What you will learn:

- What natural gas is
- Where natural gas is found
- What resources, reserves and supply regions are
- Where gas supply serving the United States and Canada comes from
- 2 How resources are discovered and brought to market

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SECTION TWO: WHAT IS NATURAL GAS AND WHERE DOES IT COME FROM?

Raw natural gas is composed primarily of methane, the simplest hydrocarbon, along with heavier and more complex hydrocarbons such as ethane, propane, butane, and pentane. In addition, natural gas typically contains non-flammable components such as nitrogen, carbon dioxide, and water vapor and may contain hydrogen sulfide which must be removed for safety and to ensure clean emissions. What we burn in our homes and offices, however, is primarily a blend of methane and ethane.

Natural gas is one of the cleanest commercial fuels available since it produces only carbon dioxide, water vapor and a small amount of nitrogen oxides when burned. Unlike the combustion of other fossil fuels, natural gas combustion does not produce ash residues or sulfur dioxides. And when used to generate electricity, natural gas emits less than 50% of the greenhouse gases emitted by coal on a per MWh basis. Natural gas is often referred to as a "bridge fuel," meaning that it is the most environmentally benign energy source widely available until we further develop our renewable energy sources.

How Did Natural Gas Develop?

While several theories exist to explain the development of natural gas, the most widely accepted holds that natural gas and crude oil are the result of the decomposition of plants and animals buried deep beneath the surface of the earth. The theory goes something like this. Organic material typically oxidizes as it decomposes. Some organic material, however, was either buried before it decomposed or deposited in oxygen-free water, thereby preventing the oxidation process. Over millions of years, sand, mud and other sediments – along with these decomposed plants and animals – were compacted into rock. As layer upon layer of material covered this rock, the weight of the earth above along with the earth’s heat changed the organic material into oil and gas. Over thousands of years the earth’s pressure pushed these substances upward through permeable material until they reached a layer of impermeable rock where they became trapped.

Natural gas accumulates in reservoirs that are typically found between 3,000 and 25,000 feet below the earth's surface. Natural gas reservoirs are usually geologic traps in which an impermeable rock traps gas that has collected in a permeable material. When water is present in the formation, the lighter gas will displace the water to the bottom of the permeable layer. Natural gas is typically found in sandstone beds and carbonate rock, and to a lesser extent coal seams and shale beds. Wells are drilled into these reservoirs and natural gas flows upward from the high-pressure condition in the buried reservoir to the lower pressure condition at the wellhead (the top of the well at the surface). The illustration below shows the underground formations most likely to contain natural gas.

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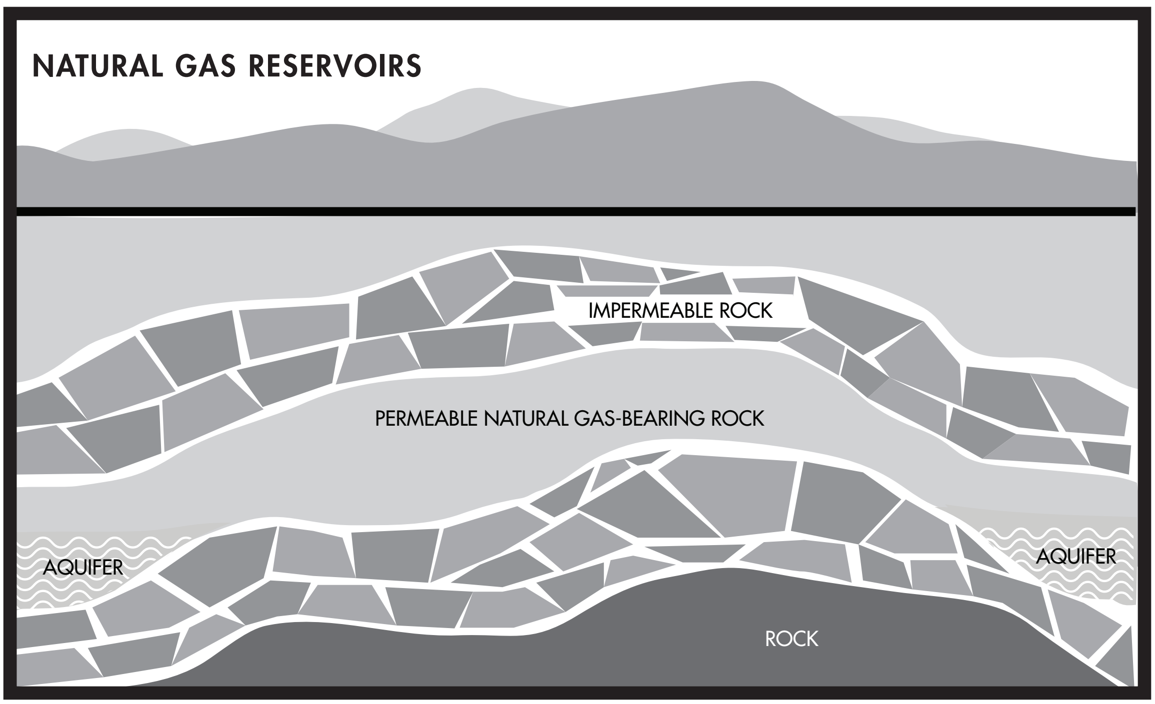


Resources

Natural gas resources are quantities of natural gas, discovered or undiscovered, that can reasonably be expected to exist in subsurface accumulations. Resources may or may not have been proven to exist by drilling. Unlike reserves (which we will discuss shortly), the resource estimations are independent of factors such as accessibility, economics or technology. Categories of resources include:

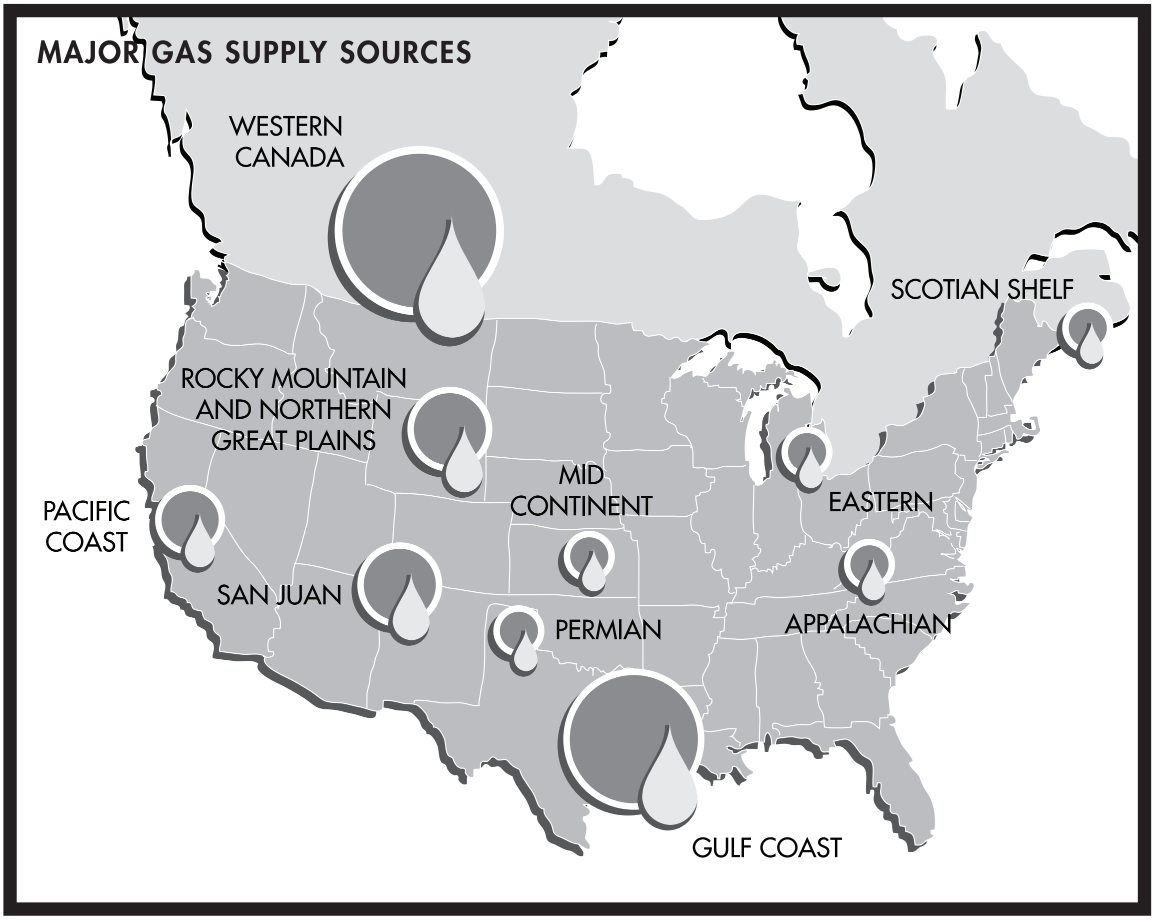
- Proved resources — Resources that are known to exist and that are recoverable under current conditions (these are also known as reserves), plus proved amounts of gas that are currently inaccessible, uneconomic, or technically impossible to produce.
- Unproved resources — Resources that are estimated to exist based on analyses of the size and characteristics of existing fields and supply basins, but have not been proved to exist through actual drilling.
- Undiscovered resources — Resources that are generally believed to exist in fields that have yet to be discovered.

Reserves

Natural gas reserves (sometimes called "proved reserves of natural gas") refer to estimated quantities of natural gas that are recoverable in future years from known reservoirs under existing accessibility, economic and technical conditions. Reserves are considered to be proved if economic producibility is supported by actual production or test drilling of the reservoir's geologic formation. Areas of a reservoir considered to be proved include portions that have been shown by drilling to contain recoverable gas as well as immediately adjacent portions that are believed to be recoverable based on geologic and engineering data.

Gas Supply Regions

Gas reserves are located in areas called gas supply regions. The major regions supplying the U.S. include the Gulf Coast, Permian, San Juan, Rocky Mountain, Mid-Continent, Pacific Coast, Eastern, and Appalachian in the U.S. and the Western Canada and Scotian Shelf in Canada. The largest producing regions currently are, in order, the Gulf Coast, Western Canada, Permian, San Juan, and the Rockies. The onshore Gulf Coast, Permian, Mid-Continent, Pacific Coast, and Eastern regions are more mature supply sources, meaning that most of the easy-to-find or produce gas has already been exploited. Regions with more recent development and significant undeveloped gas resources include deeper offshore Gulf of Mexico, San Juan, the Rockies, and the Appalachian basin. However, much of the resources in these regions require non-traditional and more expensive production techniques and may also require additional pipeline construction to bring larger volumes of gas to market. Additional significant reserves exist in northern Alaska, the MacKenzie Delta in Canada and in Mexico, but pipeline facilities do not currently exist to bring this gas to the major U.S. markets. And unfortunately, the cost of building pipelines from these areas is sig-



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nificant. In the future the U.S. will likely depend more on natural gas from areas such as Asia, the Middle East, Russia, and South America that is transported via LNG tanker.

Gas Supply in the United States

More than 80% of the natural gas consumed in the United States is produced domestically. Much of the remaining supply is imported from Canada, with smaller but growing volumes being imported via liquefied natural gas (LNG) tankers.

In the year 2008, the U.S. consumed approximately 23 Tcf of natural gas. Estimates indicate that the current U.S. supply base will be insufficient to cover future needs for some time. The Energy Information Administration (EIA) estimates that the U.S. had proven reserves of about 238 Tcf as of the end of 2007. Often, the popular press uses the consumption and reserve numbers to conclude that current reserves cover U.S. needs for less than nine years. This is, of course, a bit misleading as we are continually

U.S. GAS SUPPLY SOURCES (TCF)[1]

		Projected	
	2008	2015	2030
Consumption	23.0	21.0	23.5
Supply			
Domestic	20.5	19.2	23.1
Net Pipeline Imports[2]	2.7	0.7	-0.4
Net LNG Imports[3]	0.3	1.2	0.8
Other[4]	0.1	-0.1	0.0
Total Supply	23.6	21.0	23.5

adding to our reserve base. It does, however, point out that we must continually replenish our gas resource base to keep supply in step with demand. According to the EIA, annual production in the U.S. is expected to increase by about 2.6 Tcf during the period 2008 to 2030, while annual demand will increase by only 0.5 Tcf. This suggests that U.S. production will be able to meet increasing demand, though not total needs, in the next decades.

For the period between the mid-1980s and the early 2000s new supply needs were met by increased imports from Canada. But by the mid-2000s production from Canadian sources slowed and Canada began using more of its own supply to serve domestic demand. This suggests that future imports from Canada will remain flat or even decline. Fortunately for U.S. consumers, by the late 2000s U.S. producers were able to significantly increase production from non-conventional sources including shale gas, coalbed methane and tight sands. If this trend continues, while at the same time a pipeline is constructed to bring Alaskan gas into the Lower 48 and an expected focus on energy efficiency holds down growth in U.S. consumption, U.S. producers may be able to increase the percentage of demand that is served with domestic gas. The EIA projects that by 2015 the amount of U.S. consumption served by U.S. production will increase from today's 90% to 91% and that by 2030 it will increase to 98%. Much of the remaining gap will be filled by imports of liquefied natural gas (LNG). LNG is gas

PROVEN RESERVES BY REGION (TCF)[5]

Rockies	73
Mid-Continent	69
Canada	58
Gulf Coast	32
West Texas	23
Atlantic	18
Mexico	18
Alaska	12
North Central	5
Pacific	3

[1]Source: Energy Information Administration *Annual Energy Outlook 2009*.

[2]Net of Canadian and Mexican imports and exports.

[3]Net of LNG imports and exports.

[4]Includes net storage withdrawals and errors due to rounding.

[5]Data is for end of 2007. U.S. data from EIA website, Canada and Mexico data from *BP Statistical Review of World Energy 2009*.

that is cooled to a point at which it becomes liquid, and then transported via tanker ship. This enables the U.S. and many other countries to obtain supplies from around the world. While large gas resources also exist in Mexico, current projections are that pipeline infrastructure to bring significant quantities to the U.S. will not be built any time in the near future. Thus it is likely that Mexico will continue to use all of its production domestically.

Of course, a degree of uncertainty exists when trying to predict future supply/demand scenarios. Significant potential supplies exist in the lower-48 U.S. states, Alaska, and in various offshore basins near the U.S. coast. One recent estimate for the total U.S. natural gas resource base showed it being as high as 2,074 Tcf[6]. And technological advances and development of unconventional resources such as deep gas, gas shales, deep coalbed methane, or gas hydrates could change the equation. A key question will be whether gas price levels, technology development and environmental regulations will allow these supplies to be economically produced, or whether global supplies delivered via LNG tanker will prove to be more economical.

2 Exploration, Drilling and Completion, and Production

The process of finding natural gas and getting it out of the ground is actually threefold: exploration (finding natural gas and making the decision to drill for it), drilling and completion (drilling the well and equipping it for natural gas production), and production (extracting the gas and then processing it so that it's of usable quality). Let's take a look at the steps involved in bringing gas from reservoir to wellhead.

Exploration

As you might imagine, the way in which we explore for natural gas reservoirs has changed dramatically since William Hart dug America's first gas well in 1821. What began as a visual search for oil seepage in the ground or for gas bubbling under water has developed into a complex, technical and in most cases extremely expensive process. Today, the discovery of natural gas reservoirs begins with a model of the geologic formations most likely to house them. This model is then compared to a potential reservoir for similarities. Aerial photography or even satellite imaging may also be used to aid in the assessment of potential sites.

[6]Mean value estimate from Potential Gas Committee, *Potential Supply of Natural Gas in the United States* (December 31, 2008).

The geologist is also likely to use seismology in the search for natural gas reservoirs. Seismology (the study of how seismic waves move through the earth) enables scientists to study the lower layers of the earth's surface without actually drilling through them. Seismology gives scientists a glimpse of the various properties of the earth's layers, such as depth and thickness. This in turn enables them to determine whether such formations are likely to trap gas and oil. While the actual workings of seismic technology are complex, a simple explanation is as follows. Intense sound waves – created by explosives or strong vibrations – are aimed at the geologic area to be studied. Sensors on the earth's surface record how these waves are reflected back to the surface by the rock below. Interpretation of these signals gives us an idea of what that formation looks like. Additional data may be collected by measuring the variations in the earth's magnetic and gravitational fields.

The most accurate method of analyzing potential resources is to drill exploratory wells. As the well is drilled, logging tests allow geologists to map subsurface formations. A series of exploratory wells allows geologists to gain a picture of the likelihood of gas throughout an area. Unfortunately, as we will see, exploratory wells can be expensive.

Recent advancement in exploration technology has had significant impacts in reducing costs and improving success rates in finding natural gas reserves. In the 1990s, 3-D seismology came into widespread use. This technology allows scientists to create a detailed three-dimensional map that can predict the existence of oil and gas in a specific location (imagine a CAT scan of the earth). Possible future technology advancements that could further enhance exploration success include improvements to the density of seismic data acquisition, increased data processing rates, use of controlled source electromagnetism (CSEM) to reduce false positives, development of advanced interpretation technology, improvements to earth-systems modeling, and enhancements to sensors for subsurface measurements[7].

Drilling and Completion

Once we have enough evidence to indicate the existence of a natural gas reservoir, a decision must be made on whether the economic characteristics of the reservoir make it profitable to drill a well. But before any drilling takes place, an E&P firm must first lease or purchase mineral rights and obtain the necessary permits – a process that may require extensive environmental impact studies. Once this process is complete, an exploratory well is drilled and producers do a lot of hoping and praying! Even the best

[7]See National Petroleum Council, *Facing the Hard Truths about Energy* (2007), Chapter 3, for a deeper discussion of future technologies.

technological advances cannot guarantee that natural gas will be where they think it is. In fact over 30% of exploratory wells are dry[8], meaning no economic amounts of gas exist. Certainly not the most favorable odds for a well which could cost as much as $15 million onshore or over $100 million off-shore to drill and develop.

The placement of the exploratory well will depend on physical characteristics of the reservoir and the surface terrain, availability of gathering pipelines, as well as legal and regulatory issues such as permits. Drilling itself is performed by driving a rotating metal bit through the ground (known as rotary drilling). Offshore drilling uses similar technology but is somewhat more complicated because a platform must be constructed to hold the drilling rig. Once the drill comes in contact with natural gas, the E&P firm can begin to estimate the ultimate productivity of the new well. Hopefully the exploratory well will indicate the producers have tapped an economic resource that can be developed to a productive state.

Recent advancements in directional drilling and horizontal wells have allowed production from some formations that previously were uneconomic. Down-hole motors are used to drive the drill bit making both horizontal and multilateral wells possible.

Horizontal wells pass through more of the reservoir, markedly increasing the production rate. Multilateral wells allow many reservoirs to be drilled through the same well bore. These techniques reduce the surface footprint such that one drilling location may now replace 10-15 wells drilled vertically. This can be especially important in environmentally sensitive areas or where access is limited.

Once it is determined that a proved resource exists, the next step is to complete the well so that the natural gas can safely flow to the surface. This process is called well completion. First, steel casing is cemented into the hole to prevent it from collapsing and to keep fluids from flowing through the well bore and into another formation. This is especially important in preventing fresh water contamination. Next, the casing is perforated next to the gas-bearing formation. Then production tubing is run inside the casing and attached to the wellhead. The wellhead consists of a series of valves at the surface of the well that regulate gas pressure and prevent leakage. If the gas reservoir has enough pressure and permeability, natural gas will flow to the surface naturally due to the pressure differential. In some cases, treatments are used to increase natural gas production rates. An example of well treatment is hydraulic fracturing, which is the injection of water into the well to open up cracks within the underground forma-

[8] Data from EIA website for 2008.

tion. After water has opened a crack, a solid material like sand or beads is injected to prop the crack open. These cracks allow the gas to flow to the surface more easily.

Production

Once the well is completed, equipment is installed to meter the flow of gas. Engineers then monitor the flow rate and the pressure to evaluate the effectiveness of the completion. They also use this information to forecast future production rates and the amount of gas that can be recovered from the well.

After the natural flow has been established to the satisfaction of the engineer, the next step in production is to install piping to move the gas on each individual lease to a lease facility. At these facilities, condensate and water are separated from the gas. Condensate is an oil-like hydrocarbon that is in a vapor or gaseous state at reservoir temperature and pressure, but is a liquid at surface temperature and pressure. Condensate is sold separately. The last production function is to meter the gas going off the lease as a basis for compensating individual lease participants and royalty owners. From the lease facilities, the gas enters the gathering pipeline and is moved to a processing facility. These steps are discussed in Section Four.