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Natural Gas: A Key Part of the Global Energy Mix

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SUMMARY

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Michael Ratner
Specialist in Energy Policy

Natural Gas: A Key Part of the Global Energy Mix

The role of natural gas in the U.S. economy has been a major part of the energy policy debate in the 114th Congress. This report briefly explains key aspects of global natural gas markets, including supply and demand, and major U.S. developments.

Natural gas is considered by some as a potential bridge fuel to a lower-carbon economy, because it is cleaner burning than its hydrocarbon alternatives coal and oil. Natural gas combustion emits about one-half less carbon dioxide than coal and one-quarter less than oil when consumed in a typical electric power plant, although fugitive gas emissions offset some of the advantages. Natural gas combustion also emits less particulate matter, sulfur dioxide, and nitrogen oxides than coal or oil. Additionally, improved methods to extract natural gas from shale formations have significantly increased the resource profile of the United States, which has spurred other countries to try to develop shale gas. If the United States and other countries can bring large new volumes of natural gas to market, particularly unconventional natural gas, then natural gas could play a larger role in the world's economy. Several key factors will determine whether this happens, including price, technical capability, environmental concerns, and political considerations. Many countries, both producing and consuming, are watching how the development of U.S. unconventional natural gas resources evolves.

Key Points

- Natural gas is likely to play a greater role in the world energy mix given its growing resource base and its relatively low carbon emissions compared to other fossil fuels.
- The world used 122,442 billion cubic feet (bcf) of natural gas in 2015, of which the United States consumed 27,463 bcf (the most of any country).
- World natural gas consumption in 2015 grew by 1.7%, which was below the 10-year average of 2.3% but above the 0.6% increase in 2014; U.S. consumption grew by 3%.
- U.S. unconventional natural gas reserves and production, particularly shale gas, have grown rapidly in recent years. The United States accounts for 89% of global shale gas production.
- The new shale gas resources have changed the United States' natural gas position from a net importer to a potential net exporter. Other countries are now exploring their own shale gas resources.
- Global trade in natural gas is increasing and new players are entering on both the supply side and the import side, making the global gas market more integrated.

Contents

Introduction 1
Key Points 1
Natural Gas Consumption 2
Key Global Consumers 2
U.S. Consumption 3
Natural Gas Supply and Trade 4
Natural Gas Reserves Growing 4
Production 6
Liquefied Natural Gas 7
U.S. Development and Growth 8
Global Gas Market Becoming More Integrated 11
U.S. LNG Exports 12
Future Developments and Trends, Global and Domestic 13
Gas Exporting Countries Forum Still Ineffective 14
Production Widespread 15
Natural Gas Prices Remain Low 15
Looking Forward 16

Figures

Figure 1. Global Natural Gas Consumption 3
Figure 2. Global Natural Gas Reserves 5
Figure 3. Annual Global Reserves and Production 6
Figure 4. Global Natural Gas Production 7
Figure 5. U.S. Natural Gas Network 10
Figure 6. Global Natural Gas Trade, 2015 12
Figure 7. Global Natural Gas Prices 16

Tables

Table 1. GECF Natural Gas Statistics 2015 14

Table D-1. U.S. Imports of Natural Gas 21
Table D-2. U.S. Exports of Natural Gas 21

Appendixes

Appendix A. Global Natural Gas Consumption (2015) 18
Appendix B. Global Natural Gas Reserves (2015) 19
Appendix C. Global Natural Gas Production (2015) 20

Appendix D. U.S. Natural Gas Imports and Exports 21
Appendix E. Global Natural Gas Exporters (2015) 22
Appendix F. Major Global Gas Companies (2014) 23
Appendix G. Select U.S. Statutes Related to Natural Gas 24

Contacts

Author Information 25

Introduction

The role of natural gas in the U.S. economy has been a major part of the energy policy debate in the 114th Congress. Both the House and the Senate have held multiple hearings related to natural gas. Numerous bills have been introduced in both houses. This report highlights key aspects of global natural gas markets, including supply and demand, and major U.S. developments.[1] Select statutes of U.S. law related to natural gas can be found in **Appendix G**.

Some consider natural gas a potential bridge fuel to a lower-carbon economy, because it is cleaner burning than coal and oil. Natural gas combustion emits about one-half less carbon dioxide than coal and one-quarter less than oil when consumed in a typical electric power plant, offset somewhat by fugitive emissions.[2] Fugitive emissions, which can be intentional (i.e., vented) or unintentional (i.e., leaked), are natural gas that is released to the atmosphere during industry operations.[3] Natural gas combustion also emits less particulate matter, sulfur dioxide, and nitrogen oxides than coal or oil.

In recent years, the United States has become the home to the shale gas revolution,[4] as improved methods to extract natural gas from certain shale formations have significantly increased the resource profile of the United States. This has spurred other countries to try to develop shale gas, but progress is slow outside of North America.

If the United States continues to and other countries can bring large new volumes of natural gas to market at a competitive price, then natural gas could play a larger role in the world's economy. In 2016, the United States started exporting liquefied natural gas (LNG) from the lower 48 states. Several key factors will determine whether significant new quantities of natural gas come to market, particularly unconventional natural gas resources.[5] These factors include price, technical capability, environmental concerns, and political considerations. Many countries, both producing and consuming, are watching how the development of U.S. unconventional natural gas resources evolves.

Key Points

- Natural gas is likely to play a greater role in the world energy mix given its growing resource base[6] and its relatively low carbon emissions compared to other fossil fuels.

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[1] Data in this report are 2015 figures from the *BP Statistical Review of World Energy 2016* unless otherwise noted. For global data, BP's *Statistical Review* is considered an industry standard, http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf.

[2] International Finance Corporation, *Environmental, Health, and Safety Guidelines for Thermal Power Plants*, December 19, 2008, p. 8.

[3] For additional information on emissions issues in natural gas systems, see CRS Report R42986, *An Overview of Air Quality Issues in Natural Gas Systems*, by Richard K. Lattanzio.

[4] International Energy Agency, *World Energy Outlook 2015*, 2015, p. 5.

[5] Unconventional natural gas refers to natural gas that is not held in traditional porous rock reservoirs like limestone or sandstone, but is trapped in other types of formations. The three most common forms of unconventional natural gas are coalbed methane, shale gas, and tight gas. Coalbed methane refers to natural gas associated with coal seams. Shale gas refers to natural gas trapped in shale rock, which tends to be fine-grained sedimentary rock. Tight gas refers to natural gas trapped in impermeable and non-porous formations.

[6] Resources (or resource base) is a broad term that include reserves (see below) and natural gas less likely to be produced. Resources are not subject to today's technology or price constraints as reserves are and may be produced sometime in the future.

- The world used 122,442 billion cubic feet (bcf) of natural gas in 2015, of which the United States consumed over 27,463 bcf,[7] or about 23% (the most of any country).
- World natural gas consumption grew by 1.7% in 2015, which was below the 10-year average of 2.3%; U.S. consumption grew by 3%.[8]
- U.S. unconventional natural gas reserves[9] and production, particularly shale gas, have grown rapidly in recent years. According to the latest data, shale gas made up 51% of proved U.S. natural gas reserves[10] and accounts for 56% of dry natural gas production.[11]
- The new shale gas resources have changed the U.S. natural gas position from a net importer to a potential net exporter.
- Global trade in natural gas is increasing and new players are entering on both the supply side and the import side, making the global gas market more integrated.

Natural Gas Consumption

Key Global Consumers

In 2015, the world consumed about 122,442 bcf of natural gas[12]—23.8% of total global primary energy consumption, placing it third behind oil and coal. The United States was the world's largest consumer of natural gas, accounting for 27,463 bcf, or 22.8%, of global consumption (see **Figure 1**).[13]

Russia is the second-largest consumer of natural gas, using 13,820 bcf in 2015.[14] Natural gas accounted for 53% of Russia's total primary energy consumption, ranking it above oil and coal.[15] However, natural gas consumption has declined overall in Russia, decreasing 8% between 2011 and 2015,[16] due to a weak economic environment.[17]

Global consumption of natural gas grew at 1.7%, which was below the 10-year average of 2.3%. The United States was one of three countries with the largest consumption growth, at 3%, while also contributing the largest growth in absolute terms and accounting for almost 40% of the total

[7] *BP Statistical Review of World Energy 2016*, p. 23.

[8] *BP Statistical Review of World Energy 2016*, p. 4.

[9] Reserves is an industry term used to define the likelihood that natural gas resources can be produced using current technology and at today's prices, according to the Society of Petroleum Engineers and the World Petroleum Congress's definition.

[10] U.S. Energy Information Administration, "U.S. Crude Oil and Natural Gas Proved Reserves, 2014," November 2015, p. 15.

[11] U.S. Energy Information Administration, "Marcellus, Utica Provide 85% of U.S. Shale Gas Production Growth Since Start of 2012," July 28, 2015, https://www.eia.gov/todayinenergy/detail.cfm?id=22252.

[12] *BP Statistical Review of World Energy 2016*, p. 23.

[13] Ibid.

[14] Ibid.

[15] "BP Statistical Review 2016—Russia's Energy Market in 2015," 2016.

[16] *BP Statistical Review of World Energy 2016*, p. 23.

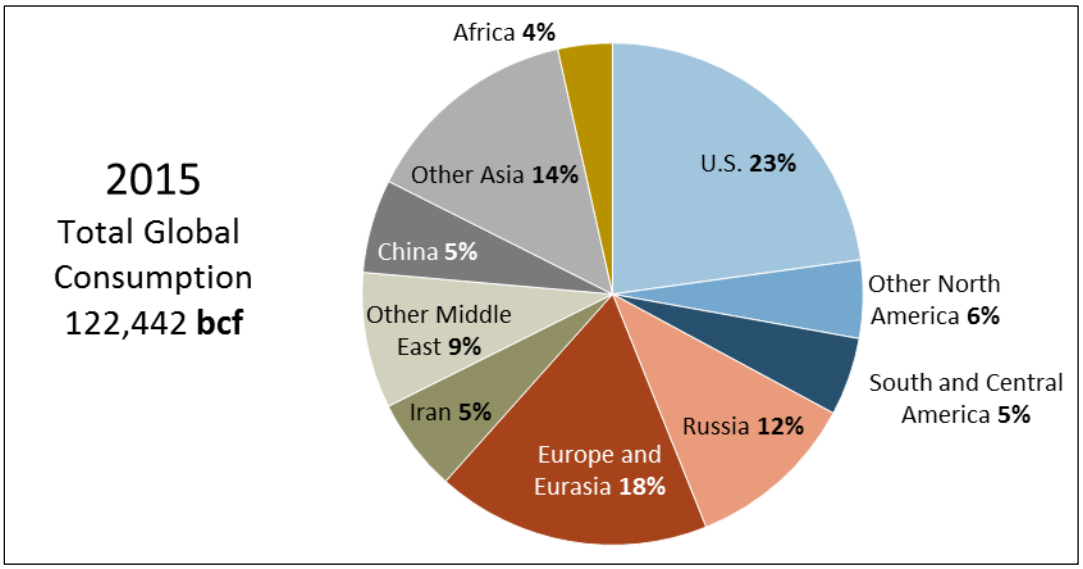
[17] "BP Statistical Review 2016—Russia's Energy Market in 2015," 2016.

growth. Iran and China also experienced increased natural gas consumption, at 6.2% and 4.7%, respectively.

China is the most populated country in the world and has a growing economy, resulting in the country being one of the largest global energy consumers. China accounts for almost half of the world's total coal consumption, and while the use of natural gas has increased over the past 10 years it remains a small percentage of China's energy consumption, at about 5%.[18] China continues to seek increased energy security by expanding natural gas imports through pipelines and as LNG.

Iran holds the world's second-largest natural gas reserves; however, its energy sector has stagnated in the past few years due to international sanctions and a lack of foreign investment and financing. Iran has a thriving domestic energy demand that has increased 50% since 2004.[19] The majority of Iran's natural gas production is consumed domestically, with natural gas comprising 60% of its total primary energy consumption in 2014. The lifting of international sanctions began in early 2016 following the implementation of the Joint Comprehensive Plan of Action. Major discussion points for policymakers in light of the lifting of sanctions may be Iran's capacity for natural gas production and its role in the global energy market.

Figure 1. Global Natural Gas Consumption



Source: *BP Statistical Review of World Energy 2016*, p. 23.
Note: Units = billion cubic feet (bcf).

U.S. Consumption

In 2015, the United States consumed 27,463 bcf of natural gas, making up nearly 23% of total global consumption. The United States is the largest consumer overall of natural gas, and the second-largest consumer overall of energy in the world.

[18] For additional information on China's natural gas use, see CRS Report R44483, *China's Natural Gas: Uncertainty for Markets*, by Michael Ratner, Gabriel M. Nelson, and Susan V. Lawrence.

[19] U.S. Energy Information Administration, "Iran," June 19, 2015, http://www.eia.gov/beta/international/analysis_includes/countries_long/Iran/iran.pdf.

Electric power generation made up 35% of U.S. natural gas consumption in 2015; industrial use accounted for 27%, residential use for 17%, and commercial use for 12%.[20] There is a noted rise in the use of natural gas for electric power generation, which can be attributed to low natural gas prices due to the abundance of domestic gas resources, and to policies that promote the use of fuels with lower emissions. Demand for natural gas for power generation has more than doubled since 2000[21] and is expected to grow by 40% by 2040.[22]

The U.S. industrial sector increased its consumption of natural gas by 10% between 2010 and 2015.[23] As the United States continues to expand its growing resource base, the industrial sector will see a wider array of fuel and feedstock choices, and manufacturing industries such as bulk or primary metals could also experience further growth.[24]

Natural Gas Supply and Trade

Natural Gas Reserves Growing

Global proved natural gas reserves—natural gas that has been discovered and can be expected to be technically and economically produced—amounted to 6,599,400 bcf (or 6,599 trillion cubic feet (tcf)) in 2015, which correlates to a 53-year supply at current production levels (see **Figure 2**).[25] New reserves are developed every year as existing reserves are consumed. Global natural gas reserves have grown about 19% since 2005, demonstrating the success of exploration and improved recovery techniques.[26] Of the top 10 reserve holding companies all are majority owned by their respective governments (see **Appendix F**).

[20] U.S. Energy Information Administration, "How Much Natural Gas Is Consumed in the United States?," April 26, 2016, https://www.eia.gov/tools/faqs/faq.cfm?id=50&t=8.

[21] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. 24.

[22] Ibid., p. 25.

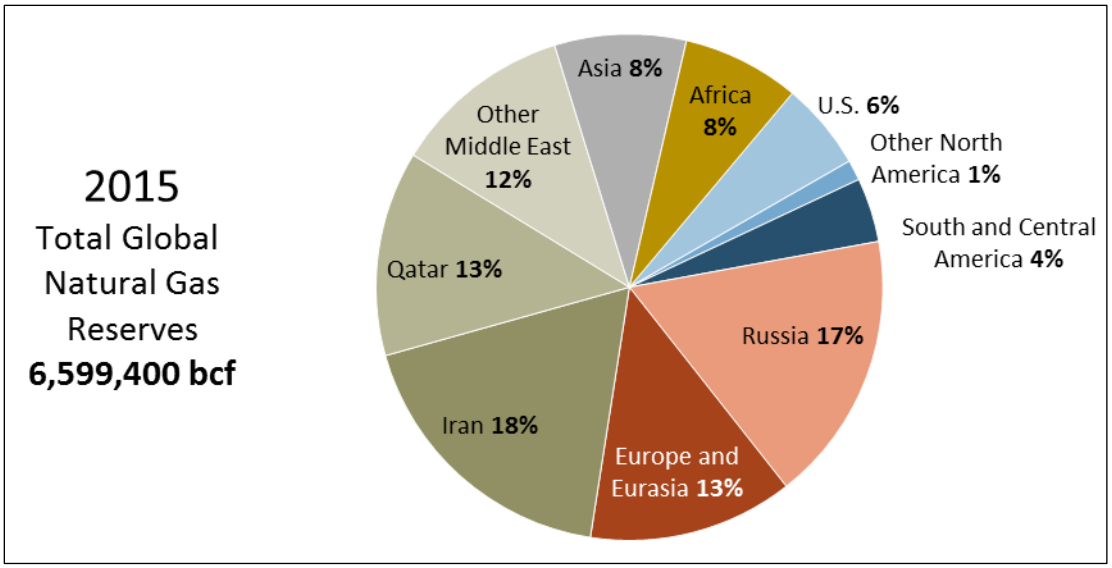
[23] U.S. Energy Information Administration, "Natural Gas Consumption by End Use," May 31, 2016, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.

[24] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. ES-6.

[25] *BP Statistical Review of World Energy 2016*, p. 21.

[26] Production has increased along with the addition to reserves, which is why the reserves-to-production ratio has stayed constant.

Figure 2. Global Natural Gas Reserves



Source: *BP Statistical Review of World Energy 2016*, p. 20.

Note: Units = billion cubic feet (bcf).

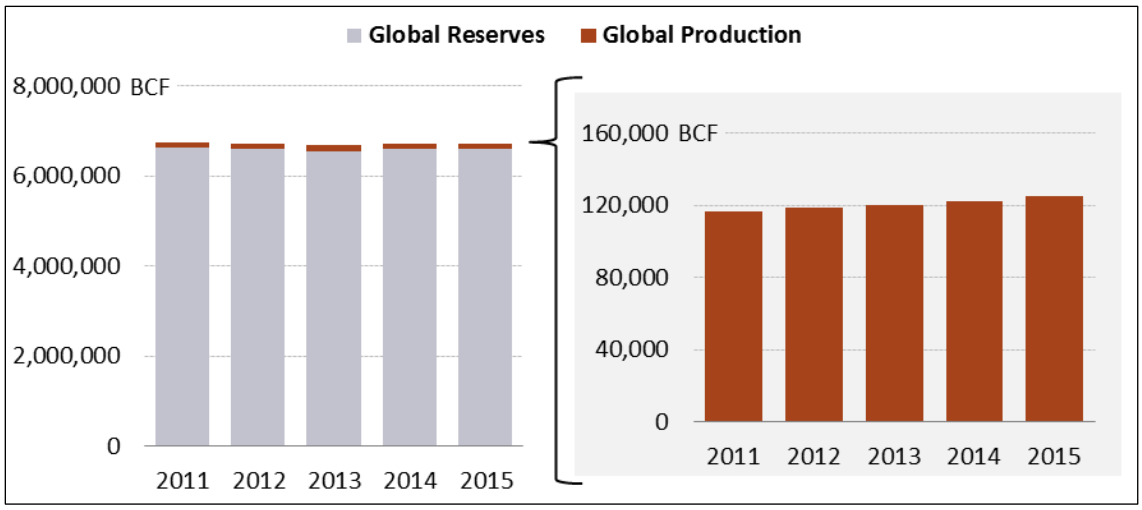
Globally, over half of the world's proven natural gas reserves are controlled by the top 10 government-owned companies, with all but one being 100% state-owned. Russia's Gazprom is majority-owned by the state and acts as an arm of the government. Iran's National Iranian Oil Company is the single largest reserve holder of natural gas.

In 2015, U.S. natural gas reserves were 368,700 bcf, about 5.6% of total world reserves.[27] The development of shale gas has been a huge driver behind the increase in U.S. natural gas resources (see **Figure 3**); in 2014, shale made up 51% of proven natural gas reserves.[28]

[27] *BP Statistical Review of World Energy 2016*, p. 20.

[28] U.S. Energy Information Administration, "U.S. Crude Oil and Natural Gas Proved Reserves, 2014," November 2015, p.15.

Figure 3. Annual Global Reserves and Production



Source: *BP Statistical Review of World Energy 2016.*

Note: Units = billion cubic feet (bcf)

Production

Global natural gas production in 2015 grew by 2.2%, which was below the 10-year average of 2.4%. Growth was below average in all regions except North America, Africa, and Asia Pacific. U.S. natural gas production accounted for 22% of total global production in 2015.

Between 2005 and 2015, total natural gas production in the United States increased 50%.[29] In 2015, the United States produced 27,086 bcf of natural gas, an increase from 25,716 bcf in 2014. The United States had the world's largest production increase, 5.4% (see **Figure 4**).[30] The increase in natural gas production can be attributed to the development of unconventional resources, specifically in the Marcellus and Utica shale formations, which have accounted for 85% of the increase in natural gas production since 2012.[31]

Overall, U.S. natural gas production is continually rising despite low prices. Between 2005 and 2015, production increased over 65%.[32]

By 2040, shale gas production is projected to increase 73% to 19.6 tcf, leading to a 45% overall increase in total U.S. natural gas production, from 24.4 tcf to 35.5 tcf.[33]

[29] *BP Statistical Review of World Energy 2016*, p. 22.

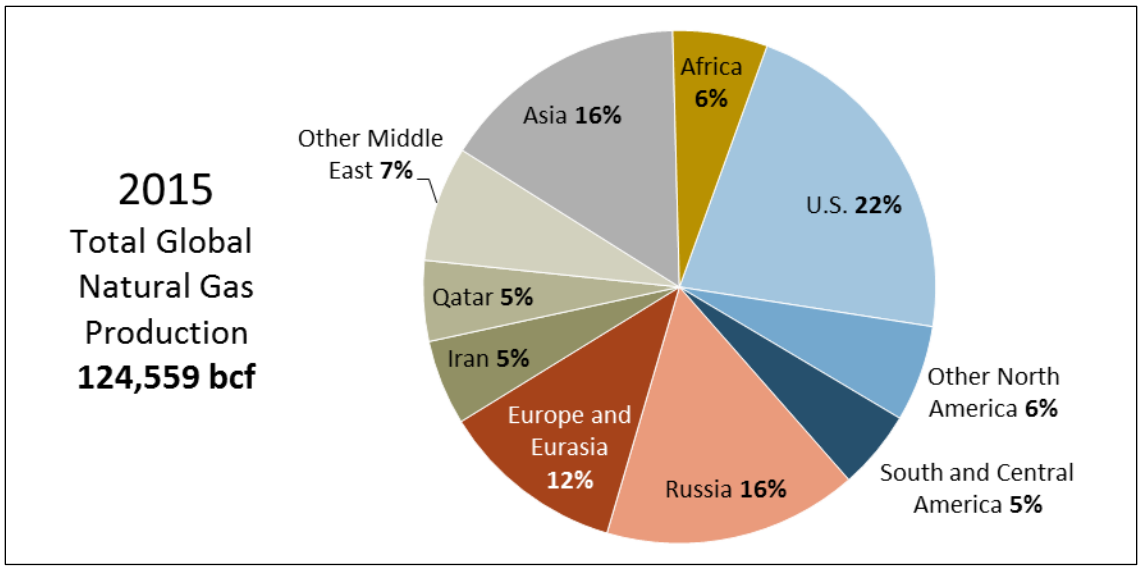
[30] Ibid.

[31] U.S. Energy Information Administration, "Marcellus, Utica Provide 85% of U.S. Shale Gas Production Growth since Start of 2012," July 28, 2015, https://www.eia.gov/todayinenergy/detail.cfm?id=22252.

[32] U.S. Energy Information Administration, "U.S. Dry Natural Gas Production," May 31, 2016, https://www.eia.gov/dnav/ng/hist/n9070us2A.htm.

[33] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. 20.

Figure 4. Global Natural Gas Production



Source: *BP Statistical Review of World Energy 2015*, p. 22.

Note: Units = billion cubic feet (bcf).

Liquefied Natural Gas

Liquefied natural gas (LNG) is natural gas that has been cooled to a liquid state, making it 600 times smaller in volume.[34] In its liquid form, natural gas can be shipped to global markets on tankers and received at LNG import terminals. LNG is becoming more prevalent in the global gas trade as new gas supplies are introduced to the market, further integrating regional gas markets.[35]

In 2015, LNG trade increased 1.8%, and the share of LNG in the global gas trade was 33%. In response to the increase in LNG trade, many countries are looking to expand their LNG export capacity. In 2016, Australia (in January) and the United States (in February) from the lower 48 launched their first shipments of LNG.

In the past decade, the United States prepared to increase imports of LNG based on forecasts of growing consumption, and began constructing LNG import terminals. However, the rise in prices gave the industry incentives to bring more domestic gas to market, reducing the need to use import terminals. Due to the abundance of domestic natural gas, there has been a push for modification and expansion of existing LNG terminals in order to expand U.S. export capacity, which requires authorization from the Department of Energy and the Federal Energy Regulatory Commission (FERC).[36]

[34] U.S. Energy Information Administration, "What Is LNG?," May 10, 2016, https://www.eia.gov/energyexplained/index.cfm?page=natural_gas_lng.

[35] Bud Coote, "Surging Liquefied Natural Gas Trade," Atlantic Council, January 2016, p. 4.

[36] For additional information on U.S. LNG exports, see CRS Report R42074, *U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes*, by Michael Ratner et al., U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes, by Michael Ratner et al.

U.S. Development and Growth

The U.S. natural gas market is in a period of transition. Technologies such as hydraulic fracturing and horizontal drilling have expanded the domestic natural gas supply, making possible the development of unconventional natural gas resources found in shale, coal seams, and tight lower-permeability rock formations.[37] Improved efficiency has lowered production costs, making shale gas economically competitive at almost any price.

Production has shifted away from the Gulf of Mexico to regions where sources of conventional natural gas are not traditionally found. (See **Figure 5**.) For instance, the Marcellus and Utica Basins are expansive shale resources located in the East and Northeast (West Virginia, Pennsylvania, New York, and Ohio). The location of these basins impacts the transportation of natural gas, as there is a reduced need for natural gas from the Rockies or Gulf Coast. The decrease in demand for gas from these areas and an increase in production from shale plays such as Marcellus have reduced prices and the number of imports needed from Canada and elsewhere.[38] Increased production in the future is expected from the Marcellus, Eagle Ford, Anadarko, Utica, and Haynesville Basins.[39]

Because of the development in supply, the United States has gone from being a net importer of natural gas to being a projected net exporter by 2017.[40] The first LNG shipments from the lower-48 occurred in February 2016 from the Sabine Pass LNG Terminal in Louisiana to Brazil, India, and the United Arab Emirates. On June 26, 2016, the Panama Canal reopened for commercial business, after undergoing construction for an additional ship traffic lane. The newly expanded canal eliminates about 10 days in transit time from the U.S. Gulf of Mexico to Asian markets, thus offering a potential shipping route for U.S. LNG. However, only 10% of LNG carriers are small enough to fit the canal; no LNG transits have been scheduled through the canal.[41]

The development in supply has placed the United States in a strategic position that may prove advantageous in the global natural gas market. However, this also raises questions for policymakers regarding the effects of the export of U.S. natural gas on domestic gas prices and the overall economy. Furthermore, questions remain about the size of U.S. shale gas resources; the price level required to sustain development; and whether there are technical, environmental, or political factors that might limit development.

The use and disposition of water in the industry process of hydraulic fracturing[42] is one of the main issues facing companies and regulators. As U.S. natural gas production continues to grow, this practice has raised concerns over the quality and quantity of drinking water in areas situated near hydraulic fracturing, the competition for other water users, and the disposal of wastewater. In 2010, the Environmental Protection Agency (EPA) announced that it would undertake a study

[37] Federal Energy Regulatory Commission, "Energy Primer: A Handbook of Energy Market Basics," July 2015, p. 10.

[38] Ibid., p. 16.

[39] The White House, *The Quadrennial Energy Review*, April 2015, pp. NG-6, http://energy.gov/sites/prod/files/2015/09/f26/QER_AppendixB_NaturalGas.pdf.

[40] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. ES-1.

[41] Jenny Mandel, "Panama Canal: They Built It. Will the LNG Tankers Come?" *EnergyWire*, June 23, 2016. http://www.eenews.net/energywire/2016/06/23/stories/1060039295.

[42] Hydraulic fracturing is an industry practice of pumping water and proppant, a granular material used to hold open fractures, into wells to improve recovery of natural gas. For additional information on hydraulic fracturing, see Appendix B of CRS Report R42032, *The Bakken Formation: Leading Unconventional Oil Development*, by Michael Ratner et al.

to assess any impact hydraulic fracturing might have on drinking water.[43] A final report has not been released.[44]

There is concern over deep-well injection and human-caused earthquakes. The wastewater produced from horizontal drilling and hydraulic fracturing is typically disposed through deep-well injection, in which the wastewater is injected into deep geologic strata. The concern is that deep-well injection may be linked to human-induced earthquakes, as the number of earthquakes of magnitude 3.0 or greater has increased.[45]

Emissions from the natural gas sector and the impact on human health is also a concern; specifically, methane emissions. As the primary component of natural gas, methane is a precursor to smog and a potent greenhouse gas.[46] While state and local authorities regulate natural gas systems, in 2012 the EPA established national minimum air standards, or New Source Performance Standards (NSPS), to reduce methane and volatile organic compound (VOC) emissions in the natural gas sector. In May 2016, the EPA updated the 2012 NSPS to include additional equipment in the gas production chain.[47] The NSPS include natural gas well sites, natural gas processing plants, and natural gas compressor stations.[48] Federal standards for methane emissions do not cover all sources of methane, such as offshore sources or coalbed methane production facilities. As the production of natural gas continues to expand in the United States, the issue of methane as an air pollutant may be a significant one for policymakers.

[43] In its FY2010 Appropriations Committee Conference Report, Congress directed the EPA to study the relationship between hydraulic fracturing and drinking water, P.L. 111-88, H.Rept. 111-316, see Title II—Environmental Protection Agency Science and Technology.

[44] For additional information on hydraulic fracturing and drinking water issues, see CRS Report R41760, *Hydraulic Fracturing and Safe Drinking Water Act Regulatory Issues*, by Mary Tiemann and Adam Vann.

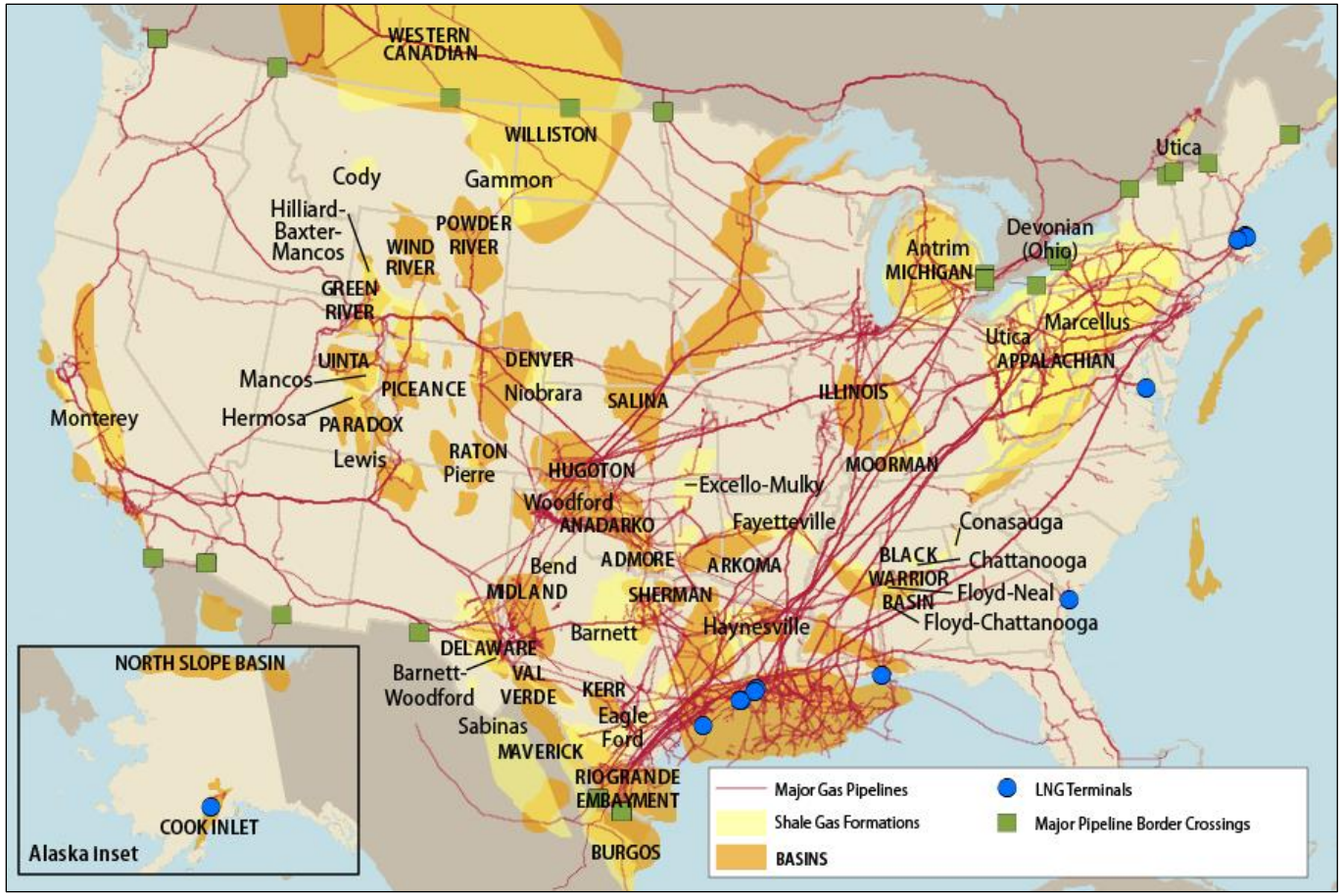
[45] For additional information on human-induced earthquakes and deep-well injection, see CRS Report R43836, *Human-Induced Earthquakes from Deep-Well Injection: A Brief Overview*, by Peter Folger and Mary Tiemann.

[46] Environmental Protection Agency, "Fact Sheet: EPA's Strategy for Reducing Methane and Ozone-Forming Pollution from the Oil and Natural Gas Industry," January 14, 2015, https://yosemite.epa.gov/opa/admpress.nsf/0/BA7961BF631C87BF85257DCD00526FF7.

[47] Environmental Protection Agency, "EPA's Actions to Reduce Methane Emissions from the Oil and Natural Gas Industry: Final Rules and Draft Information Collection Request," 2016, https://www3.epa.gov/airquality/oilandgas/may2016/nsps-overview-fs.pdf.

[48] Environmental Protection Agency, "Sources Covered by the 2012 New Source Performance Standards (NSPS) for VOCs and the 2016 NSPS for Methane and VOCs, by Site," May 12, 2016, https://www3.epa.gov/airquality/oilandgas/may2016/nsps-table.pdf.

Figure 5. U.S. Natural Gas Network



Source: Created by CRS using data from Platt's 2016 and Esri 2014.

Note: Hawaii is not included, as it does not produce natural gas or possess proved natural gas reserves.

Global Gas Market Becoming More Integrated

Although most natural gas is consumed in the country where it is produced, global and regional markets are becoming more integrated (see **Figure 6**). About 30% of natural gas is traded internationally, mostly within regional markets, and the amount of natural gas traded is increasing. Natural gas is transported primarily in two ways: by pipeline, and as a liquid in tankers. Pipelines transport gas between two fixed points, while LNG provides flexibility in the final destination. Global LNG trade increased by 1.8% in 2015, and LNG's share of the global gas trade was 33%.[49]

Traditionally, natural gas is sold under long-term contracts indexed to oil prices, except in the United States and a few other places where natural gas prices are market-based.[50] U.S. LNG exports have placed pressure on other countries to delink their gas exports from oil-indexed prices. Almost all natural gas that is traded internationally is under long-term contracts, usually 20 years in length, whether it is by pipeline or as LNG. This is primarily because natural gas transportation is expensive and long-term contracts are needed to finance construction of the transport facilities. Sometimes LNG consumers do not require the entire amount of natural gas in their contracts. LNG producers can sell the excess to other consumers on a one-time or short-term basis (e.g., sell it on "spot"). The spot market for natural gas is growing.

Russia is the world's largest natural gas exporter, primarily through its massive pipeline network to Europe. Russia opened its first LNG export terminal in 2009, primarily targeting the Asian market, to give it flexibility in its exports. Qatar is the leading exporter of LNG, accounting for 31% of the world LNG trade in 2015, the majority of which goes to Asia and Europe. Europe is the largest importing region of natural gas, receiving most of its imports by pipeline from Russia, Norway, and Algeria; however, recent developments regarding Russia and the Ukraine have pushed the European Union to consider more secure sources of natural gas.[51] Asia, the most import-dependent region, relies mostly on LNG; however, China has become more reliant on imported gas via pipeline, from Kazakhstan, Myanmar, and Turkmenistan. China has been Turkmenistan's primary importer of natural gas, with more than 70% of Turkmenistan's exports going to China in 2015.

Currently, the United States and Canada have an extensively integrated pipeline system. Canada and Mexico are the only recipients of U.S. natural gas by pipeline. Exports are expected to increase to Mexico, from 1 tcf in 2015 to almost 1.5 tcf in 2040.[52] Meanwhile, exports to Canada are projected to slightly rise from 0.7 tcf to 0.75 tcf, over the same time period.

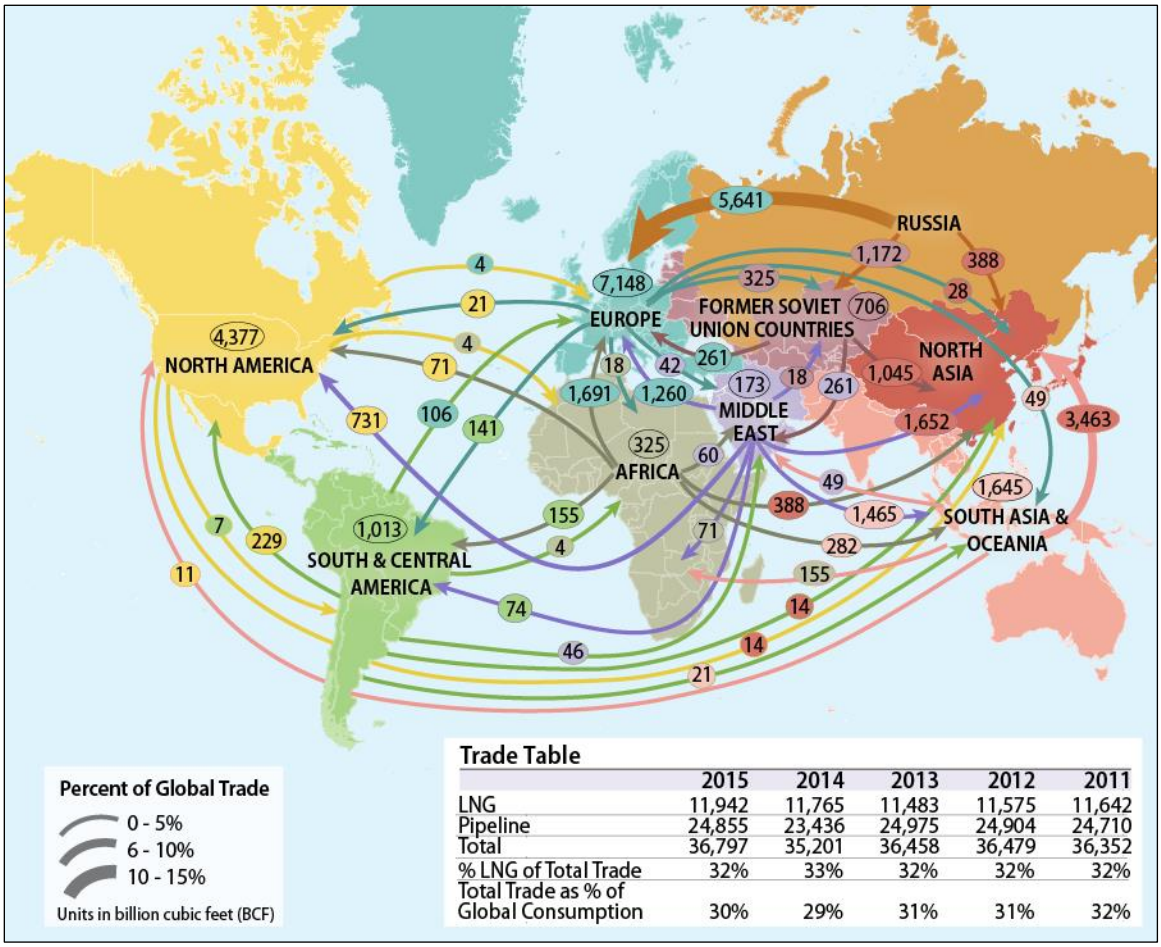
[49] *BP Statistical Review of World Energy 2016*, p. 28.

[50] "Step On It," *The Economist*, January 30, 2016.

[51] For additional information on Europe and natural gas, see CRS Report R42405, *Europe's Energy Security: Options and Challenges to Natural Gas Supply Diversification*, coordinated by Michael Ratner.

[52] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. 22.

Figure 6. Global Natural Gas Trade, 2015



Source: *BP Statistical Review of World Energy, 2016*, p. 28.

U.S. LNG Exports

U.S. LNG prices are market-based, resulting in a price differential that may create an economic incentive for the United States to export domestically produced natural gas. In February 2016, the first cargo of U.S. LNG was shipped from the Sabine Pass Liquefaction export terminal in Louisiana to Brazil.

The export of U.S. LNG has been the center of debate for policymakers, with questions focusing on how U.S. natural gas may affect the global market and geopolitics, as well as domestic prices.

As of April 2016, there is one LNG export terminal in operation and several LNG export terminal projects under construction in the lower-48 states:

- Additional LNG "trains" at Sabine Pass Liquefaction in Sabine, LA;
- Dominion-Cove Point LNG in Cove Point, MD;
- Cameron LNG in Hackberry, LA;

- Freeport LNG Expansion/FLNG Liquefaction in Freeport, TX; and
- Cheniere Marketing-Corpus Christi LNG in Corpus Christi, TX.[53]

The Kenai LNG terminal, which began operations in 1969 in Alaska, continues to operate, primarily supplying LNG to Japan.

Also, in February 2016, the United States began shipping quantities of LNG to Barbados from Miami, FL. The LNG was shipped to Barbados in cryogenic containers instead of a specialized tanker ship. Cryogenic containers are comparable to shipping containers and can be transported over land and loaded onto ships. The natural gas from these shipments has been sold at a higher price than the Sabine Pass exports, ranging from $10 per MBtus to almost $16 per MBtus. In 2014, a relatively small amount of LNG was shipped to Honolulu, HI, using this method, the first time to the state.

Alaska has great potential to become a major source of natural gas. The United States Geological Survey (USGS) estimates that conventional natural gas resources on Alaska's North Slope may potentially exceed 200,000 bcf,[54] more than eight times the total amount of current U.S. gas consumption. However, the majority of gas produced in Alaska is used for reinjection to boost oil production and is not brought to market. Alaskan officials have pushed for a pipeline to be constructed in order to sell natural gas internationally as LNG, but as of 2016 this is considered commercially challenging.

Future Developments and Trends, Global and Domestic

In February 2016, the Trans-Pacific Partnership (TPP) free trade agreement (FTA) was signed between the United States and Singapore, Brunei, New Zealand, Chile, Australia, Peru, Vietnam, Malaysia, Mexico, Canada, and Japan.[55] The TPP may have an impact on the U.S. natural gas trade, as permits for natural gas exports to countries with which the United States has an FTA receive expedited approval under the Natural Gas Act. Thus membership in the TPP would, in effect, grant free trade status to key consumers of LNG. A trade agreement called the Transatlantic Trade and Investment Partnership (TTIP) has been proposed between the United States and the EU, with the aim of promoting trade and economic growth. The areas the TTIP addresses include market access, regulation, and rules and principles for cooperation, and it would, in effect, also give free trade status to signatories regarding natural gas. Neither TPP nor TTIP has been ratified.

In December 2015, the United Nations Climate Change Conference, or COP-21, was held in Paris; the objective of the conference was to address climate change and come to a universal agreement on steps needed to mitigate it. The conference resulted in the Paris Agreement, which establishes governing measures regarding emissions mitigations, adaptation, and finance. The United States signed the agreement on April 22, 2016.

It is noteworthy that U.S. infrastructure expansion, maintenance, and construction may not be able to keep up with its growing supplies; 50% of gas transmission and gathering pipelines were built in the 1950s and 1960s. It is estimated that investment in natural gas interstate pipelines may

[53] FERC, "North American LNG Import/Export Terminals Approved," April 4, 2016, https://www.ferc.gov/industries/gas/indus-act/lng/lng-approved.pdf.

[54] Emil D. Attanasi and Philip A. Freeman, "Economics of Undiscovered Oil and Gas in the North Slope of Alaska: Economic Update and Synthesis," U.S Geological Survey, 2009.

[55] For additional information on the Trans-Pacific Partnership, see CRS Report R44489, *The Trans-Pacific Partnership (TPP): Key Provisions and Issues for Congress*, coordinated by Ian F. Fergusson and Brock R. Williams.

range from $2.6 billion to $3.5 billion annually between 2015 and 2030.[56] This amount of investment may prove difficult to raise given other infrastructure demands.

Other issues that may affect both the domestic and international markets will be oil prices; new infrastructure; technological development; increased interdependence between the gas and electric sectors; and climate and environmental policy.[57]

Gas Exporting Countries Forum Still Ineffective

The Gas Exporting Countries Forum (GECF), also referred to as gas OPEC (Organization of the Petroleum Exporting Countries), is a nascent cartel organization based in Qatar comprising 11 natural gas producing countries (**Table 1**). The GECF was formed in 2001, signing an organizing charter in 2008. Together, the countries account for 62% of global natural gas reserves, 57% of the LNG trade, and 39% of the pipeline gas trade. Given the U.S. resource base of natural gas, it is highly unlikely that the GECF could significantly affect U.S. natural gas consumption within the next five years or, most likely, longer. Canada, by far the largest source of imported natural gas to the United States, is not a member of the GECF. Europe is probably most vulnerable to possible cartel control, as more than half its imports come from cartel members, particularly Russia and Algeria. Nevertheless, the current structure of natural gas markets (i.e., long-term contracts and pipelines connecting individual sellers to specific buyers) is not conducive to supply or price manipulation, and significant changes would need to be made to how natural gas is brought to market and sold before the GECF could have influence.

Table 1. GECF Natural Gas Statistics 2015

units = billion cubic feet

	Reserves	Production	LNG Exports	Pipeline Exports	Total Exports
Algeria*	159,100	2,930	571	881	1,452
Bolivia	9,900	736	0	571	571
Egypt♯	65,200	1,609	0	11	11
Equatorial Guinea♯	2,121	217	176	0	176
Iran*	1,201,400	6,794	0	295	295
Libya*	53,100	450	0	228	228
Nigeria*♯	180,500	1,767	972	21	993
Qatar*	866,200	6,405	3,755	698	4,453
Russia	1,139,600	20,238	513	6,813	7,326
Trinidad & Tobago	11,500	1,399	601	0	601
UAE*♯	215,100	1,968	270	132	402
Venezuela*	198,400	1,145	0	0	0

[56] Department of Energy, *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure*, April 2015, p.S-5.

[57] Department of Energy, *Quadrennial Energy Review: Appendix B*, April 2015, p. NG-2.

	Reserves	Production	LNG Exports	Pipeline Exports	Total Exports
TOTAL GECF	4,102,121	45,659	6,858	9,651	16,509
% of World	62%	37%	57%	39%	45%

Sources: *BP Statistical Review of World Energy 2016* and Cedigaz statistical databases.

Notes: * denotes a member of OPEC, ♯ denotes some data from 2014.

Production Widespread

Overall, global natural gas production in 2015 grew by 2.2%, which was below the 10-year average of 2.4%. The United States surpassed Russia as the world's largest natural gas producer in 2009. The success of the United States to date and the potential for further shale gas development has initiated an evaluation by most countries of their potential natural gas resources. However, outside of Canada, whose shale gas industry is developing alongside that of the United States, it is unlikely that significant commercial production will be achieved before the end of the decade in another country. Most countries looking at shale gas currently do not have the data, technology, or equipment required to evaluate their shale gas resources, let alone successfully exploit them.

Natural Gas Prices Remain Low

The price of natural gas in the United States, Canada, and the United Kingdom is set by the market, with centers or hubs providing buyers and sellers with competitive price data (see **Figure 7**). The most well-known hub in the United States is the Henry Hub in Erath, LA, where multiple interstate and intrastate natural gas pipelines interconnect. There are various prices for natural gas in the United States depending on the category of consumer. Residential consumers pay the highest price, followed by various commercial users.[58]

By 2040, the Henry Hub natural gas spot price is projected by EIA to rise to $7.85 per million British thermal units (MBtu) due to increased domestic and international demand. This would require an increase in the number of well completions in order to meet higher production levels.[59] EIA's projection is based on existing information and does not account for significant changes in the market, such as new technologies, regulations, or discoveries.

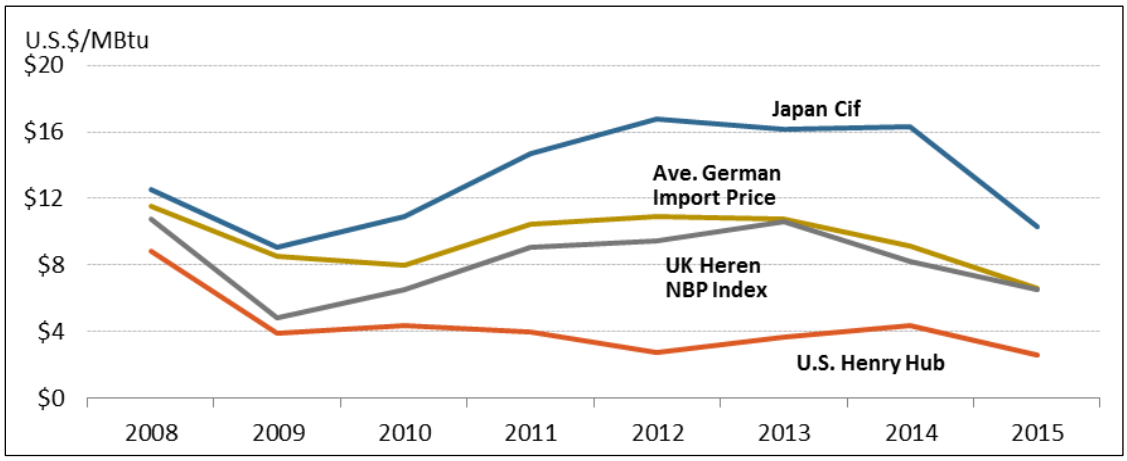
Outside the United States, Canada, and the United Kingdom, almost all wholesale natural gas is sold under long-term contracts. The price of natural gas within these contracts is commonly determined by a formula that links the natural gas price to the price of crude oil or some oil-based product. Although in many markets natural gas no longer competes as a substitute against oil-based products, this vestige of the contracts has remained. Over the last several years, the disparity between contract prices and spot prices has raised pressure on gas producers to do away with this concept. However, the recent fall in world oil prices may suspend this debate. Nevertheless, some producers have started incorporating a spot price for natural gas into their pricing formulas. The price differences reflect the regional nature of the natural gas industry and the disparity between contract and spot prices. Asia, in particular, has been willing to pay high prices to secure its natural gas supplies.

[58] EIA tracks gas prices at the well (which is the lowest price), industrial prices for manufacturing and other uses, commercial prices for nonmanufacturing activities, electric power, and residential use.

[59] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. 6.

Figure 7. Global Natural Gas Prices

U.S. dollars per million British thermal unit (U.S.$/MBtu)



Source: *BP Statistical Review of World Energy 2016*, p. 27.

Note: Contract price is a long-term price between a specific buyer and a specific seller, while the spot price is a short-term market price.

Two other contract concepts are worth highlighting: take-or-pay clauses and destination clauses. With a take-or-pay clause, a buyer of natural gas must pay the seller regardless of whether it actually receives the natural gas. Typically, in contracts, buyers must purchase at least 80% of the total volume of natural gas contracted. For example, if a contract is for 100 bcf, but the buyer only needs 80 bcf, then that is all it pays for; but if the buyer only needs 50 bcf, it still must pay for an additional 30 bcf even if it cannot use it. A destination clause allows a cargo to be redirected to a different destination and buyer. Such a clause was not common until recent years and contributes to a more efficient market.

Looking Forward

Is it time for natural gas to take center stage as the world's primary energy source? That is the main question confronting the natural gas industry over the next decade. The International Energy Agency (IEA) states that natural gas is one of the fastest growing fossil fuels, with an increase in demand of approximately 60% in 2040 over 2013;[60] natural gas is a major alternative for a world that looks to gradually decarbonize its energy system. Most of the new demand for natural gas is projected to come from non-OECD countries, primarily China and those in the Middle East. Nonetheless, the global landscape for energy is shifting; as North America continues to produce unconventional gas, the rest of the world's exploration of unconventional resources is occurring more gradually.

China is typically a driver in global energy trends. Recently, China has decided to change its economic model, shifting away from an industry-heavy economy to a services-focused one. This change will require 85% less energy to generate future Chinese growth;[61] consequently, predictions are uncertain regarding China's future in energy consumption. India, on the other hand, is projected to be a growing contributor to global energy demand, accounting for 25% of

[60] International Energy Agency, *World Energy Outlook 2015*, November 10, 2015, p. 195.

[61] International Energy Agency, *World Energy Outlook 2015*, p. 292.

the rise in global energy use to 2040.[62] However, meeting India's energy demand may prove to be a huge financial commitment—nearly $2.8 trillion. Natural gas comprises about 6% of India's primary energy supply, and is projected to make up less than 10% of India's energy mix in 2040.[63]

Sectorally, the U.S. electric power industry leads the growth in natural gas demand due to several factors, including relatively low prices, lower capital costs, excess natural gas generation capacity, and competitive financing of projects. Government policies, particularly in regard to carbon dioxide emissions, will be a key factor in determining the rate of growth of natural gas usage. Globally, natural gas is projected to account for 28% of total world electricity generation in 2040,[64] with non-OECD countries representing 61% of this.

Natural gas production would likely need to increase to meet the rise in demand and keep prices from dramatically rising. Production and growth is projected in every region except Europe. Unconventional gas resources[65]—coal bed methane, shale gas, and tight gas—account for about 60% of growth in the global gas supply. However, outside of North America unconventional resource development is slower and uneven. China does have policies that encourage production, but limited water availability, geology, and population density in resource-rich areas may hinder any attempts to fully realize its capacity.

[62] International Energy Agency, *World Energy Outlook 2015*, p. 547.

[63] International Energy Agency, *World Energy Outlook 2015*, p. 465.

[64] U.S. Energy Information Administration, "International Energy Outlook 2016," 2016, p. 82, http://www.eia.gov/forecasts/ieo/pdf/0484(2016).pdf.

[65] For further information, see U.S. Energy Information Administration, "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," June 12, 2013.

Appendix A. Global Natural Gas Consumption (2015)

Rank	Country	Consumption (bcf)	Share of World
1	United States	27,463	23%
2	Russia	13,820	11%
3	China	6,965	6%
4	Iran	6,749	6%
5	Japan	4,003	3%
6	Saudi Arabia	3,756	3%
7	Canada	3,618	3%
8	Mexico	2,937	2%
9	Germany	2,633	2%
10	UAE	2,439	2%
11	United Kingdom	2,411	2%
12	Italy	2,167	2%
13	Thailand	1,867	2%
14	India	1,786	2%
15	Uzbekistan	1,783	1%
16	Egypt	1,776	1%
17	Argentina	1,687	1%
18	Qatar	1,677	1%
19	South Korea	1,596	1%
20	Turkey	1,539	1%
	Rest of World	29,769	25%
	Global Total	122,442	100%

Source: *BP Statistical Review of World Energy 2016*, p. 23.

Note: Units = billion cubic feet (bcf).

Appendix B. Global Natural Gas Reserves (2015)

Rank	Country	Reserves (bcf)	Share of World
1	*Iran*	1,201,400	18%
2	*Russia*	1,139,600	18%
3	*Qatar*	866,200	13%
4	Turkmenistan	617,300	9%
5	United States	368,700	6%
6	Saudi Arabia	294,000	5%
7	*UAE*	215,100	3%
8	*Venezuela*	198,400	3%
9	*Nigeria*	180,500	3%
10	*Algeria*	159,100	2%
11	China	135,700	2%
12	Iraq	130,500	2%
13	Australia	122,600	2%
14	Indonesia	100,300	2%
15	Canada	70,200	1%
16	Norway	65,600	1%
17	Egypt	65,200	1%
18	Kuwait	63,000	1%
19	Libya	53,100	1%
20	India	52,600	1%
	Rest of World	500,300	6%
	Global Total	6,599,400	100%

Source: *BP Statistical Review of World Energy 2061*, p. 20.

Notes: Italics indicate GECF member. Units = billion cubic feet (bcf).

Appendix C. Global Natural Gas Production (2015)

Rank	Country	Production (bcf)	Share of World
1	United States	27,086	22%
2	*Russia*	20,238	16%
3	*Iran*	6,794	5%
4	*Qatar*	6,405	5%
5	Canada	5,773	5%
6	China	4,870	4%
7	Norway	4,135	3%
8	Saudi Arabia	3,757	3%
9	*Algeria*	2,930	2%
10	Indonesia	2,649	2%
11	Turkmenistan	2,556	2%
12	Malaysia	2,408	2%
13	Australia	2,367	2%
14	Uzbekistan	2,039	2%
15	*UAE*	1,968	2%
16	Mexico	1,878	1%
17	*Nigeria*	1,767	1%
18	*Egypt*	1,609	1%
19	Netherlands	1,519	1%
20	Pakistan	1,480	1%
	Rest of World	20,677	18%
	Global Total	124,913	100%

Source: *BP Statistical Review of World Energy 2016*, p. 22.

Notes: Italics indicate GECF member. Units = billion cubic feet (bcf). Totals may not add due to rounding.

Appendix D. U.S. Natural Gas Imports and Exports

Table D-1. U.S. Imports of Natural Gas

billion cubic feet (bcf)

Rank	Country	2010-2015 Average	2015 Imports	Share of U.S. Imports	2015 Imports as a Share of U.S. Consumption
1	Canada	967	2,626	97%	10%
2	*Trinidad & Tobago*	102	71	3%	<0.5%
3	Norway	12	12	<0.5%	<0.5%
4	Yemen	24	7	<0.5%	<0.5%
5	Mexico	6	1	<0.5%	<0.5%
6	*Egypt*	18	0	0%	0%
7	*Nigeria*	8	0	0%	0%
8	Peru	5	0	0%	0%
9	*Qatar*	30	0	0%	0%
TOTAL		1,173	2,718	100%	10%

Source: EIA's U.S. Natural Gas Imports by Country, https://www.eia.gov/dnav/ng/ng_move_impc_s1_m.htm.

Notes: Italics indicate GECF member. The United States had imported LNG from Australia, Brunei, Indonesia, and UAE prior to the time period examined in this table. Totals may not add due to rounding.

Table D-2. U.S. Exports of Natural Gas

billion cubic feet (bcf)

Rank	Country	2010-2015 Average	2015 Exports	2015 Share of U.S. Exports	2015 Exports as a Share of U.S. Production
1	Mexico	649	1,054	59%	4%
2	Canada	597	701	39%	3%
3	Japan	13	8	<0.5%	<0.5%
4	Taiwan	1	8	<0.5%	<0.5%
	Other	262	13	1%	
TOTAL		1,522	1,784	100%	7%

Source: EIA's *U.S. Natural Gas Exports by Country*, https://www.eia.gov/dnav/ng/ng_move_expc_s1_a.htm.

Notes: The United States has exported natural gas as LNG to both Canada and Mexico in addition to its more traditional pipeline exports. The LNG exports are incorporated into the figures above, but are negligible. 2016 U.S. LNG exports not included. Totals may not add due to rounding.

Appendix E. Global Natural Gas Exporters (2015)

Rank	Country	Pipeline	LNG	Total	Share of World
1	*Russian Federation*	6,813	512	7,325	20%
2	*Qatar*	699	3,756	4,455	12%
3	Norway	3,865	212	4,077	11%
4	Canada	2,623	0	2,623	7%
5	United States	1,754	7	1,761	5%
6	*Algeria*	883	572	1,454	4%
7	Netherlands	1,433	0	1,433	4%
8	Australia	0	1,405	1,405	4%
9	Turkmenistan	1,345	0	1,345	4%
10	Malaysia	0	1,207	1,207	3%
	Rest of World	5,440	4,271	9,711	26%
	Global Total	24,855	11,942	36,797	100%

Source: *BP Statistical Review of World Energy 2016*, p. 29.

Notes: Italics indicate GECF member. Units = billion cubic feet (bcf). Totals may not add due to rounding.

Appendix F. Major Global Gas Companies (2014)

Rank	Company	Country	Output (MMcf/d)
1	*Gazprom*	Russia	45,130
2	*NIOC*	Iran	16,699
3	*Qatar Petroleum*	Qatar	11,670
4	Exxon Mobil	United States	11,145
5	*CNPC*	China	11,017
6	*Saudi Aramco*	Saudi Arabia	10,473
7	Royal Dutch Shell	Netherlands/UK	9,259
8	*Sonatrach*	Algeria	7,649
9	BP	UK	7,100
10	*Petronas*	Malaysia	6,310

Source: "Top 50 and Rankings in Six Operational Criteria," *Petroleum Intelligence Weekly* 54, no. 46 (November 16, 2015): Special Supplement, pp. 2-3. Italics = majority state owned.

Rank	Company	Country	Reserves (bcf)
1	*NIOC*	Iran	1,201,405
2	*Gazprom*	Russia	667,268
3	*Qatar Petroleum*	Qatar	632,726
4	*Saudi Aramco*	Saudi Arabia	288,400
5	*PDV*	Venezuela	198,368
6	*Sonatrach*	Algeria	159,100
7	*INOC*	Iraq	126,700
8	*Adnoc*	UAE	121,260
9	*CNPC*	China	109,498
10	*NNPC*	Nigeria	106,262

Source: "Top 50 and Rankings in Six Operational Criteria," *Petroleum Intelligence Weekly* 54, no. 46 (November 16, 2015): Special Supplement, pp. 2-3. Italics = majority state owned.

Appendix G. Select U.S. Statutes Related to Natural Gas

Act	U.S. Code Citation	Purpose
Natural Gas Act	15 U.S.C. §717b et seq.	Governs siting of interstate natural gas pipelines and interstate transmission of natural gas. Also gives authority to DOE for imports and exports of liquefied natural gas.
Natural Gas Wellhead Decontrol Act of 1989	15 U.S.C. §3301 et seq.	Removed remaining price ceilings on natural gas sales.
Mineral Leasing Act of 1920	30 U.S.C. §181 et seq.	Governs leasing activity on federal lands, including leases for purposes of oil and natural gas exploration and production.
Outer Continental Shelf Lands Act	43 U.S.C. §1331 et seq.	Governs activities on Outer Continental Shelf, including leasing for purposes of oil and natural gas exploration and production.
Natural Gas Pipeline Safety Act of 1968	49 U.S.C. §60101 et seq.	Authorizes DOT to regulate pipeline transportation of natural gas and other gases as well as the transportation and storage of LNG.
Natural Gas Policy Act of 1978	15 U.S.C. §3301 et seq.	Gave FERC authority over intrastate and interstate natural gas production. The act also set price ceilings for natural gas.
Homeland Security Act of 2002	6 U.S.C. §101 et seq.	Incorporated the Transportation Security Administration (TSA), which has jurisdiction for natural gas pipeline security, into the Department of Homeland Security.
The Clean Air Act of 1970	42 U.S.C. §7401 et seq.	Comprehensive federal law that regulates air emissions from stationary and mobile sources. Authorizes the EPA to establish National Ambient Air Quality Standards (NAAQS) to protect public health and welfare, and to regulate emissions of hazardous air pollutants.
PIPES Act of 2016 (Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2016)	49 U.S.C. §60101 et seq.	Reauthorizes the Pipeline and Hazardous Materials Safety Administration's (PHMSA's) oil and gas pipeline programs through 2019. Gives Secretary of Transportation the power to quickly issue emergency orders for the pipeline industry. Requires the PMHSA to develop national regulations for the construction and operation of underground natural gas storage facilities, and ensures that the PMHSA completes directives set in previous pipeline safety bill in 2011.

Source: Compiled by the Congressional Research Service (CRS).

Notes: The above list is not exhaustive, but highlights important statutes that relate to natural gas. Certain sections of the acts referenced may be codified in other parts of the U.S. Code.

Author Information

Michael Ratner
Specialist in Energy Policy

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