Energy 101: Introduction to Natural Gas

From the CSIS Energy & National Security Program

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Natural gas is a combustible, gaseous fossil fuel that is the third-most widely used energy source in the world, accounting for approximately 21 percent of total primary energy demand in 2012. Natural gas can be produced either on its own or alongside oil production (the latter is referred to as "associated gas").

Recently, 'unconventional' gas production techniques have become common in the United States. Natural gas is often referred to as conventional or unconventional, but that classification has to do with the technique of extraction, not with the chemical or physical properties of the natural gas itself. Shale gas, tight gas, and coalbed methane are all examples of unconventional gas.

Gas is classified as either wet or dry depending on whether the gas contains so-called natural gas liquids (NGLs) such as ethane, butane, and propane (which are liquid at room temperature). These NGLs can be stripped out of the gas through processing and sold separately. NGLs have multiple and different uses from dry natural gas (which comprises just methane or CH_4), such as feedstock for petrochemicals and as a cooking fuel. Natural gas is also classified according to its hydrogen sulfide content as either sweet or sour.

The Natural Gas Value Chain

Natural gas is produced all over the world. Like oil, natural gas is found in geologic formations deep underground and must be brought to the surface. The cost of production depends on a host of factors, such as the geologic characteristics of the reservoir, the technology deployed, and regulation.

Quick Facts about Natural Gas

- Natural gas is measured in cubic feet, cubic meters, and British Thermal Units (BTU).
- The majority of proved gas reserves are in the Middle East (43 percent), Europe and Eurasia (31.2 percent), and Asia Pacific (8.2 percent).
- The United States has the fourth-largest gas reserves in the world, behind Russia, Qatar, and Iran (and by some accounts Turkmenistan).
- Major gas exporters include Qatar, Russia, and Australia, while major importers of natural gas are Germany, Japan, Italy, the United Kingdom, and South Korea.
- Total world natural gas production in 2013 was about 119 trillion cubic feet (tcf); the United States accounted for about 20 percent of global production. The OECD as a whole produced about 36 percent.
- Total world consumption of natural gas in 2013 was 118 tcf, of which total OECD consumed 48 percent and the United States alone consumed 22 percent.
- The United States is a net importer of natural gas; exports were 1.5 tcf gas in 2013, the vast majority of which were pipeline exports to Canada and Mexico.
- Unconventional gas comprises about 67 percent of U.S. dry gas production today. That figure is projected to rise to around 79 percent by 2040.

Recently, new "unconventional" techniques, often referred to as hydraulic fracturing but composed of fracturing, horizontal drilling, and other imaging technologies, have been used to extract natural gas from geologic formations that had previously been too challenging and expensive. By expanding the ability of drillers to access previously inaccessible gas trapped in low-porosity, low-permeability rock formations, hydraulic fracturing and horizontal drilling have made otherwise non-economic gas accessible. So far, these production techniques have not been successfully deployed at scale beyond North America, despite promising geology and significant interest. Analysts, countries, and companies are closely watching the scope and pace of international unconventional gas production.

Most natural gas is produced conventionally, and production for international markets is concentrated among relatively few producer countries, including Qatar, Russia, and Australia. The United States, Canada, and a handful of other countries are also set to become important natural gas producers.

Once it is produced, natural gas is transmitted via pipelines for processing. Natural gas processing removes impurities and brings natural gas in line with the quality measures necessary for it to be transported through large pipeline transmission and distribution networks to its destination for storage or consumption. In the United States, this network is extensive, encompassing over 300,000 miles of pipeline and 11,000 delivery points. Natural gas is stored in underground caverns.

Natural gas can also be transported as a liquid, although it is much more expensive. The share of natural gas traded as liquefied natural gas (LNG) is growing.

Natural Gas Consumption

There are three main end-use consumers of natural gas: residential and commercial users (for heating and cooking), who accounted for about a third of consumed gas in the United States in 2014; industrial users (for electricity generation, heating, and industrial processes), who accounted for 29 percent of consumed gas in the United States in 2014; and electric utilities (for electricity generation), who accounted for just over 30 percent of consumed gas in the United States in 2014. Small amounts are also used in oil and gas industry operations as pipeline fuel and in transportation (about 9 percent of consumed gas in the United States in 2014).

Gas accounted for 22 percent of electricity generated globally (2012) and 27 percent of U.S. electricity generation in 2013. It has increased its share of generation relative to coal in the United States in recent years, but coal remains significantly cheaper in most of the rest of the world. The use of natural gas in the electricity sector also varies considerably by region and globally. Whether natural gas will retain and expand its market share in the United States and elsewhere depends on a number of factors, including the long-term level and stability of natural gas prices, the regulation of greenhouse gas emissions from power plants, the expansion of natural gas use beyond the electricity sector, and infrastructure build-out.

Driven by high gasoline and diesel prices, natural gas has been making inroads into the transportation sector. The outlook, however, varies by mode of transportation and country. In most countries, it is currently more cost-effective to shift heavy-duty fleet vehicles to natural gas than light-duty passenger vehicles. There are currently limited government incentives for natural gas light-duty passenger vehicles, and the inroads in this sector have been narrow across most Organization for Economic Cooperation and Development (OECD) countries. However, in many other countries—notably China, Pakistan, and Iran—natural gas vehicles comprise a larger share of the passenger vehicle fleet.

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Natural Gas Markets

Compared with other commodity markets (especially the markets for other fossil fuels), natural gas markets are more regionalized. The global natural gas trade has been inhibited by the relative difficulty and expense of transporting it long distances. As a gas, it can be transported via pipeline (primarily over relatively short distances), but to be sent via ship it must be processed and cooled to extremely low temperatures and shipped under high pressure, at significant cost relative to the value of the commodity. Currently, there are several regional natural gas markets: Europe, Asia-Pacific, and North America. An integrated global market may be gradually emerging as LNG becomes more common and the economics of LNG transit improve. Nonetheless, the internationally traded volume of natural gas is relatively modest, equivalent to about 35 percent of total global gas consumption. Of that volume, about three-quarters goes to consumers in East Asia. Japan, Korea, and Taiwan are the largest global consumers of LNG. However, the vast majority of traded gas is exchanged via pipeline, mostly via long-term, oil-linked contracts.

As a result of market fragmentation, natural gas prices vary dramatically by region. The recent resurgence in U.S. production, driven by development of unconventional gas, has led to low prices for natural gas in North America; in the United States, the 2013 average cost of natural gas was around $3.73 per million BTUs, whereas in Asia spot prices hovered closer to around $17 per million BTUs.

Regardless of where the gas is sold, pricing is dependent on a variety of factors, most prominently supply and demand. The dynamics of natural gas pricing are also influenced by the relative prices of fuels that can be substituted for natural gas (primarily coal in the electricity sector and distillate and residual fuel oil in heating). Supply-side factors that influence prices include changes in production levels, import/export rules, and storage levels. Demand-side factors influencing price include rate of economic growth, seasonal factors (such as increased use in winter for heating and in summer for electricity), and regulation. Beyond the regional supply picture, the divergence in price across regions is also influenced by commercial arrangements and market structure. In some regions, the majority of natural gas sales are priced via oil-indexed contracts.

The international gas market is undergoing a period of rapid change for a variety of reasons. On the consumption side, global demand for gas is rising, due in part to environmental concerns, growing energy demand, and commitments to roll back nuclear power generation. On the production side, expanding natural gas production in the United States, the potential for unconventional gas development to spread beyond North America, and new conventional discoveries elsewhere—notably East Africa and Australia—have brightened prospects for a "Golden Age" of gas. Despite the availability of resources underground, however, there are still significant technical, regulatory, and commercial barriers to expanded production. How the demand- and supply-side landscapes evolve will impact the pace and scope of change in the international market.

Other changes in consumption that could potentially alter the size and regional integration of the global gas market include increasing penetration of natural gas in the transportation sector and concerns about air pollution in China.

Natural Gas and Climate

Natural gas is a significant source of greenhouse gas emissions both globally (20 percent) and in the United States (22 percent). In addition to releasing carbon dioxide, burning natural gas can also release other pollutants into the atmosphere that can lead to environmental and health problems. Compared with coal and oil, however, natural gas combustion releases significantly lower amounts of both carbon dioxide and other pollutants into the air (about half as much carbon

dioxide as coal and 30 percent less than oil). In addition, concerns have arisen about methane (a greenhouse gas more potent in the short term than carbon) leakage from natural gas production and transmission. If so-called fugitive methane emissions are above a certain threshold and improperly managed, the climate benefits of natural gas relative to coal disappear. In March 2014, the Obama administration announced a strategy aimed at cutting methane emissions. Further regulation of U.S. methane emissions in several sectors has been announced, with a target of cutting methane emissions 45 percent by 2025 (fully realizing the goal will require additional action).

These factors have resulted in a debate internationally and within the United States about whether expanding the use of natural gas will have a positive impact on greenhouse gas emissions. In recognition of the role that burning coal and oil play in climate change and that most renewables are not yet economically competitive with fossil fuels, some environmental groups have looked to natural gas as a more climate-friendly substitute. Other groups have argued that gas is an unsatisfactory solution; even if it is cleaner than coal, it may prolong the use of fossil energy. In addition, investment in natural gas may detract from investment in zero-carbon energy and take market share from these sources. Further, these groups argue that switching to natural gas is not a sufficient step to arrest global climate change and will not make as significant an impact as switching to renewable energy.

The regulatory landscape in the United States is an important factor influencing the competitive dynamics between gas and coal in power generation. As part of his broader blueprint to address climate change, President Obama directed the Environmental Protection Agency to propose rules to regulate carbon emissions from new and existing power plants. These regulations, in combination with other pollution regulations, may drive up coal prices and incentivize gas generation—but how much it will incentivize gas depends on the implementation. These rules will be finalized in 2015, and assuming that they withstand legal challenges, will not take effect for several years.

Natural Gas: Other U.S. Policy Issues

There are numerous other important policy issues surrounding the use of natural gas in the United States. The first is the question of LNG exports. The United States both imports and exports gas in relatively small volumes via pipeline and LNG tanker. The export volume may increase substantially, depending on permitting, financing, price differentials, and global demand.

The United States currently allows the export of LNG to countries with which the United States has a free trade agreement (FTA). For countries that do not have an FTA with the United States, the Department of Energy (DOE) grants export permits based on the guidance of the Natural Gas Act of 1938. DOE and the Federal Energy Regulatory Commission share responsibility for permitting facilities, and several have already received approval. Proponents of LNG export argue that it provides net economic benefits to the United States; opponents claim that it will raise energy prices for U.S. consumers and hamper the manufacturing sector, which reaps large benefits from cheap, stranded natural gas.

Hydraulic fracturing remains controversial in the United States and elsewhere. The process has raised environmental concerns for several reasons, including the potential for contamination of groundwater during the fracturing process, the amount of water necessary to fracture a well, and issues related to land use and development. Many studies have addressed these questions, and a growing body of scientific research suggests that the risks associated with hydraulic fracturing are similar to those associated with conventional drilling and can be adequately managed with proper oversight and regulation.

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