12 Bcfd only 72 months after development began in 2007. By comparison, the Barnett play took more than 200 months from its initial development in 1995 to reach peak production of about 5 Bcfd. The data indicate that operators are indeed able to ramp up production today much more quickly than they could 20 years ago.



The shift toward liquids-rich plays has reduced gas costs. Revenues from NG liquids (NGLs), which are produced with natural gas, such as ethane, butane, propane, and natural gasoline, defray part or all of total well costs. In many cases, NGL revenues exceed the total cost of the well, and, in such situations, the break-even price of dry gas production can be significantly lower, if not negative.[25] For example, using December 2014 NGL prices, NGL revenues in the Marcellus Shale reduce the average break-even price of gas from the play from $4.13 to $2.40/thousand cubic feet (Mcf).



The Woodford play dramatically demonstrates the impact that NGL revenues can have on project economics. In that play, break-even prices drop from $7.85 to $2.21/Mcf in the gas-directed portion of the play and from $19.35 to ($4.50)/Mcf in the oil-directed portion. This means that despite a negative price of ($4.50)/Mcf, operators in the oil portion of the Woodford would receive a positive 10% return on their projects. In contrast, the dry Haynesville shale play has few liquids, and the difference between the breakeven price with and without NGL revenues is only about $0.10/Mcf.

Table 1
North American full-cycle "IHS outlook" break-even prices ($/Mcf)

Play	Without NGL credit 2015	With NGL credit 2015
Barnett	$9.13	$6.31
Cotton Valley	$5.98	$4.62
Haynesville Shale	$3.87	$3.76
Fayetteville Shale	$4.29	$3.98
Jonah	$6.29	$4.11
Marcellus Shale	$4.13	$2.40
Montney	$5.79	($1.28)
Pinedale	$4.60	$3.32
Utica Gas	$5.96	$3.48
Woodford	$11.52	$0.07
Woodford Gas	$7.85	$2.21
Woodford Oil	$19.34	($4.50)

Source: IHS Energy

Note 1: Full-cycle unit break-even prices are calculated at the play level for the "typical" gas w ell and include leasehold, F&D, royalty, opex, taxes, and return. Capital costs are success-w eighted and based on equipment needed for the "typical" w ell. WACC is assumed to be 10%. Taxes are based on tax benefits available to all producers. Well useful life is assumed to be 20 years. Costs show n here do not include transportation costs to Henry Hub.

Note 2: Reflects IHS Energy's first quarter 2014 price outlooks for crude oil and NGLs.

Note 3 : Negative numbers indicates a negative gas prices is required to reduce the return to 10%, given that the liquids revenues produce a much higher return

Note 4: Break-even prices for Woodford are show n both at a play level and subplay level to demonstrate how play economics can vary w ithin a play.

Source: IHS Energy

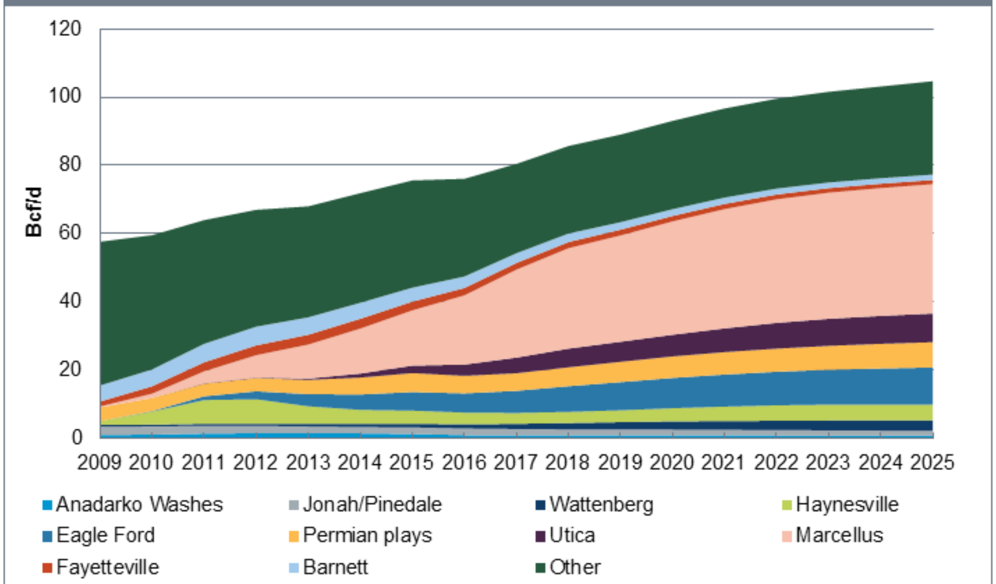
Production growth is likely to be concentrated in Appalachia, but Texas and Louisiana will grow as well. Unconventional gas activity is concentrated in five major regions throughout North America: Western Canada, the Rocky Mountains, the Permian and San Juan basins in West Texas and New Mexico, the Texas Gulf Coast, and Appalachia. Most of the recent growth, as well as projected development, have been centered in the Appalachian region of the Eastern United States, where gas activity had been sparse prior to 2007. The unexpected growth of Appalachian production has upended traditional gas flows and created new infrastructure needs.

Over the past two years, the Marcellus play has been the most prolific contributor to gas supply growth, with gas production from this formation growing by more than 10 Bcfd between 2012 and 2014. Combined with the Utica, the other major Appalachian play, the Marcellus is expected to account for almost 75% of the total growth, or 22.7 Bcfd, in the U.S. Lower-48 productive capacity between 2015 and 2025. The Haynesville play, which has declined in recent years as operators have shifted toward plays with more NGLs, is expected to rebound, driven by demand growth in southern U.S. markets and increasing well productivity within that play. As a result, the Haynesville production will grow by more than 3 Bcfd by

[25] The break-even price calculation assumes a 10% internal rate of return (IRR) on investment. Therefore a negative break-even price for gas can be interpreted as indicating an IRR greater than 10%. Alternatively, an operator could pay a customer to take the gas and still generate a 10% rate of return.

2025, or almost 75% higher than 2015 levels. The Eagle Ford Play in Texas, which combines a mixture of oil- and gas-directed drilling, will also see production increase. Outside of the United States, production in Western Canada, which exports significant quantities of gas to the United States via pipeline, will also grow significantly, driven by anticipated LNG exports and the need to replace declining conventional production in the Western Canada Sedimentary Basin. This growth could potentially be constrained by transportation costs on the TransCanada Mainline (Canadian Mainline), the main route for Western Canadian gas to reach U.S. Midwest and Northeast markets, if those rates make gas from Western Canada uncompetitive in destination markets.

US lower-48 natural gas productive capacity by play



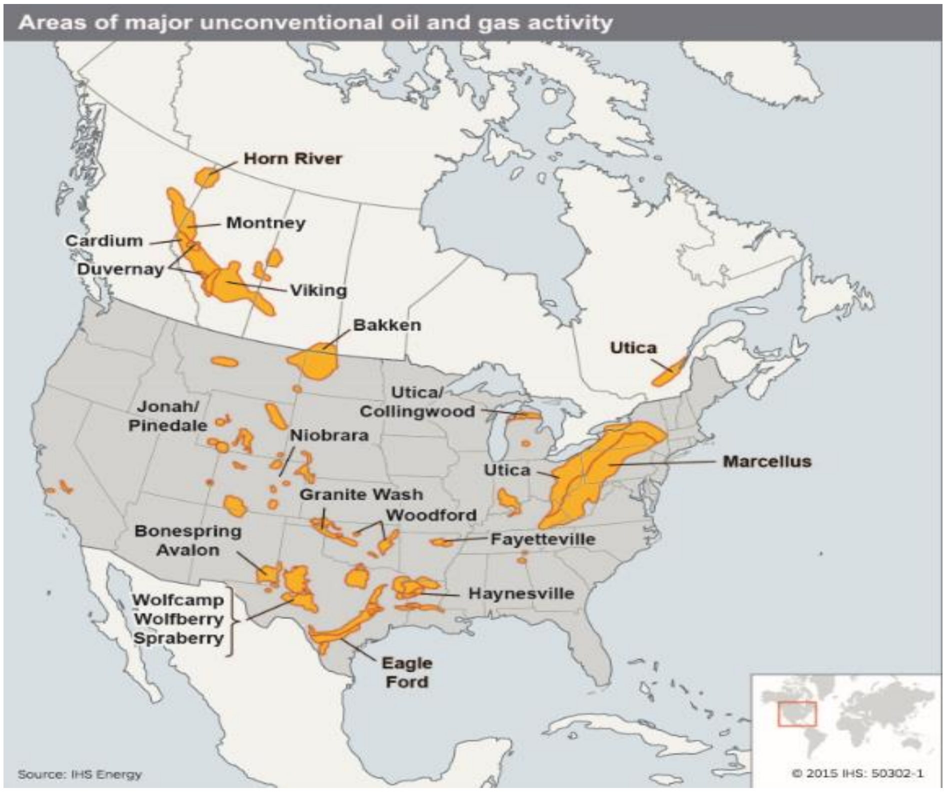
Source: IHS Energy © 2015 IHS

IHS Energy expects that the ongoing development of unconventional gas plays in the U.S. Lower 48 will keep supply growth robust between 2016 and 2025 and will help supply keep up with rapidly growing demand. Our outlook projects an average annual gas production growth of 3.0 Bcfd in the U.S. Lower 48, the majority of which will come from plays in the Appalachian basin. By 2025, total U.S. Lower 48 gas production is expected to reach 102.9 Bcfd, an increase of 33.3 Bcfd, or 48% higher, relative to 2014.

Infrastructure Development

Infrastructure development in the North American pipeline and storage grid over the next 10 years will be driven by producers' choices of how to profit from production growth out of the Marcellus and Utica plays. The rapid growth of low-cost production out of these areas has created a bottleneck, as drillers are unable to find pipeline capacity to move gas from the well to consumer markets. IHS expects new infrastructure development to spread in all directions from Appalachia to support 22.7 Bcfd of productive capacity growth from the Marcellus (19.3 Bcfd) and Utica (3.4 Bcfd) between 2015 and 2025. Producers and shippers have signed up for long-term contracts on pipeline capacity additions to downstream consuming markets totaling about 23.7 Bcfd at this point and representing almost $30 billion in investment. The majority of new additions are designed to send gas to the U.S. Southeast. 14.6 Bcfd, or 62% of total contracted capacity additions, is heading to the Southeast. 3.5 Bcfd/ (15%), 3.2 Bcfd (13%), and 2.5 Bcfd (10%) are designed to bring Appalachian gas to the U.S. Northeast, U.S. Midwest, and Eastern Canada, respectively.

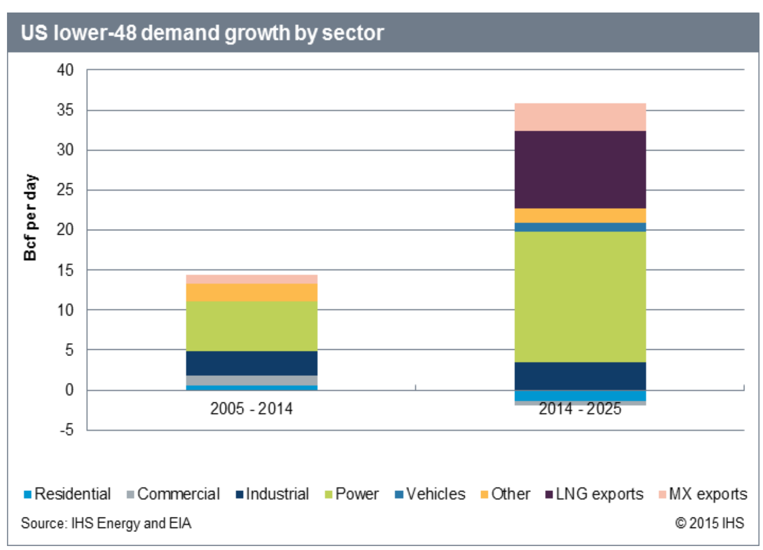
This investment has already created new flow patterns, as Appalachia has been able to displace other supply regions out of the Northeast markets. The Appalachian production will be forced to gain access to additional new downstream markets, requiring the necessary pipeline capacity to deliver the gas. This is partially possible by re-engineering existing pipelines historically importing gas into the northeastern United States and Eastern Canada to reverse the direction of flow and send low-cost Appalachian gas to additional demand regions. Many pipelines, like the Rockies Express Pipeline, which just reversed its Zone 3 between Illinois and Ohio to carry gas west into the Midwest and Chicago market, are already doing this. As the potential for reversal of existing pipelines is exhausted, the supply growth in Appalachia will require the construction of brand-new pipeline capacity.



Additionally, as U.S. production activity shifts to Appalachia, many pipelines originating in traditional Western and Gulf Coast supply regions are facing increasingly difficult operating conditions. Pipelines out of the Rockies, the Haynesville, the Barnett, and even the Fayetteville may have difficulty renewing long-term contracts that expire later this decade or in the early 2020s. Beyond 2025, the growth in demand for gas-fired power generation will have a significant impact on the pipeline system. This is particularly true if additional pipelines are needed in order to ensure the reliability of electric demand.

Demand Growth

Abundant low-priced NG is driving a massive ongoing and upward shift in NG demand. Low prices together with new environmental regulations are resulting in the retirement of a significant number of coal-fired power plants, many of which will be replaced by gas-fired capacity. Gas-intensive industries, which are identified in Chapter Four, are relocating facilities to North America from overseas, attracted by low prices and abundant supplies of NG and NGL. Domestic trucks, vans, ships, and even locomotives are being built or retrofitted to run on NG. LNG exports are planned from the U.S. Lower 48 and Canada, and U.S. pipeline exports to Mexico are increasing. And all of the growth in NG production will require greater use of NG for field operations and as a pipeline transportation fuel. Total NG demand is poised to increase by 40 percent over the next decade—double the growth of the past 10 years.

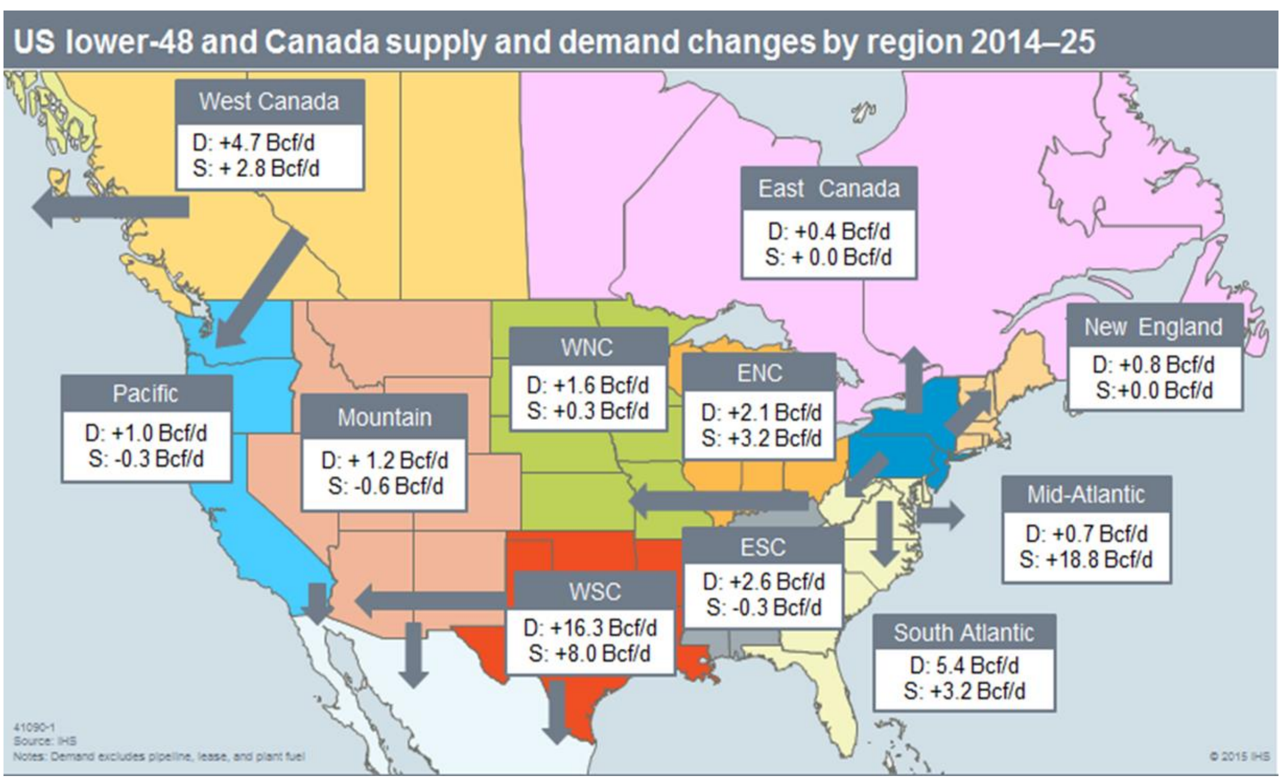


Such demand growth represents a fundamental change for gas producers that for the past 10 years have struggled to find enough markets to sell the production surge accompanying the "shale gale." Meeting the expected demand growth will require production growth to exceed even the steep increases of recent years. IHS Energy expects that the required supply will become available. Resources are ample, and operators have demonstrated an ability to increase production steadily despite declining prices and rig counts. New pipeline and processing infrastructure expansion will be a key to connecting new supply sources with new and growing sources of demand.

Drivers of New Natural Gas Demand

The power sector will provide the largest growth in gas demand in the next decade. Demand for natural gas in the power sector depends on two major drivers: growth in total electric generation and growth in the gas share of electric generation. With respect to the first driver, the U.S. Lower 48 electricity demand growth averaged 0.9% in the past five years, and electricity demand is projected to increase by an average of 1.6% annually from 2014 to 2025. From a geographic viewpoint, the strongest power sector growth will be in the South Atlantic and Mountain regions, driven by stronger manufacturing output and robust population growth as demographics continue to shift from the cold New England and East North Central (ENC) and West North Central (WNC) to the warmer Southern regions. By contrast, electricity demand growth will be tempered in New England and California, owing largely to expected gains in energy efficiency.

Most of the growth in power-sector demand will be met by increasing amounts of NG–fired generation and also by renewables. IHS Energy expects gas demand for power generation in the U.S. Lower 48 to increase by 73% (16.3 Bcfd) between 2014 and 2025, in comparison to a 39% (6.2 Bcfd) increase between 2005 and 2014. Coal-fired power plants will be retired in response to more stringent environmental regulations and more competitive low gas prices, which will lead to a change in the mix of generation fuel and an increase in NG's market share. Market-altering environmental regulations include the Environmental Protection Agency's (EPA) Mercury and Air Toxics Standard (MATS) rule, which that took effect in spring 2015, and the Clean Power Plan (CPP), where final rules were finalized in August 2015. Under our reference case, which assumes no CPP, IHS Energy expects a total of 63 gigawatts of coal-fired generation capacity will be retired between 2015 and 2030 while 167 gigawatts of NG-fired generation capacity will be added over the same period.[26]



[26] The CPP effect on natural gas will take some time to ramp up. Most effects of the CPP will occur after 2025 and, therefore, will have little impact within this timeframe.

The ENC, East South Central (ESC), and South Atlantic (SA) census divisions are expected to account for the majority of the net coal capacity retired in North America over this period. Hence, IHS Energy projects these regions will have some of the biggest increases in power-sector gas demand.

The second-largest demand increases are being felt in the U.S. industrial sector, which uses NG as both a fuel and a feedstock to meet a variety of energy requirements. The manufacturing sector accounts for about 80% of total industrial gas demand, with the remaining 20% coming from agriculture, construction, and mining. Within manufacturing, 91% of NG consumption is for fuel (including drying, melting, machine drive, space heating) and the remaining 9% is feedstock use in the refining, chemicals and primary metals sectors. Manufacturing's use of NG is concentrated in a few mature sectors. Chapter Four of this report describes the use of NG in manufacturing, identifying nine sectors at the three-digit North American Industry Classification System (NAICS) code level that accounted for 91.3% of consumption in 2010 as NG–intensive sector. The nine sectors are (in descending order of NG consumption): chemicals, petroleum and coal, food, primary metals, paper, non-metallic minerals, fabricated metals, wood products, and textile mills. The remaining 8.7% is used in 12 subsectors such as: transportation equipment, plastics and rubber products, machinery, computers and electronics, and electrical equipment.

Many of these industries—most notably the chemicals industry—are actively pursuing strategies to take advantage of low NG prices. Standing alone, the chemicals industry is expected to be the third-largest source of growth in gas demand through 2025. IHS has estimated that as much as $100 billion will be invested between 2013 and 2025 in new chemical, plastics, and related derivative manufacturing facilities in the United States. These investment figures are for manufacturing facilities only; additional infrastructure investment will go hand in hand to support feedstock requirements. IHS Energy estimates that NG demand in the chemical industry will grow by about 40% between 2014 and 2020.

Despite the advantages of lower NG prices, NG demand in most industries is a derived demand, depending on the level of output of the industry in question. Except for a few select industrial segments, such as ammonia and methanol, which use NG as their primary feedstock, gas expenses are only a small fraction of the total cost base when it is being used as a fuel. An expanding industry is likely to increase its demand for NG, regardless of the level of gas costs, more readily than an industry that is not expanding. Therefore, the growth prospects of the major gas-consuming industries are an important indicator of future NG demand in the industrial sector. Prospects are mixed for various industries. Three of the top four gas-consuming industries are projected to realize strong growth: chemicals, iron and steel, and processed foods are expected to increase output by 30% or more above their pre-recession 2007 levels by 2025. Three other industries—petroleum and coal products, non-metallic minerals, and pulp and paper—are expected to show small gains compared with 2007. Lagging gas demand in the slow-growing industries will partly offset the strong growth in the growing industries.

"There is a mismatch, geographically, in the growth in natural gas demand and supply in the U.S. Lower 48. The sum of exports, power, and industrial demand will substantially exceed supply growth in the West South Central, East South Central, and Mountain regions, creating a demand for new natural gas infrastructure to serve these divisions."

IHS Energy expects industrial-sector NG demand in the U.S. Lower 48 to rise by 17% from 20.9 Bcfd in 2014 to 24.5 Bcfd in 2025. The West South Central (Texas and Louisiana) and the East North Central and Pacific regions, the home of growing manufacturing activity and petrochemical plants, are expected to account for 44%, 15% and 11% of industrial NG demand by 2025, respectively.

The U.S. Lower 48 will be a net exporter of NG in 2018.[27] With U.S. Lower 48 NG supplies more than adequate to meet domestic demand and significantly cheaper than global supplies, an increasing amount will be desired by export markets. Pipeline exports to Mexico from the West South Central (Texas) and Mountain (Arizona) divisions are increasing significantly in the medium term, and LNG exports from the West South Central (Texas and Louisiana) are expected to

[27] U.S. Lower 48 net exports include LNG exports and natural gas pipeline exports to Canada and to Mexico. North America (Canada and the U.S. Lower 48) has been a net exporter since 2011.

begin in 2016. By 2025, LNG exports and pipeline exports to Mexico from the U.S. Lower 48 are expected to reach 15 Bcfd, up by 15% since 2014.

There is a mismatch, geographically, in the growth in NG demand and supply in the U.S. Lower 48. The sum of exports, power, and industrial demand will substantially exceed supply growth in the West South Central, East South Central, and Mountain regions, creating a demand for new NG infrastructure to serve these divisions. In contrast, supply growth will significantly outpace demand growth in the Mid-Atlantic region. In addition to the Marcellus and Utica gas production developments, there will be some other areas of significant pipeline and processing plant infrastructure activity. For instance, LNG exports will, in many cases, require upstream pipeline capacity expansions—of varying degrees—to support steady-state utilization of liquefaction facilities. These will range from 50 to 100 miles for pipeline header systems in the U.S. Gulf Coast to transport NG from existing pipeline systems to the LNG terminal facilities. New pipeline capacity will also be required in New England, parts of the Southeast, and Florida to support power-sector demand for gas.

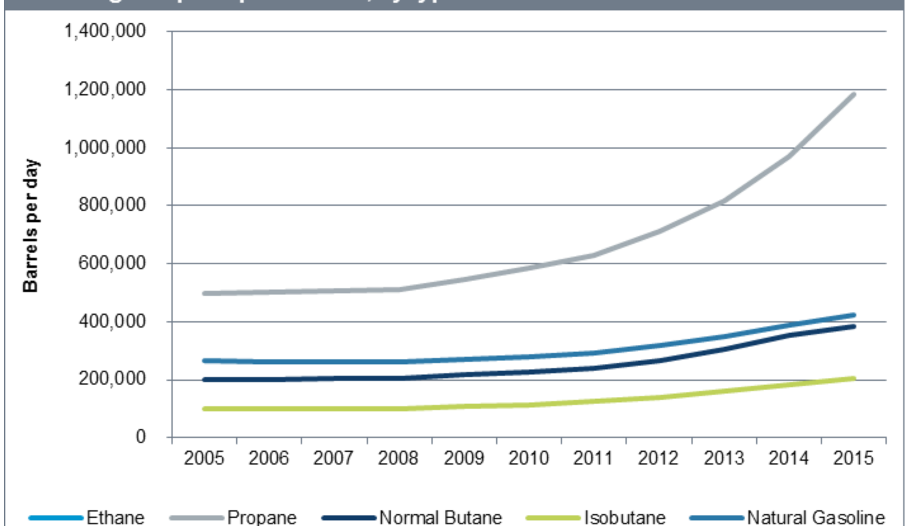
The need for new capacity would increase existing regional constraints and bottlenecks in the NG transmission network, with the extent of the effect varying by region. As we note above, the primary drivers of growth in demand for NG are increased use of it to generate electricity and higher production in manufacturing. The map above presenting demand growth for NG between 2014 and 2025 by Census region shows that absolute increases in demand will range between 0.7 Bcf/d and 2.6 Bcf/d in seven of the nine regions, with the largest increases of 5.4 Bcf/d and 16.3 Bcf/d occurring in the South Atlantic and West South Central Regions, respectively. As states and electric utilities proceed with planning to comply with the most recent set of CPP regulations, the demand for NG to generate electricity is likely to change. Our December 2015 analysis of the CPP finds that between 2022 and 2040 NG consumption for electric power generation under mass trading will average 4.6 Bcfd higher than under our reference case that assumes no CPP. The same analysis finds that average annual coal consumption for the electric power generation during the same period will be 15% lower than under the reference case.

Natural Gas Liquids and Petrochemicals

The production of NGLs has grown more than 60% from 2010 through 2015, and is forecast to grow another 42% through 2020. Newer current and forecast productive capacities and volumes of NGLs from the Eagle Ford shale, Utica shale, Marcellus shale, and tight oil plays and sub-plays in the Permian Basin present large potential opportunities for petrochemical feedstock consumption.

NGLs, such as ethane, propane, butane, isobutane, and pentane, are used in a variety of industries including cooking and heating for residential and commercial and petrochemical and plastic. Manufacturers that require large volumes of NGLs as a feedstock must be connected to a pipeline, as other modes of transportation are unable to provide the volumes they require.

Natural gas liquids production, by type

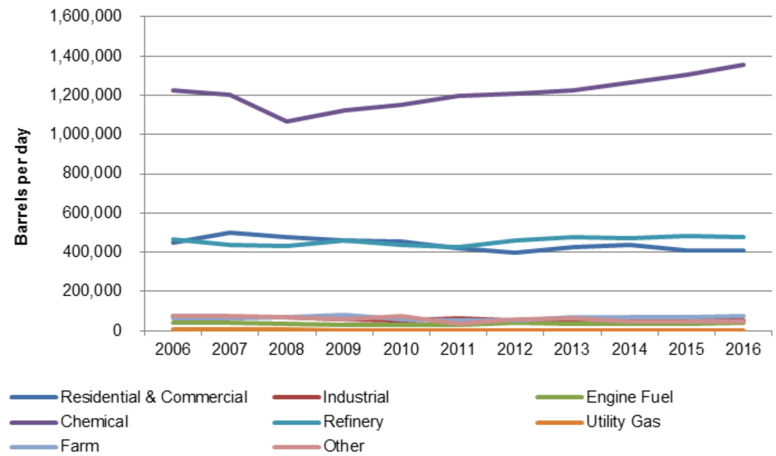


Source: IHS

Regions and manufacturers have experienced some limitation in their ability to make use of additional NGLs supply as the midstream processing and pipeline capacity has not kept up with resource development.

Integrating the refining capacity into the area to a petrochemical complex could improve the competitive position of an area's refiners relative to international refiners. Similarly, the added flexibility and markets the U.S. Gulf Coast refiners enjoy because of the local petrochemical complexes give them an operational and cost advantage over refiners that do not have petrochemical complex access. As midstream pipeline capacity expands to regions with insufficient or no current access to NGLs, opportunities will expand for NGL processing, and most especially, for industries that require large volumes of forward-linkage products, such as manufacturers that use NGLs as their raw material.

Base demand for natural gas liquids, by industry



Source: IHS

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An example of midstream capacity challenges

The increase in NGL supply in the Marcellus region has led Sunoco Logistics to develop the Mariner East system that will deliver NGLs via pipeline to its Marcus Hook Industrial Complex in Delaware County, Pennsylvania; the first phase started operating in December 2014. The availability of NGLs will be a key factor in creating an integrated petrochemical complex in the Philadelphia market. If petrochemical capacity can be built, additional opportunities could be realized through the integration with surrounding refineries and into the local economy. In 2012, there was some concern of potentially 'stranded' NG in Marcellus due to the lack of takeaway capacity which would have created a supply of discounted gas that could have been used in gas-to-liquid (GTL) options. However, the development of GTL options depends upon the relative competitiveness of pricing between oil and NG, and the cost of converting NG into petroleum products. Given current oil market pricing, the pricing differential between the two resources is too small to justify conversion costs. Additionally, the lead time required for the construction of the Mariner East 2 pipeline, which would carry NGLs, specifically propane, from Marcellus to the Philadelphia area, also limits the speed with which manufacturers can take advantage of the large supply availability.

The completed Mariner East 1 pipeline has the capacity to deliver 70,000 barrels per day of ethane and propane to the MHIC. The proposed Mariner East 2 pipeline project consists of two new pipelines, the first phase of which would have a capacity of 275,000 b/d of NGLs such as propane, butane and ethane. When complete, the entire Mariner East pipeline system would have a capacity of between 350,000 and 750,000 bpd. The Marcellus and Utica supply potential for ethane as a petrochemical feedstock for the manufacturing of ethylene could be as much as 1.1 million barrels per day, assuming 80 percent of the ethane produced with NG is extracted. Ethane crackers produce ethylene, a basic chemical commodity that is a major building block used widely in the overall petrochemical value chain. Ethylene is the root chemical for many varieties of plastics, resins, adhesives, synthetic products,[28] and also used in solvents, urethanes, and pharmaceuticals. In March 2016, the first vessel carrying an export shipment of ethane was loaded at the Marcus Hook Industrial Complex bound for a petrochemical plant in Norway.

[28] http://www.alleghenyfront.org/story/frequently-asked-questions-about-ethane-crackers.

CHAPTER THREE: NATURAL GAS PIPELINE CONSTRUCTION & OPERATION COSTS

Backward Linkages

The economic sectors that provide the goods and services used in the construction and operation of NG pipelines are referred to, in this report, as backward linkages. The backward linkages consist of the economic sectors that provide intermediate inputs required to construct the pipelines that deliver NG to end users, such as commercial and industrial businesses, transportation, electric-generating plants that use it as a fuel, and residential customers. Pipeline construction generates increases in economic activity when inputs (e.g., steel pipe, coatings, construction equipment, compressors, motors, gauges and instruments, sand and gravel, engineering and design services, etc.) are purchased from suppliers, defined as the indirect impacts, and through the spending of disposable income by the construction workers. The total economic impacts generated in a regional economy when a NG pipeline is built or expanded will depend on the mix of intermediate inputs required and the extent to which they can be obtained from within the region as opposed to from suppliers in distant locations. The purposes of this section are to describe the types and shares of goods and services used in constructing and operating NG pipelines and to present unit capital cost estimates (i.e., dollars per mile) for typical pipelines to provide an estimate of the level of direct spending that can occur in regional economies when they are installed.

Capital expenditures for constructing, expanding, and repurposing existing NG pipelines have had a significant contribution to the U.S. economy since the expansion of unconventional oil and gas technology. In this section, we will describe the components of pipeline construction and operations and their respective costs. In Chapter Five, we will measure their economic impacts of constructing and operating NG transmission lines in the United States

Capital expenditures for constructing new, and expanding or repurposing existing, NG pipelines, and related infrastructure, such as compressor and pump stations, have had a significant impact on the U.S. economy. The rapid growth in the supply of affordable domestically produced NG resulting from the rise of the unconventional energy sector has greatly increased the demand for new NG pipelines and related infrastructure and, by extension, for the goods and services they require, especially for the capital equipment from the manufacturing sector. In this section, we will describe the cost components of pipeline construction and operation and also present unit capital costs (i.e., dollars per mile) for typical pipelines. Capital and O&M cost estimates are presented for typical diameters of gathering, transmission, and distribution NG pipelines. Both the capital and annual O&M costs apply only to new 2015 pipeline construction.

The construction and operating costs for NG pipelines will vary based on a number of factors that affect the design of the pipeline, including:

- Nominal diameter.
- Length.
- Function (e.g., gathering, transmission or distribution).
- Volumetric flow.
- Pressure.
- Number and spacing of compressor or booster stations.
- Physical and environmental conditions along a right of way that affect costs, such as topography, weather, soil and geologic conditions, types of habitat and adjacent land uses, number of crossings required for rivers, highways, rail, etc.
- Costs for obtaining permits, engineering design fees, insurance, and other services.
- Cost of acquiring rights of way.

The IHS approach for estimating pipeline capital and operating costs included several tasks summarized below. IHS analyzed data from the Pipeline and Hazardous Materials Safety Administration (PHMSA)[29] on the existing mileage of gathering and transmission lines by nominal diameter to determine the most frequent diameters. IHS utilized this information along with its industry and project-related experiences to identify and determine the diameter of typical distribution pipelines. IHS then selected two diameters for the three types of pipelines, resulting in six different cost scenarios. Current design and performance standards, such as pressure and capacity for typical pipelines, were applied by IHS. Once the design assumptions were finalized, IHS then used publically available pipeline cost information from historical and proposed NG pipeline projects along with its proprietary estimating tool, IHS QUE$TOR software, to produce a detailed breakdown of capital and operation costs for typical NG pipelines. Average price levels for United States were assumed. A description of QUE$TOR is provided at the end of this chapter. As a result, the capital and operating costs presented below for typical NG pipelines are based on actual project information as compiled by IHS.

Natural Gas Pipeline Projects, Top 10

State	Project capacity (MMscf/d)	New pipe mileage	Proportion of new mileage	Proportion of capacity
PA	21,605	10,268	30%	21%
OH	14,277	9,427	27%	14%
WV	4,315	2,726	8%	4%
IN	1,210	2,050	6%	1%
KY	1,294	1,962	6%	1%
AL	7,947	1,717	5%	8%
WY	3,773	1,114	3%	4%
TX	12,745	1,056	3%	12%
NJ	3,406	697	2%	3%
ND	693	568	2%	1%

Source: IHS Energy, 2015.

Notes: Rankings based on mileage, forecasted in-service dates range from 2010 to 2018.

Length of Onshore Natural Gas Transmission and Gathering Pipelines Lines by Diameter, 2014

Nominal Diameter	Transmission Lines Miles	Transmission Lines Share	Gathering Lines Miles	Gathering Lines Share
4" or less	21,715	7.3%	2,114	18.6%
6"	21,963	7.4%	1,292	11.3%
8"	24,968	8.4%	1,382	12.1%
10"	16,443	5.5%	963	8.5%
12"	27,586	9.3%	963	8.5%
14"	2,395	0.8%	131	1.1%
16"	24,175	8.1%	575	5.0%
18"	4,824	1.6%	46	0.4%
20"	25,720	8.6%	306	2.7%
22"	4,589	1.5%	28	0.2%
24"	29,787	10.0%	501	4.4%
26"	13,497	4.5%	23	0.2%
28"	149	0.0%	35	0.3%
30"	42,437	14.3%	27	0.2%
32"	19	0.0%	-	0.0%
34"	1,913	0.6%	54	0.5%
36"	25,639	8.6%	67	0.6%
38"	0	0.0%	5	0.0%
40" and above	9,521	3.2%	2,861	25.1%
Not Classified	460	0.2%	19	0.2%
Total	**297,800**		**11,390**	

Note 1: transmission lines include both interstate and intrastate lines

Note 2: gathering lines include both type A and type B

Source: US Department of Transportation, Pipeline And Hazardous Materials and Safety Administration, June 2015 http://phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print

As described in Chapter Two, the most recent pipeline developments have occurred as a result of new unconventional shale production in the Marcellus and Utica plays. Pennsylvania, Ohio, and West Virginia have had the greatest number of new NG pipeline mileages proposed and in the process of development since 2010. Unconventional oil activity in North Dakota has also triggered the need for pipeline infrastructure in North Dakota and Wyoming. Portions of the South, such as Texas, Kentucky, and Alabama, continue to experience growth in pipeline demand.

Capital and operation costs are fairly standard across regions, but can vary somewhat based on conditions along the right of way. For example, in mountainous regions or those with harsh climates, costs for booster stations are likely to be higher to account for additional pressure requirements. Similarly, building through densely populated regions will result in additional costs for crossings of linear transportation infrastructure, such highways, railroads, and other pipelines.

[29] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, August 2015, Distribution, Transmission and Gathering, LNG, and Liquid Annual Data.
http://phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print.

The costs for capital equipment used in pipelines, such as steel pipe, coatings, equipment, pumps, etc., will be very similar across the United States for most projects at the point of production (i.e., there may be only a small number of manufacturers and locations where the capital equipment is made) but the delivered costs will vary based on the distance to the construction site and the transport mode used to ship the input. Companies that design and build NG and oil pipelines usually have the experience and capability to work under local construction regulations and labor laws and can smoothly work with the applicable government agencies and labor organizations. These companies provide planning, engineering, construction, and project management services, utilizing their fleets of specialty construction equipment on country-wide basis. Thus, some capital goods and construction services are "imported" into a region, especially if the project is located in a remote, rural area, which reduces the overall local economic benefits that new pipeline construction provides.

Wage Levels in Oil and Natural Gas Pipeline Construction Occupations

State	Average Annual Wage in 2014	Index (US = 1.00)
Arizona	$ 48,411	0.97
Colorado	$ 52,552	1.05
Massachusetts	$ 61,032	1.22
Michigan	$ 45,340	0.91
Virginia	$ 47,189	0.95
US	$ 49,892	1.00

Note: w age levels w ere calculated as w eighted averages using employment in occupational category

Source: Bureau of Labor Statistics, 2015, Occupational Employment Statistics (OES) for the 2014

One of the largest potential variations in construction costs for NG pipelines comes from labor costs, which, as shown in the accompanying table, vary substantially by state. Companies that provide specialized pipeline construction services will hire local workers in the construction trade occupations if they are available and are often required to first hire them from the local union. In North Dakota's Bakken play, demand for pipeline construction rose rapidly and due to insufficient quantities of locally skilled labor, many skilled workers were brought to the region as temporary labor. In Pennsylvania's Marcellus play, the local supply of skilled labor was larger, and fewer temporary workers were required, but even there, specialized workers, such as foremen with pipeline construction expertise, were imported from outside the region.

Construction and Operating Costs for Typical Natural Gas Pipelines

As noted above, IHS identified a variety of typical pipeline characteristics using current and historical pipeline construction trends and national statistics on pipeline characteristics from PHMSA. A diameter-inch range of pipeline costs were developed for two diameters for each pipeline type to provide high and low cost estimates, which were expressed on a unit basis or the cost per mile. The construction costs presented below do not include the cost of acquiring rights of way, as it is highly project specific.

Natural Gas Gathering Pipelines

Based on the PHMSA database, there were 11,390 miles of NG gathering pipelines in 2014. Gathering pipelines are located in oil and gas fields and, therefore, are concentrated in the major oil and NG–producing states.

Capital costs for NG gathering lines assumed a pressure of 200 pounds per square inch gauge (psig), capacity of 25 MMCF/D, and a length of 25 miles in level terrain. These assumptions resulted in a total cost per mile ranging from $1.4 million to $1.8 million, respectively. Capital costs for gathering pipelines account for 39 percent and 46 percent respectively of total costs for the two sizes of gathering pipes. This averages to approximately $560,000 and $828,000, respectively, per mile of gathering pipeline mile. The construction costs for labor (i.e., wages and fringe benefits) comprise 23% and 21% respectively of the total cost for the two diameters of gathering pipes.

Unit O&M costs for the two sizes of newly constructed gathering pipelines are $154,000/mile and $163,000/mile annually. The largest shares of costs are for operations labor and logistic and consumables, which accounted for about 80% of operations costs. Gathering pipeline systems have the highest levels of operations labor of the three analyzed pipeline systems. The unit O&M cost declines steadily after the first few years of operation as the new lines are integrated into existing systems.

Natural Gas Transmission Pipelines

Based on the PHMSA database, there were 297,800 miles of on-shore NG gathering pipelines in 2014. NG transmission pipelines convey pipeline-ready NG from production locations to demanding regions. As described in Chapter One, they flow along general transportation corridors and through switching hubs. Costs for transmission lines assumed a pressure of

900 psig, a capacity of 700 MM/d, and a length of 200 miles, resulting in a total unit construction cost per mile of $1.9 million and $3.6 million, respectively, for the two diameters.

Capital costs, which include equipment and materials, account for 44.3% and 56.1% of the total cost of constructing the two sizes of pipeline, equivalent to approximately $860,000 and over $2 million of capital expenses per transmission pipeline mile. The construction cost figures for labor (i.e., wages and fringe benefits) comprise 27% and 21.9% respectively, of the total cost for the 12-inch and 30-inch lines.

Operations costs for newly constructed transmission pipelines ranged from $86,000 to $116,000 per pipeline mile. Given the cumulative distance and activities needed to operate and maintain networks of transmission pipelines, the bulk of costs are composed of operations labor, logistics and consumables, and insurance expenses. Operation labor costs account for a smaller portion of costs than for gathering lines, as do inspection and maintenance costs. Insurance costs and logistics and consumables are significantly higher as compared to gathering lines, the potential risks involved when moving large volumes of NG through long distances.

Natural Gas Distribution Pipelines

In 2014, there was a total of 1,264,387 miles of NG distribution lines in the United States. Natural gas distribution pipelines connect transmission lines to the consumer through an intricate series of small lower-pressure lines. As described in Chapter One, distribution pipelines systems are typically built and operated by local gas distribution utilities.

Costs for distribution pipelines were estimated for 4-inch and 8-inch diameters, assumed a pressure of 100 psig, a capacity of 10 MMcf/d, and a distance of 5 miles. The assumptions are for newer projects, and they resulted in total construction costs per mile of $1.4 million and $1.6 for the two sizes. Capital costs for distribution pipelines, which include equipment and materials, account for just under half of the total cost of constructing the pipeline. This averages to approximately $141,000 to $262,000 of capital expenses per distribution pipeline mile. Capital costs for distribution pipelines account for 10% and 16.7% of the total cost, much lower than the shares for the transmission and gathering lines, and equivalent to $141,000 and $262,000, respectively, per pipeline mile.

Annual O&M unit costs for newly constructed distribution lines were $90,000 and $93,000 per pipeline mile for the two sizes. The largest shares of costs were for operations labor and logistic and consumables, which accounted for about 70% of operations costs. The annual O&M costs only apply to new construction; over time, as new distribution lines become fully integrated into the existing pipeline distribution systems, and as network and economies of scale effects are captured, annual unit O&M costs for distribution lines will decline.

IHS QUE$TOR Model

Over the years, IHS has developed and continuously refines a software tool called QUE$TOR that is used for analyzing the costs of new oil and gas projects. It was used to determine the NG pipeline construction and operating costs contained in the tables above. The program has recently undergone a complete software rewrite, retaining all the former capabilities but adding a significant increase in speed and functionality. QUE$TOR™ is a project modeling, evaluation and decision-support system for global application in the oil and gas industry. The program enables users to estimate and run sensitivities on the CAPEX and OPEX of alternative field development plans. Using detailed technical algorithms and regional databases, QUE$TOR™ provides a consistent methodology for generating cost estimates and optimizing development plans. At the heart of QUE$TOR™ are cost and technical databases (user accessible and customizable) covering all producing regions of the world. These databases are updated every six months with costs gathered from actual projects, fabricators, vendors, and service companies. Using primary input data (recoverable reserves, reservoir depth, and water depth), a production profile is generated, the development concept is defined, and design flowrates calculated. The program then sizes facilities, pipelines, and substructures, and calculates capital costs, drilling costs, operating costs, and abandonment costs. These costs are then scheduled to provide project cash flows. The regional databases are populated with unit rates for equipment items, materials, fabrication installation, hookup and commissioning, and other project costs. QUE$TOR™ has been benchmarked against actual project costs and is continuously maintained to reflect the latest changes in technology

CHAPTER FOUR: NATURAL GAS PIPELINE, MANUFACTURERS, AND THEIR FORWARD LINKAGES

Natural Gas–Intensive Sectors

The manufacturing sector uses NG primarily as a fuel and feedstock and to support activities performed during the production of manufactured goods. As described in a recent IHS report[30] the manufacturing sector uses NG as a fuel in the following specific ways:

- Direct process uses: drying, melting, process cooling and refrigeration, and driving machines
- Direct non-process uses: heating facilities, ventilation and air conditioning, lighting
- Indirect uses: as a boiler fuel for producing steam and generating electricity

Fuel use accounts for approximately 91% of total NG used by the manufacturing sector with the remaining 9% used as a feedstock, concentrated primarily in three sectors: petroleum and coal products (i.e., refining), chemicals, and primary metals. The first two sectors accounted for 48.4% and 44.2% of total feedstock use of NG by the U.S. manufacturing sector in 2010.[31]

To identify the manufacturing subsectors that are most dependent on, and thus would benefit directly from, increased supplies of NG in a regional economy, we updated our March 2014 study on industrial gas demand by analyzing the use of NG by manufacturing subsectors at the 3-digit NAICS level. The purpose of this analysis was to identify subsectors that were both:

- Intensive users, defined as consuming high amounts of NG in billions of cubic feet per $1 billion of real, or
- Large aggregate users of NG.

The primary source of NG consumption information by manufacturing subsectors was the U.S. Department of Energy's Manufacturing Energy Consumption Study (MECS).[32] The MECS presents the 2010 consumption of nine types of energy by manufacturing subsectors, generally at the 3-digit NAICS level, but with some selected four-digit sectors also included. We combined this information with IHS estimates of real output by manufacturing subsector to derive estimates of NG use intensity. We also estimated the intensity of electric power use by subsector to capture the effect of lower prices of NG as a fuel used to generate electric power either purchased from utilities or generated on site. The manufacturing sector accounted for about 23% of total U.S. consumption of NG in 2010.[33]

Manufacturers generate substantial amounts of electric power on site, so they benefit indirectly from lower NG prices. According to the EIA[34] in 2014 the industrial sector generated just over 144 million megawatt hours of electric power on site, 60% of which was produced by burning NG.

The following table presents the results of the analysis. A total of nine three-digit sectors are identified as intensive NG–using sectors; they are also, for the most part, the largest absolute consumer of NG. The nine NG–intensive sectors accounted for 91.3% of total NG used by the manufacturing sector in 2010. At the time this report was performed (late 2015), the 2010 MECS was the most recent year for which data was available.

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[30] IHS CERA, March 2014, U.S. Industrial Gas Demand – The Striking Turnaround Progresses.

[31] U.S. Department of Energy, Energy Information Administration, 2010, Manufacturing Energy Consumption Survey, Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel).
http://www.eia.gov/consumption/manufacturing/data/2010/.

[32] U.S. Department of Energy, Energy Information Administration, 2010, Manufacturing Energy Consumption Survey, Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel).
http://www.eia.gov/consumption/manufacturing/data/2010/.

[33] U.S. Department of Energy, Energy Information Administration, 2010, Annual Energy Review 2010.
http://www.eia.gov/totalenergy/data/annual/archive/038410.pdf.

[34] U.S. Department of Energy, Energy Information Administration, October 2015, Electric Power Monthly.
http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01.

Natural Gas and Electricity Use by Manufacturing Sub-sectors in 2010							
Manufacturing Sub-sector	**Natural gas consmption (billions of cubic feet)**	**NG Intensity: billions of cubic feet/$1 billion in constant 2010 output**	**Intensity rank**	**Net electricity use (million kWh)**	**Electricity use intensity: million kWh/$1 billion in constant 2010 output**	**Intensity rank**
311 Food	**567**	**0.94**	**7**	**75,407**	**124.74**	**9**
312 Beverage and Tobacco Products	37	0.21	**16**	8,449	48.06	**19**
313 Textile Mills	**31**	**1.08**	**6**	**13,240**	**459.99**	**1**
314 Textile Product Mills	9	0.42	**11**	2,458	114.15	**11**
315 Apparel	2	0.16	**18**	1,069	83.44	**15**
316 Leather and Allied Products	1	0.11	**19**	243	26.14	**21**
321 Wood Products	**34**	**0.47**	**10**	**15,323**	**210.26**	**6**
322 Paper	**390**	**2.40**	**3**	**60,497**	**372.13**	**3**
323 Printing and Related Support	33	0.37	**12**	13,704	154.02	**8**
324 Petroleum and Coal Products	**892**	**1.93**	**5**	**47,014**	**101.70**	**12**
325 Chemicals	**2,192**	**3.41**	**1**	**131,932**	**205.52**	**7**
325 Plastics and Rubber Products	101	0.52	**9**	45,797	234.20	**5**
327 Nonmetallic Mineral Products	**266**	**2.65**	**2**	**32,576**	**324.68**	**4**
331 Primary Metals	**550**	**1.99**	**4**	**117,284**	**423.51**	**2**
332 Fabricated Metal Products	**159**	**0.52**	**8**	**37,206**	**121.61**	**10**
333 Machinery	70	0.21	**15**	20,386	61.34	**17**
334 Computer and Electronic Products	41	0.09	**21**	29,503	66.00	**16**
335 Electrical Equip., Appliances, and Components	35	0.32	**13**	10,689	99.17	**13**
336 Transportation Equipment	125	0.16	**17**	38,832	50.52	**18**
337 Furniture and Related Products	13	0.23	**14**	4,960	88.89	**14**
339 Miscellaneous	16	0.10	**20**	7,598	47.01	**20**
Durables	1,309	0.49		314,357	117.26	
Non-durables	4,255	1.77		399,810	166.31	
Total	5,564	1.09		714,167	140.45	

Sectors in grey and bold are natural gas intensive sectors

Soources: IHS CERA, March 2014, US Industrial Gas Demand – the Striking Turnaround ProgressesIHS, 2015. US Industry Service, Output by Manufacuring Sector. United States Deparment of Energy, Energy Information Administration, 2010, Manufacturing Energy Consumption Survey, Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel) http://w w w .eia.gov/consumption/manufacturing/data/2010/.

The table shows that the nine NG–intensive sectors are generally the largest, and most intensive, users of electricity; they used 74.3% of all electricity consumed by the U.S. manufacturing sector in 2010. Because the NG–intensive sectors both consume a lot of electricity and use it intensively, it means that lower NG prices will have two beneficial effects on them: 1) a direct reduction in the costs of purchasing and using NG, especially in the three sectors that use it as a feedstock and 2) an indirect reduction in costs through the use of cheaper electricity.

In addition to the long-term effect of the CPP in increasing the use of NG as a fuel to generate electricity, the EPA's November 2015 final revisions to "National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers, and Process Heaters," known as Boiler MACT (for maximum achievable control technology) also provides an incentive for manufacturing establishments to use increasing amounts of NG as a fuel for boilers and process heaters. Boilers produce steam that is used in production processes; to directly generate electricity on site; in cogeneration applications, such as combined heat and power (CHP) facilities that produce both steam and electricity; and to heat commercial and institutional buildings. Process heaters heat intermediate inputs used during manufacturing production.

Electric Use by the Manufacturing Sector

The immediately preceding table presents the total amount of electric power used by the 3-digit manufacturing subsectors in 2010, along with the intensity of use in millions of k per $1 billion in real 2010 output. For the most part, the largest and most intensive uses of NG are also the largest and most intensive users of electric power, with the exception being the petroleum and coal sector, whose use intensity for electric power is below average. The consumption of electric power is more evenly distributed across the manufacturing sector than NG, with durable and non-durable manufacturing accounting for 44% and 56% respectively of total electricity use. The intensity of electricity use in the non-durables is 41.8% higher than in the durable sectors.

States with Clusters of Natural Gas-Intensive Sectors

Based on the nine NG intensive sectors identified above, IHS used our propriety Business Markets Insights (BMI) database to identify states that have above-average concentrations of economic activity (e.g., employment and output) in these sectors. The BMI database allows us to analyze, at the 6-digit NAICS level detail, the economies of all U.S. states, metropolitan statistical areas, and counties.

The next table below presents estimates of economic activity—employment and output—in the NG–intensive sectors by state in 2015, excluding the District of Columbia. IHS uses output when measuring the level of economic activity within the NG intensive sectors, in addition to showing the total value of production, as it is also a good indicator of both demand for inputs through the backward linkages and demand for output through the forward linkages. Because productivity (i.e., output per worker) varies so widely across the manufacturing sector, including within the nine NG–intensive sectors, employment figures can be somewhat misleading, as sectors like petroleum and coke products have very high output per worker.

The five states with highest absolute levels of output in the NG–intensive sectors are Texas, California, Illinois, Ohio, and Pennsylvania. Another group of five states—Texas, California, Louisiana, Illinois, and Pennsylvania—all have very large petroleum refining sectors; these five plus New Jersey and Ohio also have high levels of activity in chemical manufacturing.

The five states with the highest output location quotients (LQs) in the NG–intensive sectors are Louisiana, Indiana, Arkansas, Iowa, and Wisconsin. These five states have smaller economies that specialize in individual sectors such as food (e.g., Arkansas, Iowa, and Wisconsin), petroleum refining, and chemicals (e.g., Louisiana), paper (e.g., Arkansas, Louisiana, and Wisconsin), and primary and fabricated metals (e.g., Indiana). The five states with the highest output LQs also tend to have the highest employment LQs, along with Alabama, Ohio, and Nebraska. Louisiana's employment LQ in the NG–intensive sector is relatively low, as much of its output occurs in petroleum refining, a capital-intensive sector with a very high output/employment ratio.

Twenty-nine states had output LQs greater than 1.0 for the NG–intensive sector and accounted for 68.5% of total U.S. output in these sectors in 2015. Similarly, 27 states had employment LQs greater than 1.0 higher for the entire NG–intensive sector and accounted for 61.7% of total U.S. employment that same year.

According to the EIA,[35] the top NG–producing states in 2014, in descending order, were Texas, Pennsylvania, Alaska, Oklahoma, Wyoming, Louisiana, Colorado, New Mexico, Arkansas, and West Virginia, all with annual gross withdrawals of at least 1,000,000 MMcf. Together these 10 states accounted for 87.4 of total U.S. NG production that year. Three states—Alaska, Colorado, and New Mexico—had output LQs for the entire NG sector of less than 1.0, suggesting that a high proportion of the NG they produce is exported to other states instead of being used within them as an intermediate input by other manufacturing subsectors.

[35] EIA, 2015, Natural Gas Gross Withdrawals. http://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm

Employment and Output in Natural Gas Intensive Sectors by State in 2015

State	# of Jobs	% of Mfg. Sector	Employ. LQ	Output (millions of $)	% of Mfg. Sector	Output LQ
Alabama	130,814	50.4%	1.69	$62,260.2	51.7%	1.56
Alaska	13,156	87.3%	0.99	$5,400.7	92.7%	0.67
Arizona	51,911	33.0%	0.51	$25,749.3	34.9%	0.46
Arkansas	95,475	61.0%	1.96	$38,659.7	70.8%	1.72
California	468,015	37.3%	0.75	$381,001.8	53.6%	0.90
Colorado	60,127	42.8%	0.61	$34,902.2	51.0%	0.59
Connecticut	62,806	38.3%	0.96	$36,375.1	45.1%	0.79
Delaware	17,035	67.0%	0.98	$10,989.1	79.9%	1.08
Florida	131,591	39.7%	0.42	$56,682.8	46.6%	0.35
Georgia	185,773	50.7%	1.13	$78,825.6	56.2%	0.84
Hawaii	8,359	60.6%	0.34	$4,125.3	79.6%	0.36
Idaho	34,319	56.7%	1.27	$16,218.1	64.7%	1.27
Illinois	278,815	48.7%	1.21	$179,827.0	57.8%	1.20
Indiana	212,295	40.8%	1.78	$117,229.9	47.1%	1.82
Iowa	107,212	49.6%	1.66	$53,057.7	57.7%	1.68
Kansas	68,535	42.5%	1.21	$39,572.3	51.1%	1.34
Kentucky	98,764	42.4%	1.30	$50,371.0	39.9%	1.32
Louisiana	98,489	66.7%	1.25	$145,509.2	88.7%	2.92
Maine	26,662	52.4%	1.10	$10,931.1	61.3%	1.00
Maryland	45,729	44.2%	0.45	$28,932.6	55.4%	0.46
Massachusetts	99,478	40.0%	0.75	$61,624.5	49.0%	0.67
Michigan	201,883	35.1%	1.23	$107,521.4	30.0%	1.08
Minnesota	140,879	44.2%	1.25	$71,943.7	56.4%	1.12
Mississippi	60,389	42.4%	1.33	$27,983.9	50.7%	1.38
Missouri	120,445	46.7%	1.07	$55,108.6	50.6%	0.97
Montana	11,611	59.8%	0.61	$8,230.6	80.3%	0.96
Nebraska	57,050	58.3%	1.40	$23,426.8	66.7%	1.19
Nevada	18,205	43.0%	0.38	$7,486.8	51.1%	0.32
New Hampshire	26,143	39.2%	1.03	$10,635.4	42.7%	0.73
New Jersey	133,119	54.6%	0.86	$110,852.3	71.6%	1.04
New Mexico	12,819	47.8%	0.39	$9,317.2	66.4%	0.60
New York	194,483	43.7%	0.55	$96,016.3	54.9%	0.38
North Carolina	215,603	48.0%	1.30	$94,538.4	51.1%	1.09
North Dakota	11,622	46.2%	0.59	$6,240.1	58.2%	0.55
Ohio	312,061	45.7%	1.49	$159,625.4	50.1%	1.39
Oklahoma	65,993	46.0%	0.97	$37,026.8	58.2%	1.06
Oregon	87,829	48.2%	1.25	$38,397.0	52.4%	1.02
Pennsylvania	301,965	53.7%	1.33	$156,177.6	63.3%	1.22
Rhode Island	17,671	43.1%	0.95	$7,177.1	51.2%	0.74
South Carolina	114,981	49.2%	1.50	$52,735.2	51.3%	1.40
South Dakota	19,864	45.9%	1.11	$6,192.7	48.5%	0.80
Tennessee	145,166	44.3%	1.29	$75,693.4	47.2%	1.26
Texas	433,371	48.2%	0.93	$419,273.5	68.1%	1.34
Utah	53,411	43.0%	1.00	$29,230.5	58.7%	1.05
Vermont	14,316	44.5%	1.16	$5,845.7	53.8%	1.03
Virginia	100,670	43.1%	0.67	$45,200.5	48.5%	0.53
Washington	104,546	36.3%	0.85	$71,308.5	46.6%	0.87
Washington DC	331	40.5%	0.01	$355.0	55.7%	0.02
West Virginia	32,309	65.1%	1.05	$17,738.9	75.7%	1.32
Wisconsin	235,690	50.2%	2.04	$95,947.7	56.5%	1.68
Wyoming	6,634	67.7%	0.55	$9,917.4	89.9%	1.41

Source: IHS, 2015, Business Markets Insights database.

Note: location quotient values of 1.0 or higher are shaded grey

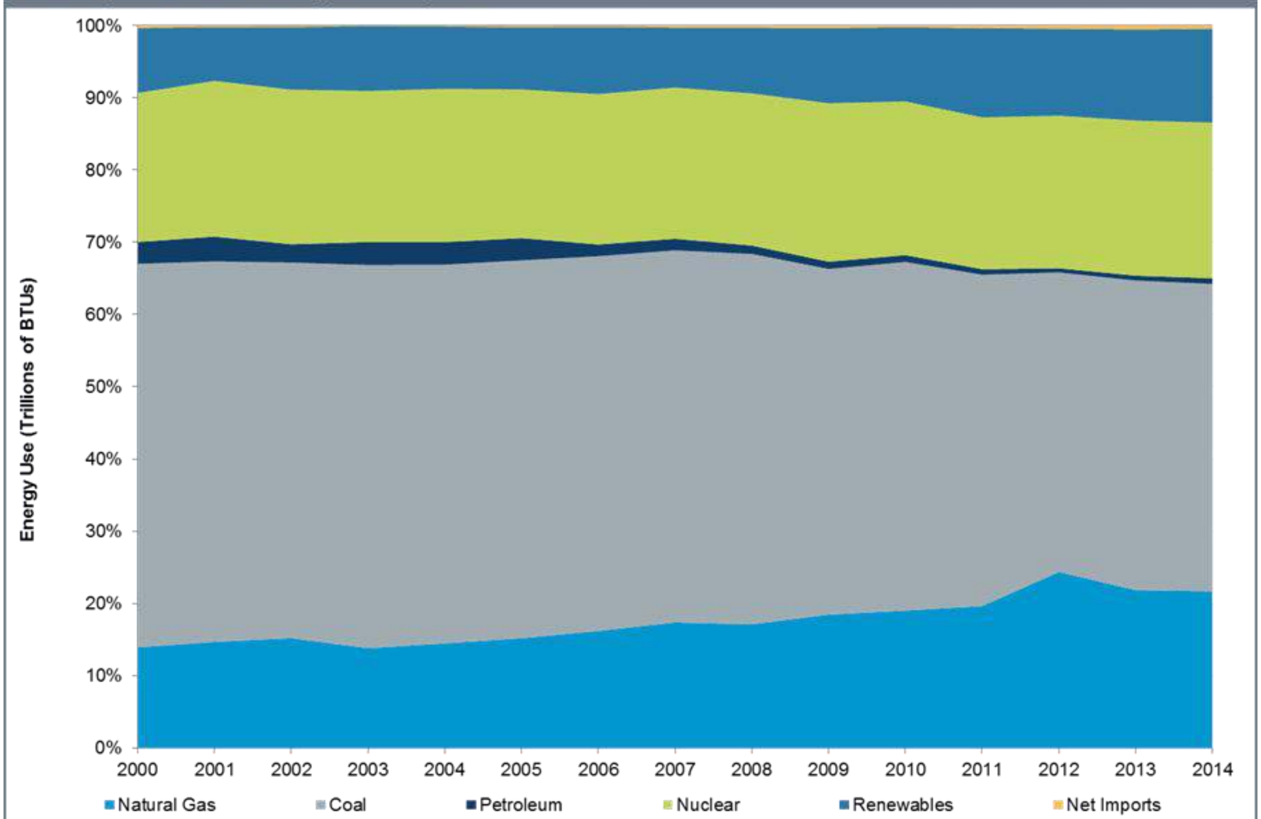
By contrast, there are a number of large states with high levels of output and employment in the–intensive sectors that produce little or no NG, showing they are dependent on the NG pipeline system to receive their inputs. The large, pipeline-dependent states include California, Illinois, Indiana, Michigan, New Jersey, Ohio, New York, and Wisconsin.

Finally, the NG–intensive sectors account for high shares of manufacturing economic activity in a number of smaller states including Alaska, Arkansas, Delaware, Louisiana, West Virginia, and Wyoming. These states have less diversity, with NG–intensive activity concentrated in few sectors, resulting in high LQs. By contrast, the NG–intensive sectors account for below-average shares of manufacturing activity in some large states with diverse manufacturing sectors including Arizona, California, Florida, Michigan, Virginia, and Washington. These larger states have higher concentrations of manufacturing activity in high-tech subsectors such as transportation equipment, computers and electronics, machinery, and electrical equipment.

Use of Natural Gas for Electric Energy Generation

The amount of NG being used as a fuel to generate electricity has been gradually increasing in recent years due in part to the decreasing price and increased supply of NG. Electric utilities have been increasingly turning to NG as a fuel source, especially for new electric-generating plants, such as combustion turbines and combined-cycle plants. The primary benefit to the manufacturing sector is that the increasing use of low-cost NG as a fuel will result in lower generation cost for electric power. Between 2007 and 2014, the amount of NG used in the generation of electricity rose at a CAGR of 2.6%, increasing by 19.4%. Over that same period, the total amount of energy used by electric power from all sources (e.g., fossil fuels, nuclear, renewables, and imports) fell by 4.4% at a CAGR of -0.6%. The significance of shifting electric power sources to this study is that the rising demand for the use of NG as a fuel in electric power generation will contribute to investment in new NG infrastructure, such as transmission lines, gas processing plants, and compressor stations.

Electric power section: Energy consumption



Source: Energy Information Administration, 2015, Table 2.6 Electric Power Sector Energy Consumption
http://www.eia.gov/beta/MER/?tbl=T02.06#/?f=M

Forward Linkages

The outputs from the NG–intensive sectors are used as inputs by other sectors of the economy in a variety of ways. These uses will be referred to as forward linkages and include:

- Intermediate inputs (e.g., goods and services sold to other sectors that are used in production processes to make other types of good and services, with no sales to final demand occurs).
- Sales to final demand (e.g., goods and services that are not used as intermediate inputs and no further processing of the output occur).

Types of final demand include:

- Personal consumption expenditures (e.g., purchases of refined products such as gasoline at filling stations or home heating oil).
- Gross private investment.
- Private inventory accumulation.
- Exports or imports.
- Government consumption and gross investment.

The forward linkage, or downstream manufacturing sectors, will potentially benefit from increases in the supply and/or reductions in the price of NG that occur when the construction of new, or the expansion of existing, NG pipelines occurs. The existing establishments in the nine NG–intensive sectors in a regional economy could potentially decide to expand, which would, in turn, increase the supplies of, or reduce the prices of, their outputs that are used as intermediate inputs by downstream sectors. IHS identified forward linkages in the manufacturing sector by analyzing the detailed input/output tables for the U.S. economy, and by using the results of other recent energy studies we have performed.

Final demand sectors, such as personal consumption, exports, and imports, are also affected by changes in NG production and pricing, but indirectly, through industry production changes captured by intermediate inputs shifts to industry production. For example, personal consumption impacts, such as those resulting from lower electricity prices, are captured first by the feedstock inputs to the electricity industry and flow-through to all industries before resulting in lower prices for the consumer. U.S. industries' substitution of domestic NG over higher-cost NG imports or higher-priced NG–derived goods from abroad (such as manufactured chemicals) flow-through intermediate inputs, either adjusting production processes toward less-expensive items or as increases in value-add or outputs. We, therefore, focus on the intermediate inputs in this section, but describe indirect final demand results in our macroeconomic analysis later on.

The accompanying table shows the percentage distribution of output sold as an intermediate input by a NG–intensive sector (i.e., the columns). The purchasing manufacturing subsectors are shown at the 3-digit NAICS code level. For example, 25.1% of the total output sold as an intermediate input by the primary metals sector was purchased by fabricate metals, while 11.7% went to machinery. The intermediate inputs used by industries varies widely across the nine NG–intensive sectors, ranging from lows of 13.7% in the petroleum and coal sector (i.e., a high share of refined products are sold to non-manufacturing sectors such as utilities, transportation, and construction) up to 70.3% in chemicals and 94.6% for primary metals (most primary metal is then fabricated to make other products). Natural gas–intensive sectors with high shares of their output sold as an intermediate input to other manufacturing sectors are those that are potentially more likely to generate increased downstream economic development within a regional economy if their production increases, and prices fall, due to the completion of a new NG pipeline.

Use of output from the natural gas intensive sectors as an intermediate input by other sectors										
NAICs Code	Description	311- Food	313- Textile Mills	321-Wood Products	322- Paper	324- Petroleum and Coal	325- Chemicals	327- Non Metallic Minerals	331- Primary Metals	332- Fabricated Metals
	Manufacturing Sectors									
311	Food	44.0%	0.2%	0.1%	11.3%	0.6%	0.8%	0.8%	0.0%	2.3%
312	Beverage and Tobacco Product	4.0%	0.1%	0.2%	2.3%	0.1%	0.2%	2.8%	1.4%	1.6%
313	Textile Mills	0.0%	10.9%	0.0%	0.2%	0.0%	1.6%	0.1%	0.0%	0.1%
314	Textile Product Mills	0.0%	14.6%	0.1%	0.1%	0.0%	1.0%	0.0%	0.1%	0.1%
315	Apparel	0.0%	7.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
316	Leather and Allied Product	0.3%	0.6%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
321	Wood Product	0.0%	1.6%	20.0%	0.4%	0.2%	0.5%	1.0%	0.1%	1.0%
322	Paper	0.2%	5.1%	3.6%	26.2%	0.5%	1.9%	0.2%	0.1%	1.2%
323	Printing and Related Support Activities	0.3%	1.1%	0.0%	7.6%	0.5%	1.1%	0.0%	0.0%	0.5%
324	Petroleum and Coal Products	0.1%	0.1%	0.0%	0.2%	4.4%	1.8%	0.8%	0.1%	0.2%
325	Chemical	1.4%	0.0%	0.3%	3.9%	4.7%	40.9%	1.1%	0.1%	2.7%
326	Plastics and Rubber Products	0.0%	5.2%	1.3%	3.1%	0.3%	11.4%	1.2%	0.6%	2.0%
327	Nonmetallic Mineral Product	0.0%	0.8%	0.4%	1.2%	0.3%	0.9%	12.7%	0.4%	1.0%
331	Primary Metal	0.0%	0.0%	0.3%	1.0%	0.4%	0.4%	1.9%	24.7%	1.6%
332	Fabricated Metal Product	0.0%	0.0%	0.2%	1.5%	0.2%	1.5%	1.0%	25.1%	11.8%
333	Machinery	0.0%	2.0%	0.8%	1.5%	0.4%	0.9%	1.6%	11.5%	8.9%
334	Computer and Electronic Product	0.0%	0.1%	0.7%	1.2%	0.1%	1.3%	0.8%	3.4%	4.1%
335	Electrical Equip.& Appliances	0.0%	0.0%	0.3%	0.9%	0.3%	0.7%	1.2%	6.5%	2.9%
336	Transportation Equipment	0.0%	7.9%	2.9%	2.1%	0.2%	1.7%	4.5%	16.3%	13.6%
337	Furniture and Related Product	0.0%	7.8%	7.4%	0.9%	0.1%	0.4%	0.3%	1.3%	1.1%
339	Miscellaneous	0.0%	5.2%	1.0%	1.4%	0.1%	1.2%	0.5%	2.6%	1.4%
	Total share to manufacturing	**50.4%**	**70.8%**	**39.7%**	**67.3%**	**13.7%**	**70.1%**	**32.5%**	**94.4%**	**58.2%**
	Non-Manufacturing Sectors									
	Construction, NR, & Mining	8.7%	4.4%	41.7%	2.2%	17.8%	7.2%	52.8%	2.2%	24.8%
	Trade, Transportation & Utilities	0.3%	9.0%	4.3%	5.2%	33.5%	1.1%	1.0%	0.6%	3.3%
	Information	0.0%	0.4%	1.9%	2.8%	0.2%	0.3%	1.3%	0.2%	2.8%
	Financial Activities	0.0%	0.4%	3.7%	1.3%	1.3%	1.0%	0.3%	0.9%	0.6%
	Professional and Business Services	0.2%	1.0%	1.1%	4.2%	2.1%	3.4%	3.5%	1.0%	3.0%
	Education and Health Care Services	7.2%	3.7%	0.9%	4.5%	1.5%	10.0%	2.5%	0.2%	0.6%
	Leisure & Hospitality Services	22.6%	3.4%	3.2%	3.8%	1.5%	0.4%	3.3%	0.2%	2.4%
	Other Services	0.2%	1.7%	0.2%	0.5%	0.6%	0.8%	0.8%	0.1%	1.0%
	Government	10.3%	5.2%	3.4%	8.1%	27.7%	5.8%	2.1%	0.3%	3.2%
	Total share to non-Mfg. uses	**49.6%**	**29.2%**	**60.3%**	**32.7%**	**86.3%**	**29.9%**	**67.5%**	**5.6%**	**41.8%**

Note: The figures show the percent of the total output, commodity basis, produced by the natural gas intensive sectors (top of each column) that are purchased by the row industry as in intermediate input. For example, 11.4% of the output of chemicals sector (colum 8) is sold to the plastics and rubber sector as an intermediate input (row 15).

Source: Bureau of Economic Analysis, 2015, 2007 Benchmark Input-Output coefficients After Redefinitions

Macroeconomic Impacts of Lower Natural Gas Prices

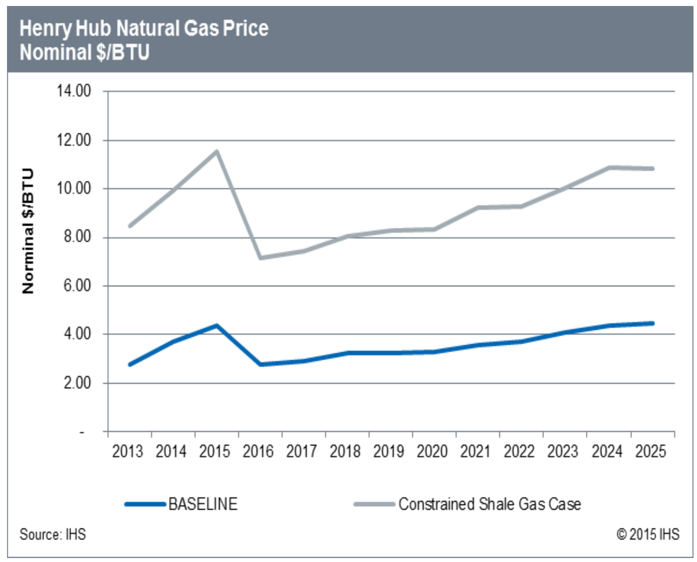
IHS estimated the macroeconomic impacts of lower NG prices on the U.S. economy, with a specific focus on the effects on the manufacturing sector. The wholesale and retail prices of NG in the United States have remained low, and even declined, in recent years due to the rapid increase in production from shale formations, such as the Marcellus play in western Pennsylvania and the Eagle Ford play in Texas.

In addition to the direct, indirect, and induced economic contributions of investing in and operation of new NG pipelines built to carry the increased supplies to the market, the surge in domestic production, due in large part to the increased supplies from shale gas production, has led to NG and, subsequently, electricity prices that are significantly lower than they otherwise would have been. The result has been low and stable NG prices that have had a positive macroeconomic impact across all sectors of the economy, as costs of intermediate inputs have been lowered. We find this effect has been especially positive in the NG–intensive sectors identified above and in other manufacturing subsectors that use large amounts of electricity.

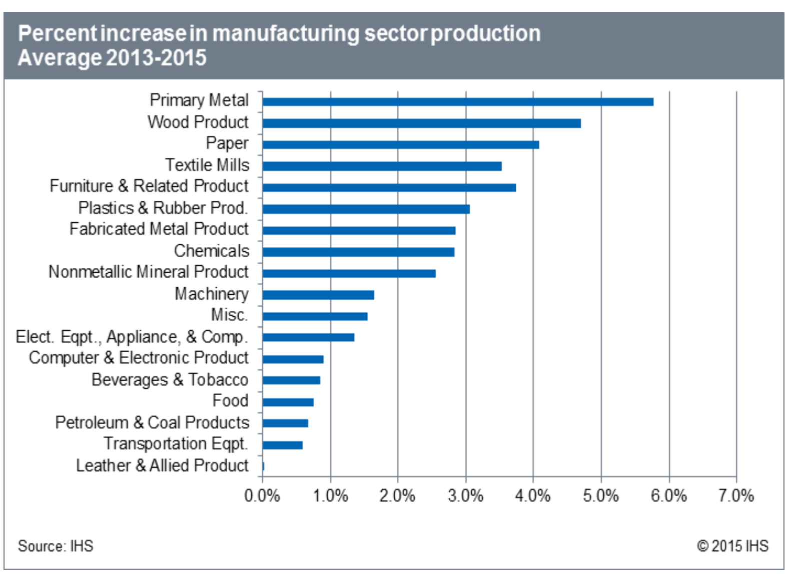
In this section, IHS estimates the economic effects of lower prices for NG using the IHS U.S. Macroeconomic Model.

The supply of NG at the wellhead in the United States has grown substantially in recent years, from 48.2 Bcfd in 2005 to an estimated 74.3 Bcfd in 2015, an average annual growth rate of 4.4%. The significant increase in production volumes has contributed to a sharp drop in prices, with the average annual Henry Hub price, in nominal dollars, falling from \$8.80/MMBtu in 2005 to an estimated \$2.60/MMBtu in 2015, a decline of 238.2%. According to IHS's December 2015 Monthly Gas Briefing Outlook, NG prices are expected to decline slightly in 2016 to \$2.51/MMBtu before rising steadily thereafter, reaching \$3.36/MMBTU by 2020.

To capture the macroeconomic contributions of NG pricing decreases, we compared the price of NG to the prices of alternative competing energy sources and feedstock. We performed an update to a previous counterfactual analysis performed by IHS in 2011 for America's Natural Gas Alliance (ANGA). Consistent with the previous study, we also considered the long-term expectation of future lower NG prices, where manufacturers and other industries will transition production processes to incorporate additional use of NG as a fuel and/or feedstock. Until recently, repeated and persistent historical price volatility of domestic NG resources had resulted in import dependency from Middle Eastern and Asian resources, particularly for the chemical manufacturing industry. We incorporated the declining reliance of the U.S. economy on NG imports that will result from the decrease of pricing and increased availability of domestic NG sources.



The IHS macroeconomic forecast is updated monthly and has already incorporated the short- and longer-term effects of NG price and availability on the U.S. and global economy. As a result of this methodological restraint, and to be consistent with the 2011 IHS study, we performed a counterfactual analysis that we refer to as the Constrained Shale Gas Case. We started the scenario runs in 2012, reducing U.S. NG production growth rates to historical trends and increased NG prices to global LNG prices, specifically following European oil-linked prices. Reduced domestic NG availability would be met, in the short term, with a return to historical trends of higher-level imports of NG resources to meet the growing domestic demand for NG as a feedstock and fuel source (and the indirect use of NG for electricity production). The counterfactual impacts were evaluated for short-term and long-term price effects alone, without consideration of capital investment shifts.



Results

The short-term impacts of today's NG prices, as opposed to constrained shale gas case with European oil-linked prices, are increases to GDP, employment, and disposable income (across all consumers). GDP increased to a peak of 1.3 percent in 2014 and maintained a 1.2 percent increase into 2015. The employment contribution was 1.2 million in 2014 and 1.4 million in 2015. The long-term impacts through 2025 represent a shift toward equilibrium, with the scenario differences decreasing with time, in terms of pricing and GDP. The short-term boost in domestic manufacturing competitiveness results in a 2 percent increase in U.S. manufacturing capacity utilization, which is sustained at 1 percent higher than the constrained shale case from 2020 through 2025. The U.S. economy also enjoys reductions in inflation and unemployment. Overall, North American NG prices have increased in stability, which contributes to long-term investment planning.

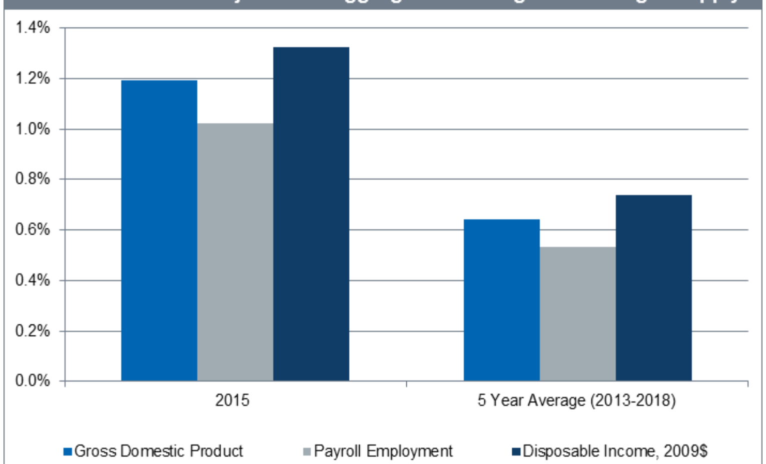
Declining NG prices directly reduce electricity prices, as 30 percent of total NG consumption goes to electricity. The model impacts found that retail electricity prices dropped 11 percent in 2013, and the declines in retail electricity prices are expected to persist through 2025.

"Lower gas and electricity prices serve to directly reduce the energy costs of households and businesses. Going forward, consumers have greater purchasing power and higher confidence, businesses experience higher profits, and domestic manufacturers are more cost-competitive relative to their international competitors as a result of lower NG prices."[36]

Reduction in NG and electricity prices result in an increase in real personal consumption expenditures in the short-term period of 2013 to 2016, peaking in 2014, with an increase in personal consumption expenditures of consumer durables of 3.1 percent. Investment also increases in the short term, with investment growing an average of 2.7 percent between 2013 and 2015, but increases return to equilibrium after 2015. Both exports and imports, overall, receive a modest increase with the reduction of NG pricing, with increases ending by 2016. Imports grow at an average rate of 1.4 percent between 2013 and 2016, faster than exports, which grow at a rate of 0.3 percent in the same time period. The increase in imports is mostly associated with an increase in consumption spending.

The benefits of higher NG supply to the economy, which lowers and stabilizes energy prices and electricity prices in particular, can be summarized by the three main macroeconomic aggregates that impact households: real GDP, employment, and real disposable income. The gains in in 2015 alone are significant. IHS estimates that, as a result of the increase in domestic shale gas production, real GDP (goods and services) is $190 billion greater and there are 1.4 million more jobs, contributing up to $156 billion more dollars of real disposable income in 2015. Over the five-year period of 2013 to 2018, IHS forecasts, on average, $101 billion more dollars in real GDP each year. This is produced with an average 730,000 more jobs in the economy each year contributing to $87 billion more dollars in real disposable income per year.

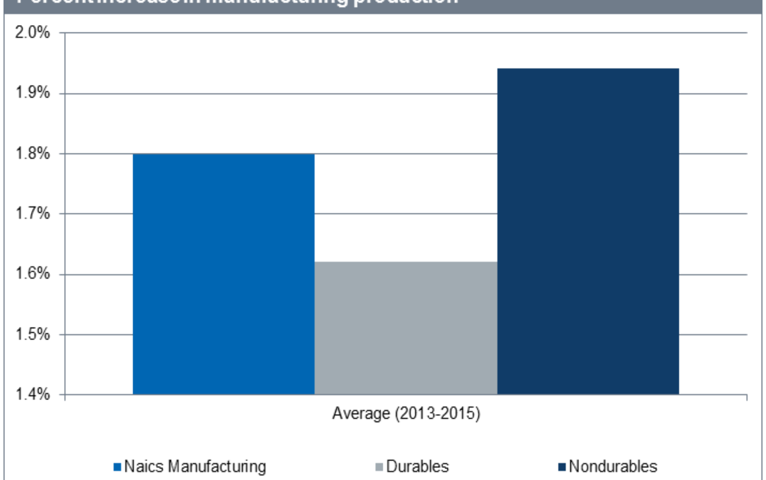
Percent increase in major macro aggregates from higher natural gas supply



Source: IHS

Impact on Key Manufacturing Sectors

Percent increase in manufacturing production



Source: IHS

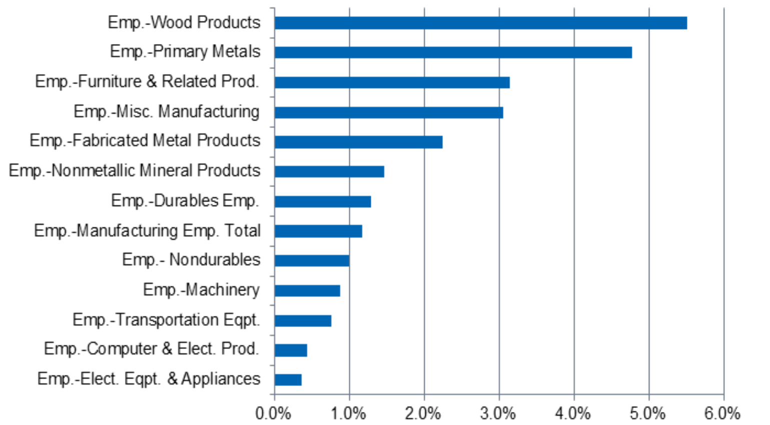
In addition to the demand generated by energy-intensive sectors and the indirect and induced impacts on manufacturing, lower gas prices, from higher gas supply, that help to lower energy costs also increases employment and productivity, which results in a corresponding increase in personal income. From 2013 to 2015, personal income averaged 1.4% higher and households also spent less on electricity, which had the combined effect of greater spending on consumable goods and services. The overall impact on manufacturers across a broad swath of industries is positive.

As expected, the increase in production due to lower NG prices is significantly greater in the non-durable sectors than in the durable sectors. The benefits from the reduction in electricity prices are more evenly

[36] "The Economic and Employment Contribution of Shale Gas in the United States," IHS 2011. Prepared for America's Natural Gas Alliance.

distributed across the manufacturing sector. In 2010, the durable and non-durable sectors accounted for 44% and 56% respectively of the total electricity used by the manufacturing sector. The intensity of electricity use in non-durable sector was 41.8% greater than in the durable sector.

Percent increase in manufacturing sector employment from higher NG Supply (Average 2013-2015)



Source: IHS © 2015 IHS

The reason for the difference in the use-intensity of electricity is that several of durable sectors use relatively little electricity in their production processes while generating high levels of output. The impact in the short term is greater than over the longer term due to the natural adjustments that occur in a dynamic economy. As industries adjust to the new reality (in the counterfactual case, higher gas prices), all other prices begin to adjust so that the relative price differentials reach equilibrium. As this occurs, the initial production gains begin to level out and return to their normal path of growth.

A closer look at the distribution of the percent increases in production by subsector shows that the NG intensive–sectors rank high on the list shown in the accompanying chart. Five of the NG intensive sectors—primary metals, paper, fabricated metals, chemicals, and non-metallic minerals—rank in the top 10. By contrast, the percent production increases in the food and petroleum and coal products sectors are much lower. Similar patterns can be seen in the employment contribution.

CHAPTER FIVE: ECONOMIC EFFECTS OF NATURAL GAS PIPELINE CONSTRUCTION AND OPERATION

The purpose of this section is to assess the economic impact of the construction and operation and maintenance (O&M) of NG pipelines on the U.S. economy, with a detailed analysis of the impacts on the manufacturing sector. The focus of this section is on NG transmission lines. We first summarize unit costs for the construction and operation of NG transmission lines.

Natural Gas Pipeline Costs

As described in earlier sections of this report, there are three types of NG pipelines: gathering, transmission, and distribution. We performed a two-part analysis: first, we estimated the economic impact from the construction and operation of transmission pipelines forecast to be commissioned and begin operations in 2015, and second, we derived the economic contribution of transmission pipelines operating prior to 2015. To estimate the economic impact from the construction and operation of the proposed 2015 transmission pipelines, we determined their unit construction costs, in dollars per mile, for two typical diameters. Based on our proprietary data, IHS estimated unit capital and O&M costs for the two sizes of transmission pipelines as presented below; the O&M costs apply to only newly constructed pipelines during their first few years of operation.

- **12” diameter:** Capital costs of $1,942,000/mile with corresponding annual O&M costs of $86,000/mile.
- **20” diameter line:** Capital costs of $3,591,000/mile with corresponding annual O&M costs of $116,000/mile.

To estimate the economic impacts of operating and maintaining the existing NG transmission pipeline system, additional research was required. The NG transmission system in 2014 consisted of about 297,800 miles of on-shore pipeline, including active, inactive, and abandoned pipelines. IHS combined our proprietary data with an analysis by IHS Energy of the FERC[37] Form 2 and 2a company-level data to estimate an average annual O&M expenditure of about $32,900 per existing transmission pipeline mile.

Because costs vary widely by project, and due to the difficulty of tracking and obtaining accurate data for many local projects, we did not estimate the economic impacts of constructing and operating NG gathering or distribution lines in the United States While IHS continually collects data on proposed NG transmission lines, we do not track proposed gathering or distribution line projects. We note that the primary impacts on the manufacturing sector occur during the construction phase, especially for transmission lines with their larger sizes and higher unit costs, because of the need for manufacturing products such as steel, pumps and compressors, and equipment.

U.S. Economic Impacts of Natural Gas Transmission Line Construction

IHS estimates that approximately $25.8 billion was spent in the United States in 2015 to construct the proposed 6,028 miles of new NG transmission pipelines. IHS continually monitors the status of major NG transmission pipeline projects across the country because of their importance to the NG pipeline system, so this expenditure figure is based on actual data. Approximately 92% of the spending was for transmission pipelines with a diameter of at least 30 inches. The accompanying table shows that the construction spending generated a temporary increase in employment of 348,789 jobs, including 59,874 in the manufacturing sector. Similarly, the proposed spending is expected to contribute $34 billion to total U.S. GDP, with 23.2% of that increase flowing to the manufacturing sector. The contribution to labor income was $21.9 billion in 2015, with 21.5% occurring in the manufacturing sector. The share of the total U.S. economic impacts occurring in the manufacturing sector is lowest for employment because of the sector’s high level of worker productivity (i.e., high values of output and GDP per worker) and its above-average wage levels.

[37] Federal Energy Regulatory Commission, 2015, Form 2/2A Major and Non-Major Natural Gas Pipeline Annual Report http://www.ferc.gov/docs-fling/forms/form-2/data.asp

The accompanying table shows that for every mile of NG transmission line pipeline built, a total of 57.9 jobs would be created in the United States, including 9.9 manufacturing jobs per mile. The total U.S. economic impacts presented in the table are the sum of the direct spending, and the indirect and induced multiplier effects.

A major of objective of this study is to measure how the construction of new NG transmission pipelines affects the manufacturing sector. The share of economic benefits flowing to the manufacturing sector for the 30-inch diameter pipeline is higher than the share for the 12-inch diameter pipeline because expensive capital goods and equipment, such as steel pipe and pumps, comprise a higher share of the unit cost for the 30-inch diameter line.

IHS estimated the total U.S. economic impacts within manufacturing. Appendix A presents the U.S. impacts for each of the 86 4-digit NAICS codes within the manufacturing sectors. While the appendix shows that all of the manufacturing subsectors will benefit to some extent, between 71% and 75% of the economic impacts, depending on the unit of measurement considered (e.g. jobs, labor income, output, and value-added), will occur in the following 14 subsectors:

US Economic Impacts of Construction Spending for New Natural Gas Transmission Lines in 2015

Impact Measure	Total Change in Economic Activity	% in the Mfg. Sector	Impact per Mile
Employment (# of jobs)	348,789	17.2%	57.9
Direct	112,760	27.5%	18.7
Indirect	104,336	20.8%	17.3
Induced	131,693	5.8%	21.8
Labor Income (Millions of US$)	$ 21,855.3	21.5%	$ 3.63
Direct	$ 7,845.1	32.2%	$ 1.30
Indirect	$ 7,253.5	23.6%	$ 1.20
Induced	$ 6,756.7	6.8%	$ 1.12
Output (Millions of US$)	$ 32,267.9	37.5%	$ 5.35
Direct	$ 11,602.4	44.5%	$ 1.92
Indirect	$ 10,990.3	46.1%	$ 1.82
Induced	$ 9,675.1	18.3%	$ 1.61
Contribution to GDP (Millions of US$)	$ 33,979.7	23.2%	$ 5.64
Direct	$ 10,164.8	37.6%	$ 1.69
Indirect	$ 11,736.1	26.2%	$ 1.95
Induced	$ 12,078.9	8.2%	$ 2.00

Note: The figures above include only the construction of 2015 proposed transmission lines. Additional economic impacts from the construction of gathering and distribution lines are. IHS does not track gathering or distribution line projects.

- 3241 Petroleum & Coal
- 3251 Basic Chemicals
- 3255 Paint, Coating, & Adhesives
- 3261 Plastics
- 3273 Cement & Concrete
- 3311 Iron & Steel Mills
- 3312 Steel Product Mfg. From Purchases
- 3315 Foundries
- 3323 Architectural & Structural Metals
- 3327 Machine Shops
- 3329 Other Fabricated Metal Products
- 3331 Agriculture, Construction, & Mining Machinery
- 3339 Other Machinery
- 3344 Semiconductor & Computers

Manufacturing Employment Impacts by State

The increase in manufacturing employment (59,874 direct jobs) from building NG transmission lines in 2015 was disaggregated by 3-digit NAICS manufacturing subsector within each state. The first step in this analysis was to determine where direct pipeline spending would occur in 2015 by state. IHS distributed the $25.8 billion of direct spending as follows:

- 30% for specialized capital goods and equipment such as steel pipe, compressors, and off-highway machinery was allocated to those states where potential suppliers are located. IHS industry experts identified the states most likely to receive the direct spending. For example, IHS steel industry experts identified producers in 16 states with mills capable of producing the type of steel pipe required for NG transmission lines.

- 70% for items such as construction materials and labor compensation was allocated primarily within states and local economies where pipeline would be built. The distribution was based on shares of project pipeline mileage in each state.

Based on the location of companies capable of providing necessary components such as pipeline steel, we identified 21 states where direct spending on specialized capital goods would occur. The direct spending total in each state was then allocated by economic sector and entered into the appropriate Impact Analysis for Planning (IMPLAN) sector based on the unit pipeline construction cost figures developed for this study.

Appendix B presents the distribution of the U.S. increase in manufacturing jobs by state by 3-digit NAICS manufacturing subsector. As expected, the employment effects largely track with the distribution of direct spending by state, although every state benefits to some extent through the indirect and induced multiplier effects of capital and operating expenditures. The following 10 states combined, listed in descending order of their employment increases, will receive about 74% of the total increase in manufacturing employment: Texas, California, Louisiana, Ohio, Wyoming, Oklahoma, Colorado, Indiana, Illinois, and Pennsylvania. Employment increases are also concentrated in the durable manufacturing sectors because of the composition of the direct spending; nationally, 86% of the employment increase is in the durable goods sectors (e.g., wood, non-metallic minerals, primary and fabricated metals, machinery, electrical equipment, computers, transportation equipment, furniture, and miscellaneous).

U.S. Economic Impacts of Natural Gas Transmission Pipeline Operation and Maintenance

US Economic Impacts of Projected O&M Spending for Natural Gas Transmission Lines in 2016

Impact Measure	Total Change in Economic Activity	Impact per $1 billion of O&M spending
Employment (# of jobs)	119,754	11,423.6
Direct	22,914	2,185.8
Indirect	27,369	2,610.8
Induced	69,472	6,627.1
Labor Income (Million US$)	$ 11,814.8	$ 1,127.0
Direct	$ 6,362.2	$ 606.9
Indirect	$ 1,830.5	$ 174.6
Induced	$ 3,622.1	$ 345.5
Output (Million of US$)	$ 27,143.1	$ 2,589.2
Direct	$ 10,305.8	$ 983.1
Indirect	$ 5,768.7	$ 550.3
Induced	$ 11,068.6	$ 1,055.9
Contribution to GDP (Million U$	$ 16,510.4	$ 1,575.0
Direct	$ 6,950.9	$ 663.1
Indirect	$ 3,091.0	$ 294.9
Induced	$ 6,468.5	$ 617.0

Note: The above impacts are the combined O&M expenditures for the 303,828 miles of NG transmission lines operating in 2016, w hich includes the 6,028 miles of new pipeline constructed in 2015 w hose first full year of operation is 2016, and 297,800 miles of existing pipeline. While the spending occurs in 2016, impacts are presented in current 2015$

IHS estimated the economic contribution of existing NG transmission lines O&M using an average per mile expenditure of $32,900 for the 297,800 miles of transmission pipeline. IHS estimates that the total U.S. O&M spending for existing NG transmission pipelines was $9.8 billion in 2015. This spending resulted in nearly 111,800 jobs in 2015. Detailed manufacturing contributions are located in Appendix C. Natural gas transmission line O&M spending contributed about $15.4 billion to the U.S. economy in 2015.

The estimates for the annual unit cost of operating and maintaining newly constructed NG transmission lines were $86,000 and $116,000/mile for the 12- and 30-inch-diameter pipes, respectively. These cost assumptions were applied to the 6,028 miles of new NG transmission lines that IHS Energy estimates were constructed in 2015, whose first full year of operation is in 2016.

The accompanying table presents the combined impacts on the US economy of O&M spending for both the 297,800 miles of existing natural gas transmission line, and the 6,028 miles of new pipeline built in 2015. These impacts would be generated in 2016 (i.e., during the first full year of operation for new pipelines completed in 2015), but the impacts are presented in 2015 dollars to be consistent with the rest of the report. The combined total of almost $10.5 billion in O&M spending will contribute 119,753 jobs and $16.5 billion in GDP in 2016. On a unit basis, for every $1 billion in direct O&M spending on natural gas transmission lines, the total increase in US employment would be 11,424 jobs, and $1,575 billion in US GDP. Approximately 4.3% of the total employment increase would occur in the manufacturing sector while 13.7% of the additional GDP would be in manufacturing.

Annual O&M spending generates permanent increases in state and local economic activity, such as employment and value added, as the NG pipeline system has to be continually operated and maintained. At the state and local levels, the economic multiplier effects of O&M spending are usually comparable to or slightly higher than during construction, as higher shares of inputs, including labor, maintenance and repair services, and supplies, are purchased locally. Finally, although the per-mile economic impacts of O&M spending shown in the accompanying table are much lower than for construction, the spending is distributed across roughly 50 times more pipeline miles. Consequently, annual O&M spending generates more permanent benefits overall.

Projections for Continued Growth in Pipeline Spending

United States on-shore NG production rose 30.6% between 2007 and 2013 according to EIA.[38] EIA estimates total annual U.S. NG withdrawals in 2014 of 31.346 trillion cubic feet (Tcf). In 2013, on-shore NG production was 93.7% of total U.S. production; if this share holds in 2014, total on-shore gross withdrawals would be 29.4 Tcf. On-shore production, as a share of total U.S. NG production, has been steadily rising in recent years; as recently as 2007, it was 85.9%. Similarly, the EIA estimates U.S. crude oil production has risen from 5.1 million barrels per day in 2007 to 8.7 million barrels per day in 2014, approaching the peak level of domestic oil production of just under 9.0 million barrels per day in 1985.

U.S. pipeline capital spending grew significantly over this same six-year period to support U.S. upstream oil and NG activity and production plans. U.S. oil and NG transmission pipeline project spending increased from approximately $10.1 billion in 2010 to almost $37.4 billion in 2015. Average annual U.S. onshore pipeline capital spending over this period was approximately $20.5 billion, with $14 billion spent on expanding NG transmission lines and the balance spent on crude oil pipelines. Pipeline project spending was underpinned by the upstream production plans established in prior periods. While the rate of capacity additions could slow over the short term, additions are needed over the medium to long term to meet IHS's view of supply and demand fundamentals.

[38] EIA, November 2015, Natural Gas Gross Withdrawals. http://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm.

Appendix A: U.S. Economic Contributions of Constructing Natural Gas Transmission Lines in 2015 by Manufacturing Subsector

Economic Contributions by 4-digit NAICs Mfg. Sector from Constructing Natural Gas Transmission Lines in the US in 2015

NAICS Code and Description	Employment (Number of jobs)	Labor Income (Millions of US$)	Output (Millions of US$)	Contribution to GDP (Millions of US$)
3111 Animal Food Manufacturing	61	4.7	86.7	13.4
3112 Grain & Oilseed Manufacturing	62	5.7	126.7	15.8
3113 Sugar & Products Manufacturing	75	5.0	42.1	8.9
3114 Fruit & Vegetable Preserving	192	11.5	87.0	18.2
3115 Dairy Product Manufacturing	150	10.9	158.2	20.8
3116 Animal Slaughtering & Processing	509	23.3	203.9	27.5
3117 Seafood Product Preparation	45	2.5	17.4	2.8
3118 Bakeries & Tortilla Manufacturing	323	16.0	80.4	22.9
3119 Other Food Manufacturing	190	14.2	151.7	46.6
3121 Beverage Manufacturing	221	19.5	181.1	50.4
3122 Tobacco Manufacturing	15	2.2	46.6	31.3
3131 Fiber, Yarn, & Thread Mills	26	1.1	9.2	1.6
3132 Fabric Mills	47	2.6	15.7	3.8
3133 Textile & Fabric Mills	42	2.3	12.0	2.9
3141 Textile Furnishings Mills	64	3.1	17.0	4.3
3149 Other Textile Product Mills	98	4.3	15.7	5.2
3151 Apparel Knitting Mills	19	0.6	2.3	0.8
3152 Cut & Sew Apparel Manufacturing	186	7.7	24.8	9.2
3159 Accessories & Other Apparel Mfg.	12	0.5	1.9	0.6
3161 Leather & Hide Finishing	2	0.1	1.2	0.2
3162 Footwear Manufacturing	14	0.6	2.3	0.8
3169 Other Leather Products	12	0.5	2.1	0.7
3211 Sawmills & Wood Preservation	346	18.1	93.9	21.4
3212 Plywood & Engineered Wood Mfg.	245	13.0	58.2	20.0
3219 Other Wood Manufacturing	672	32.1	117.0	38.1
3221 Pulp, Paper & Paperboard Mills	159	17.9	139.2	38.6
3222 Converted Paper Products	481	38.8	218.9	57.0
3231 Support Activities - Printing	727	39.8	123.4	44.9
3241 Petroleum & Coal Prod. Mfg.	392	93.8	2,105.3	634.4
3251 Basic Chemical Mfg.	350	49.9	1,000.9	137.8
3252 Resin, Rubber, & Fiber Mfg.	173	22.8	266.9	37.9
3253 Agricultural Chemical Mfg.	57	6.8	96.1	14.9
3254 Pharmaceutical & Medicine Mfg.	251	44.3	350.3	116.3
3255 Paint, Coating, & Adhesive Mfg.	1,615	172.8	1,264.0	263.2
3256 Soap, Cleaning, & Toiletry Mfg.	108	10.9	129.9	41.5
3259 Other Chemical Product Mfg.	137	14.0	89.1	20.2
3261 Plastic Product Mfg.	1,280	84.1	447.9	144.1
3262 Rubber Product Mfg.	320	22.8	121.1	40.4
3271 Clay Product & Refractory Mfg.	141	9.2	28.7	11.6
3272 Glass & Glass Product	104	7.3	31.2	10.9
3273 Cement & Concrete Products	1,289	83.7	352.6	114.4
3274 Lime & Gypsum Products	69	5.5	33.9	9.9
3279 Other Nonmetallic Mineral Products	337	22.5	120.7	42.4

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Economic Contributions by 4-digit NAICs Mfg. Sector from Constructing Natural Gas Transmission Lines in the US in 2015

NAICS Code and Description	Employment (Number of jobs)	Labor Income (Millions of US$)	Output (Millions of US$)	Contribution to GDP (Millions of US$)
3311 Iron & Steel Mills	1,085	115.8	1,370.7	187.4
3312 Steel Product Mfg. From Purchases	662	54.8	518.9	71.1
3313 Alumina & Aluminum Production	168	14.0	130.3	17.7
3314 Other Nonferrous Metal Production	264	22.1	339.4	36.1
3315 Foundries	1,093	78.4	313.4	92.1
3321 Forging & Stamping	599	47.8	263.6	68.4
3322 Cutlery & Handtool Mfg.	100	7.7	27.5	11.7
3323 Architectural & Structural Mfg.	2,115	139.3	564.8	185.7
3324 Boiler, Tank & Container Mfg.	402	31.1	182.8	49.9
3325 Hardware Manufacturing	36	2.7	12.0	4.4
3326 Spring & Wire Product Mfg.	221	14.0	57.6	21.6
3327 Machine Shops Mfg.	2,004	134.0	374.9	166.8
3328 Coating, Engraving, & Heat Metals	780	47.1	192.5	69.7
3329 Other Fabricated Metal Products	28,771	2,138.2	8,087.7	2,952.9
3331 Ag., Construction, & Mining Machinery	1,869	192.9	1,957.6	530.4
3332 Industrial Machinery Mfg.	60	5.1	24.8	8.7
3333 Commercial & Service Industrial Machi	130	10.6	60.9	21.6
3334 HVAC & Commercial Refrig. Equipmen	236	16.0	69.0	25.0
3335 Metalworking Machinery	225	16.5	45.5	21.7
3336 Turbine & Power Transmission Equip.	239	23.0	193.6	49.5
3339 Other Machinery Mfg.	3,533	322.9	1,644.0	570.8
3341 Computer & Peripheral Eq. Mfg.	77	14.0	89.9	27.4
3342 Communications Eq. Mfg.	116	13.2	56.9	20.0
3343 Audio & Video Eq. Mfg.	14	1.5	8.0	2.0
3344 Semiconductor & Comp. Mfg.	570	62.8	446.1	200.3
3345 Electronic Instrument Mfg.	122	12.0	47.4	18.4
3346 Magnetic Media Mfg.	20	2.6	10.6	3.8
3351 Electric Lighting Eq. Mfg.	156	13.4	57.2	18.8
3352 Household Appliance Mfg.	61	4.9	33.2	8.5
3353 Electrical Equipment	398	36.7	166.6	55.3
3359 Other Electrical Eq. & Comp. Mfg.	258	22.5	114.5	35.8
3361 Motor Vehicle Mfg.	88	9.6	167.5	14.5
3362 Motor Vehicle Body & Trailer Mfg.	100	6.2	31.7	6.2
3363 Motor Vehicle Parts Mfg.	552	41.5	291.7	42.7
3364 Aerospace Product & Parts Mfg.	33	3.8	15.3	4.2
3365 Railroad Rolling Mfg.	32	2.9	18.4	3.4
3366 Ship & Boat Building	30	1.9	8.3	2.1
3369 Other Transportation Eq. Mfg.	25	2.0	18.5	3.1
3371 Household & Institutional Furniture Mfg	289	13.9	50.4	20.0
3372 Office Furniture & Fixtures Mfg.	33	1.8	8.6	3.3
3379 Other Furniture Related Mfg.	39	2.1	11.4	4.0
3391 Medical Eq. & Supplies Mfg.	232	19.5	61.2	38.6
3399 Other Misc. Mfg.	417	29.5	96.3	48.8
Total in Manufacturing	59,874	4,701.3	26,716.1	7,893.0

Note: The figures above are based on an IHS estimate of $25.8 billion in spending to construct 6,028 miles of new , on-shore natural gas transmission lines in the US during 2015. Right-of-w ay acquisition costs are not included.

Appendix B: Employment Contribution of Constructing Natural Gas Transmission Lines in 2015 by State and Manufacturing Subsector

Employment Increases From Constructing of Natural Gas Transmission Lines in 2015 by State and Mfg. sub-sector

State	311 Food	312 Beverage & Tobacco	313 Textile Mills	314 Textile Product Mills	315 Apparel	316 Leather	321 Wood Products	322 Paper	323 Printing	324 Petroleum & Coal	325 Chemicals
AK	16	1	0	0	0	0	1	0	1	20	0
AL	0	0	0	0	0	0	1	0	0	0	4
AR	82	2	0	2	8	3	26	31	10	9	21
AZ	21	7	1	3	3	0	13	7	13	3	26
CA	49	15	3	5	45	2	10	25	30	8	32
CO	6	2	0	0	1	0	1	4	4	0	1
CT	12	3	1	2	2	0	2	10	13	2	43
DE	19	1	0	0	0	0	1	1	1	6	11
FL	0	0	0	0	0	0	1	0	0	0	4
GA	124	12	27	58	14	0	45	56	33	8	82
HI	12	2	-	0	4	0	1	0	2	5	1
IA	97	3	0	2	5	0	23	14	17	4	44
ID	32	2	0	1	1	0	17	5	3	0	10
IL	31	4	1	4	1	1	20	23	38	13	52
IN	55	14	1	8	5	2	166	27	48	25	364
KS	60	1	0	2	3	0	4	4	19	17	36
KY	51	13	2	2	10	1	25	28	24	9	50
LA	9	3	0	0	1	0	2	6	4	7	4
MA	51	8	5	4	13	2	6	25	28	6	73
MD	1	1	0	0	0	0	2	0	1	1	11
ME	10	4	2	1	2	3	12	16	3	1	9
MI	12	3	1	3	1	0	47	11	18	2	49
MN	91	6	1	4	6	2	30	29	57	21	40
MO	72	13	0	5	16	2	19	23	29	9	79
MS	39	1	1	3	9	0	22	11	4	23	36
MT	5	2	0	1	0	0	8	0	2	8	3
NC	4	0	28	3	2	0	15	5	5	0	12
ND	9	0	0	1	0	0	5	0	2	4	1
NE	66	1	0	1	1	0	4	5	8	0	21
NH	4	2	3	1	1	0	4	6	5	1	10
NJ	0	0	0	0	0	0	0	0	0	0	2
NM	10	2	0	0	1	0	4	2	3	5	9
NV	9	2	0	1	0	0	2	3	7	2	7
NY	11	2	2	3	4	1	16	8	18	1	27
OH	160	39	3	9	9	1	296	71	100	65	1,016
OK	7	3	0	0	1	0	1	2	4	2	1
OR	51	11	0	2	6	1	62	13	15	4	17
PA	38	8	4	6	5	1	179	19	32	21	155
RI	6	1	3	1	0	0	2	4	4	0	13
SC	36	2	20	8	10	0	22	39	12	1	83
SD	16	1	1	1	1	0	5	2	3	0	5
TN	3	1	0	0	1	0	8	1	2	2	18
TX	82	18	2	5	8	2	20	46	47	34	70
UT	31	2	0	2	4	0	6	11	12	11	36
VA	3	1	0	0	0	0	11	1	2	1	19
VT	10	1	0	0	2	0	5	3	3	2	6
WA	74	17	1	4	6	1	37	26	14	23	31
WI	18	1	2	1	0	0	45	18	24	0	12
WV	1	0	0	0	0	0	8	0	1	0	32
WY	0	1	0	0	0	0	0	0	2	1	0
Sector Total	1,608	235	115	162	217	28	1,263	640	727	392	2,691

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Employment Increases From Constructing of Natural Gas Transmission Lines in 2015 by State and Mfg. sub-sector

State	326 Plastics & Rubber	327 Non Metallic Minerals	331 Primary Metals	332 Fabricated Metals	333 Machinery	334 Computer & Electronics	335 Electrical Equip. & Appliances	336 Trans. Equip.	337 Furniture	339 Misc.	State Total
AK	2	0	0	4	0	0	0	0	0	0	46
AL	0	3	0	2	0	0	0	0	0	0	13
AR	23	22	119	153	16	3	16	13	6	8	572
AZ	35	13	56	187	10	52	7	27	10	19	512
CA	56	13	297	4,679	1,041	120	55	18	12	38	6,552
CO	8	2	47	1,339	468	3	2	0	1	5	1,895
CT	18	13	62	292	19	19	26	38	4	17	598
DE	4	4	12	18	1	2	2	1	1	3	88
FL	0	4	0	2	0	0	0	0	0	0	14
GA	94	42	82	272	28	16	37	46	22	24	1,122
HI	6	1	0	4	0	0	0	1	1	2	42
IA	33	23	123	201	55	19	17	16	16	6	720
ID	6	3	10	61	4	20	3	2	3	3	186
IL	72	55	89	338	653	43	83	23	11	30	1,584
IN	108	288	140	354	83	17	43	59	28	33	1,866
KS	33	20	41	159	25	9	9	35	7	6	493
KY	46	33	197	204	26	8	31	57	10	8	835
LA	2	4	55	4,299	1	0	0	1	0	2	4,402
MA	38	26	45	327	23	86	25	12	7	38	848
MD	1	7	0	2	0	0	0	0	0	0	31
ME	7	5	5	56	3	3	0	8	2	3	157
MI	77	44	53	297	82	21	20	78	12	16	847
MN	60	31	129	425	44	69	28	11	17	44	1,143
MO	49	32	124	284	35	15	30	40	12	21	909
MS	28	12	54	94	16	5	17	25	32	6	439
MT	7	1	11	20	2	0	0	1	1	4	77
NC	22	7	12	77	24	12	34	10	5	6	284
ND	8	3	3	28	8	2	1	2	2	2	81
NE	18	11	25	88	13	7	4	8	3	10	294
NH	10	10	36	112	10	22	11	2	2	10	261
NJ	0	1	0	1	0	0	0	0	0	0	7
NM	9	2	6	21	2	10	2	1	1	4	93
NV	26	7	25	55	2	4	2	1	2	14	174
NY	25	25	21	130	48	35	31	11	5	15	439
OH	222	828	125	723	140	33	84	75	32	66	4,096
OK	16	3	76	2,469	396	1	2	5	0	3	2,992
OR	34	13	140	156	17	58	8	11	8	15	642
PA	66	159	115	362	59	26	68	16	16	21	1,378
RI	3	5	31	57	3	5	3	5	2	11	159
SC	48	43	140	265	27	10	35	35	4	12	852
SD	12	3	15	43	9	3	3	4	5	7	138
TN	2	19	0	8	1	0	1	1	1	1	71
TX	117	32	494	12,526	2,572	86	57	41	17	50	16,329
UT	28	10	68	125	10	19	5	11	13	34	438
VA	2	21	0	10	1	0	1	0	1	1	77
VT	9	3	4	24	3	8	3	2	3	3	93
WA	68	18	103	199	22	31	13	95	12	19	813
WI	40	6	72	214	286	15	52	13	10	9	840
WV	1	12	1	4	0	0	0	0	0	1	63
WY	0	0	8	3,256	0	0	1	0	0	1	3,271
Sector Total	1,600	1,941	3,271	35,028	6,291	920	873	861	360	649	59,874

Appendix C: U.S. Economic Contribution of Operating & Maintaining Existing Natural Gas Transmission Pipelines in 2015 by Manufacturing Subsector

US Economic Impacts of Existing Natural Gas Pipeline Operation & Maintenance Spending in 2015 by 4-digit Mfg. sector

NAICS Code and Description	Employment	Labor Income (Millions of US$)	Output (Millions of US$)	Contribution to GDP (Millions of US$)
3111 Animal Food Manufacturing	29	2.3	40.7	6.6
3112 Grain & Oilseed Manufacturing	27	2.5	51.5	7.1
3113 Sugar & Products Manufacturing	36	2.4	20.3	4.4
3114 Fruit & Vegetable Preserving	92	5.6	42.0	8.9
3115 Dairy Product Manufacturing	71	5.3	75.3	10.1
3116 Animal Slaughtering & Processing	243	11.3	96.4	13.4
3117 Seafood Product Preparation	21	1.2	8.2	1.3
3118 Bakeries & Tortilla Manufacturing	155	7.8	38.9	11.2
3119 Other Food Manufacturing	90	6.9	70.1	22.5
3121 Beverage Manufacturing	106	9.6	87.7	24.7
3122 Tobacco Manufacturing	7	1.0	22.7	15.0
3131 Fiber, Yarn, & Thread Mills	9	0.4	3.2	0.6
3132 Fabric Mills	17	0.9	5.4	1.3
3133 Textile & Fabric Mills	15	0.8	4.2	1.1
3141 Textile Furnishings Mills	26	1.3	6.6	1.8
3149 Other Textile Product Mills	48	2.2	7.5	2.6
3151 Apparel Knitting Mills	9	0.3	1.1	0.4
3152 Cut & Sew Apparel Manufacturing	79	3.4	11.2	4.1
3159 Accessories & Other Apparel Mfg.	6	0.2	0.9	0.3
3161 Leather & Hide Finishing	1	0.0	0.4	0.1
3162 Footwear Manufacturing	7	0.3	1.1	0.4
3169 Other Leather Products	5	0.2	1.0	0.3
3211 Sawmills & Wood Preservation	65	3.4	18.5	4.1
3212 Plywood & Engineered Wood Mfg.	37	2.0	9.5	3.1
3219 Other Wood Manufacturing	103	4.9	18.0	5.8
3221 Pulp, Paper & Paperboard Mills	47	5.4	41.5	11.7
3222 Converted Paper Products	132	10.9	62.6	17.1
3231 Support Activities - Printing	276	15.4	46.9	17.4
3241 Petroleum & Coal Prod. Mfg.	141	42.5	1,211.2	305.2
3251 Basic Chemical Mfg.	40	6.0	134.1	18.0
3252 Resin, Rubber, & Fiber Mfg.	26	3.4	38.1	5.5
3253 Agricultural Chemical Mfg.	12	1.5	20.5	3.9
3254 Pharmaceutical & Medicine Mfg.	124	22.2	180.8	58.4
3255 Paint, Coating, & Adhesive Mfg.	27	3.0	21.9	4.5
3256 Soap, Cleaning, & Toiletry Mfg.	50	5.1	59.4	19.1
3259 Other Chemical Product Mfg.	30	3.1	18.5	4.5
3261 Plastic Product Mfg.	272	17.9	92.3	30.6
3262 Rubber Product Mfg.	36	2.7	14.3	4.8
3271 Clay Product & Refractory Mfg.	13	0.8	2.7	1.1
3272 Glass & Glass Product	30	2.2	9.3	3.4
3273 Cement & Concrete Products	79	5.3	22.2	7.2
3274 Lime & Gypsum Products	9	0.7	4.6	1.3
3279 Other Nonmetallic Mineral Products	24	1.6	7.7	2.8

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US Economic Impacts of Existing Natural Gas Pipeline Operation & Maintenance Spending in 2015 by 4-digit Mfg. sector				
NAICS Code and Description	**Employment**	**Labor Income (Millions of US$)**	**Output (Millions of US$)**	**Contribution to GDP (Millions of US$)**
3311 Iron & Steel Mills	36	3.9	45.8	6.3
3312 Steel Product Mfg. From Purchases	23	2.0	18.8	2.5
3313 Alumina & Aluminum Production	21	1.8	16.4	2.3
3314 Other Nonferrous Metal Production	16	1.4	19.9	2.3
3315 Foundries	34	2.4	9.4	2.8
3321 Forging & Stamping	27	2.0	11.0	3.0
3322 Cutlery & Handtool Mfg.	29	2.2	7.9	3.4
3323 Architectural & Structural Mfg.	352	23.9	97.7	32.2
3324 Boiler, Tank & Container Mfg.	29	2.3	14.3	3.8
3325 Hardware Manufacturing	7	0.6	2.5	0.9
3326 Spring & Wire Product Mfg.	22	1.4	5.7	2.2
3327 Machine Shops Mfg.	171	11.6	31.5	14.3
3328 Coating, Engraving, & Heat Metals	103	6.3	25.3	9.3
3329 Other Fabricated Metal Products	103	8.0	40.4	15.2
3331 Ag., Construction, & Mining Machinery	12	1.1	8.3	2.4
3332 Industrial Machinery Mfg.	8	0.7	3.4	1.2
3333 Commercial & Service Industrial Machinery	3	0.3	1.4	0.5
3334 HVAC & Commercial Refrig. Equipment	218	15.4	58.9	21.9
3335 Metalworking Machinery	19	1.4	4.0	1.9
3336 Turbine & Power Transmission Equip.	10	1.0	7.1	2.1
3339 Other Machinery Mfg.	22	1.9	9.0	3.2
3341 Computer & Peripheral Eq. Mfg.	29	5.5	24.5	10.9
3342 Communications Eq. Mfg.	20	2.4	9.8	3.8
3343 Audio & Video Eq. Mfg.	6	0.6	2.9	0.8
3344 Semiconductor & Comp. Mfg.	63	7.1	43.2	22.7
3345 Electronic Instrument Mfg.	30	3.1	12.1	4.8
3346 Magnetic Media Mfg.	9	1.3	4.9	2.1
3351 Electric Lighting Eq. Mfg.	16	1.4	5.9	2.0
3352 Household Appliance Mfg.	23	1.9	12.4	3.3
3353 Electrical Equipment	30	2.9	12.6	4.4
3359 Other Electrical Eq. & Comp. Mfg.	37	3.2	16.5	5.5
3361 Motor Vehicle Mfg.	38	4.3	75.7	6.5
3362 Motor Vehicle Body & Trailer Mfg.	23	1.5	7.3	1.5
3363 Motor Vehicle Parts Mfg.	123	9.4	64.2	9.6
3364 Aerospace Product & Parts Mfg.	6	0.7	2.9	0.7
3365 Railroad Rolling Mfg.	2	0.2	1.2	0.2
3366 Ship & Boat Building	13	0.8	3.8	0.9
3369 Other Transportation Eq. Mfg.	12	0.9	8.7	1.5
3371 Household & Institutional Furniture Mfg.	118	5.7	19.8	8.1
3372 Office Furniture & Fixtures Mfg.	6	0.3	1.6	0.6
3379 Other Furniture Related Mfg.	18	1.0	5.0	2.0
3391 Medical Eq. & Supplies Mfg.	108	9.1	28.1	18.0
3399 Other Misc. Mfg.	99	7.1	25.9	13.6
Total in Manufacturing	**4,769**	**388.7**	**3,458.5**	**924.7**