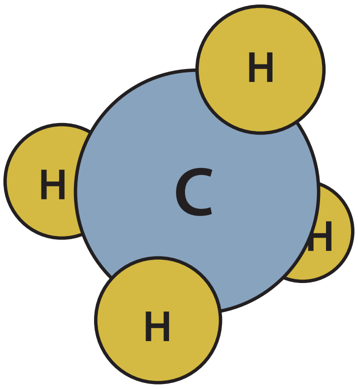
NATURAL GAS BASICS

Natural gas is a combustible, gaseous mixture of simple hydrocarbon compounds, usually found in deep underground reservoirs formed by porous rock. Natural gas is made almost entirely of methane, a molecule containing one carbon atom and four hydrogen atoms. Natural gas also contains small amounts of other hydrocarbons including ethane, propane, butane and pentane.



A Methane Molecule

Natural gas is categorized according to its composition. It can be dry gas, containing few liquid hydrocarbons; wet gas, heavy in liquid hydrocarbons (and sometimes water); sour gas, containing hydrogen sulfide; or sweet gas, which may have a trace of sulfur but no hydrogen sulfide. The following properties are inherent to natural gas:

- Has a flammability range of five to 15 percent. Any mixture containing less than five percent or greater than 15 percent natural gas to air will not burn.
- Burns with a blue flame, producing water and carbon dioxide when completely combusted.
- Is colorless, odorless and tasteless.
- Has a heating value of 800 to 1200 BTUs per cubic foot.

The Origins of Natural Gas

Fossil Fuel Theory

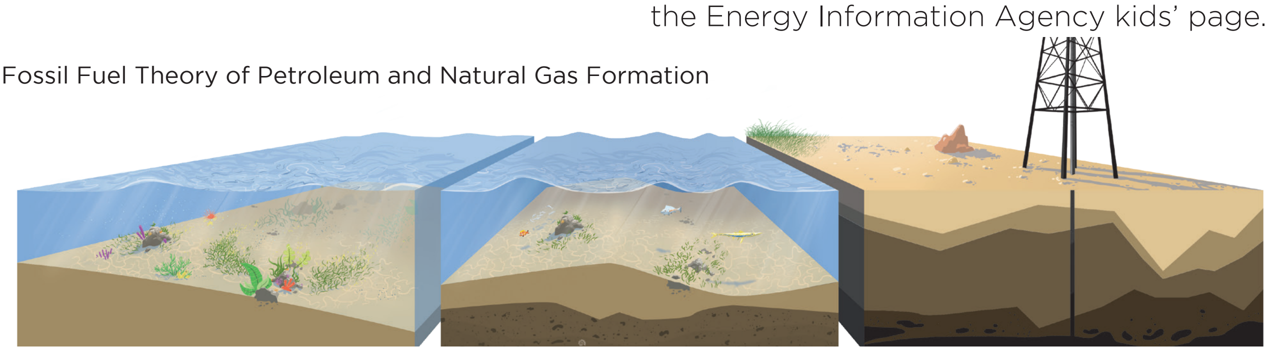
The prevailing scientific theory is that natural gas was formed millions of years ago when plants and tiny sea animals were buried by sand and rock. Layers of mud, sand, rock, plant and animal matter built up until the pressure and heat from the earth turned them into a tar-like substance called kerogen. As temperatures continued to increase and the kerogen continued "cooking," more complex compounds of carbon and hydrogen known as oil were formed. Natural gas is generated at the same time as oil; however, peak generation occurs when oil begins to break down at temperatures greater than 205 C (400 F).

Deep Gas Theory

Thomas Gold, of Cornell University, published the first papers to contend that "on Earth, as on other planets, most hydrocarbons were formed from nonbiological sources." The deep gas theory proposes that the earth is made up of primordial materials that combined in space billions of years ago when its basic structure evolved. The materials are believed to still be buried far below the crust, where they have been trapped for 4.5 billion years. Cracks and fissures in the crust allow the gases to migrate into reservoirs and to the surface. In this manner, it is believed that the supply of hydrocarbons produced from the primordial materials was instrumental in the creation of the atmosphere.

Learn more about natural gas at *eia.gov/kids*, the Energy Information Agency kids' page.

Fossil Fuel Theory of Petroleum and Natural Gas Formation



300 – 400 Million Years Ago

Tiny sea plants and animals died and were buried on the ocean floor. Over time they were covered by layers of silt and sand.

50 – 100 Million Years Ago

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today

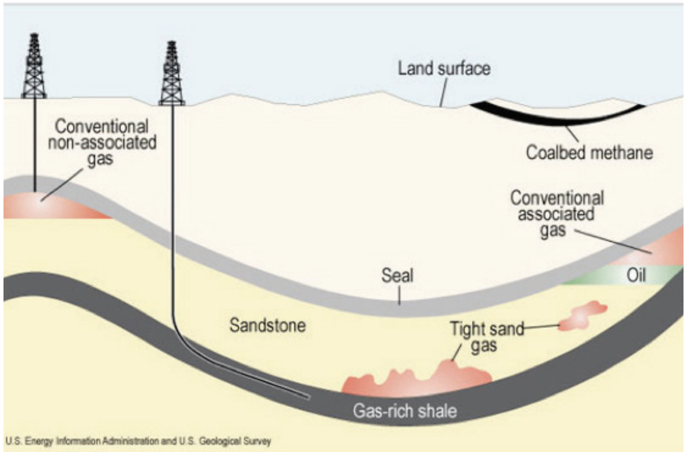
We dig down through layers of sand, silt and rock to reach the rock formations that contain oil and gas deposits.

(Adapted from: *eia.gov/kids*)

NATURAL GAS

Types of Natural Gas Deposits

As natural gas molecules form, they migrate from the source rock into more porous areas such as sandstone. They either continue rising to the earth's surface, where they escape into the atmosphere or they are trapped when their path is blocked by nonporous rock. In the latter case, the impermeable rock layer forms a seal which allows natural gas to build up.



Conventional and Nonconventional Natural Gas Formations (Image: U.S. Energy Information Administration and U.S. Geological Survey)

Traditionally, natural gas was pumped from the ground in areas where the layers of rock had been bent into folds that allow gas to build up at high points, as shown in the diagram. Natural gas is often found with oil, as associated gas, but it can be found alone, as nonassociated gas. Natural gas can also be found with coal beds, in a sedimentary rock called shale and even in sand deposits. These less conventional sources of natural gas are abundant and increasingly more important to our natural gas supply.

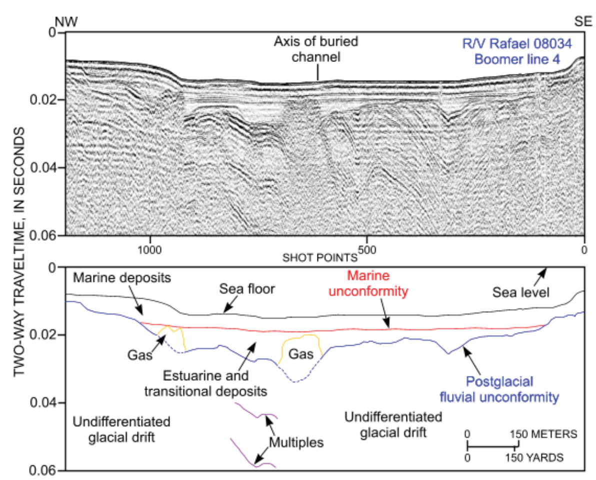
Finding Natural Gas

A variety of tools are often used to study the earth before new wells are drilled. These tools include satellite imagery of the area, studying rock layers in existing wells and remote sensing tools such as magnetometers, gravimeters and seismometers.

Seismology has improved the effectiveness of natural gas exploration. Seismic waves sent underground reflect off dense layers of rock differently than extremely porous layers of rock, allowing the geologist to determine exactly what types of rock layers exist underground, and at what depth, without drilling. Computers have increased the value of seismic data by allowing geologists to construct a 3D map of the rock layers beneath the earth's surface.

Time lapse, or 4D, imaging is one of the latest breakthroughs in exploration. Various seismic readings of a particular area are taken at different times and this sequence of data is fed into a powerful computer. The different images are joined to create a movie of what is going on under the ground. By studying how seismic images change over time, geologists can gain a better understanding of many properties of the rock. Although 4D seismology is expensive, it can increase the amount of gas recovered from a well significantly. The blue dots on the map below show natural gas wells. Orange areas show shale and sand gas deposits. Brown dots are oil and gas combined wells.

Natural Gas Wells in the United States (Image: EIA Energy Mapping System)



Seismic Image of Natural Gas Fields with Interpretation (Image: U.S. Geological Survey)

NATURAL GAS EXTRACTION AND PRODUCTION

Natural gas production has increased greatly in recent years and will need to do so to meet growing demands. Most of the natural gas used in the United States is produced domestically, with most imports coming from Canada. Canada has abundant shale and tight gas resources, with British Columbia the most active in production. Canada and Mexico also import natural gas from the United States.

Once the best place to drill has been located by a team of exploration geologists and geophysicists, the drilling company must get permits, make arrangements to extract and sell the gas with the landowners and design a system of pipes to carry the gas away from the well.

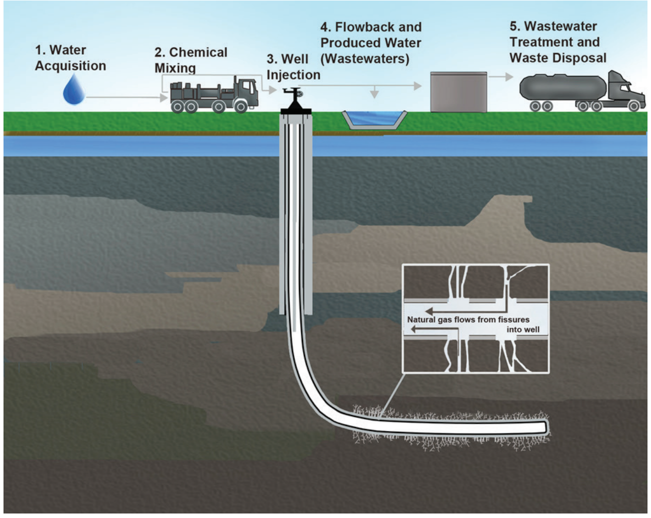
Wells are dug by drilling rigs, which are basically just enormous drill bits. Once wells are dug, cement is poured around the hole to prevent a collapse and to stabilize the well. Gas is pushed into the tube of the well by underground pressure.

Drilling for natural gas offshore, in some instances hundreds of miles away from the nearest landmass, poses a number of different challenges over drilling onshore. The actual drilling mechanism used is similar to an onshore rig. However, the sea floor can be thousands of feet below sea level, so an artificial drilling platform must be constructed at the surface. Moveable rigs are often used for exploratory purposes because they are much cheaper to use than permanent platforms.

Once large deposits of hydrocarbons have been found, a permanent platform is built to allow their extraction. There are many different types of platforms, depending on the depth of the ocean and typical wave conditions for the area.

A mobile drillship, rear and its support vessel search for natural gas in a new offshore field.
(Image: Wikimedia Commons)

Two technologies that have dramatically increased production of wells are horizontal drilling and hydraulic fracturing. They are often used together to allow hard to reach and unconventional natural gas deposits to be tapped economically. Coalbed methane, shale and tight sand deposits are extracted using these technologies.



The Hydraulic Fracturing Process
(Image: U.S. Environmental Protection Agency)

Horizontal drilling uses special equipment to extend horizontal shafts into areas that could not otherwise be reached. In offshore drilling, one platform may service many horizontal shafts. Horizontal drilling is flexible in that it allows for the extraction of natural gas that had previously not been feasible. Although on the surface it resembles a vertical well, beneath the surface, the well changes direction so that it runs parallel to the natural gas formation. Well legs can go in different directions at different depths. Horizontal drilling allows one surface well to branch out underground and tap many different natural gas resources. It also allows one well to make contact with larger areas.

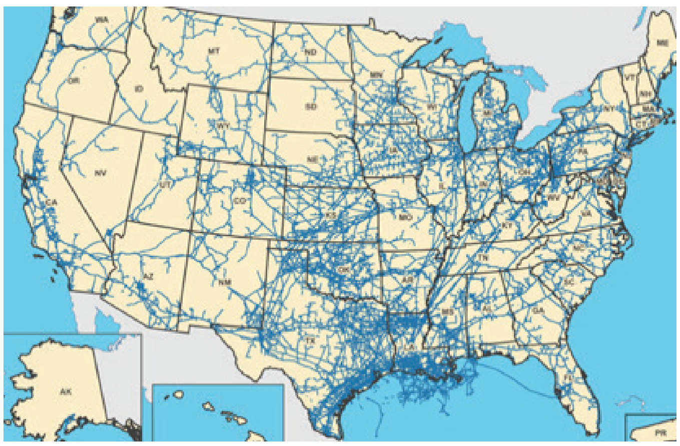
Hydraulic fracturing is a process where fluids, under very high pressure, are injected into a rock formation. This cracks the rock formation that holds the natural gas or petroleum. Glass beads, sand or other particles are added to the fluid to help prop the fracture open once the pressure is decreased. This allows the natural gas or petroleum to flow better through the rock, increasing well productivity.

NATURAL GAS PROCESSING AND DISTRIBUTION

Natural Gas Processing

Before natural gas is distributed, it must be sent to a processing plant where it is cleaned and separated. At the processing plant, the gas is sent through a separator where impurities, such as hydrogen sulfide, and heavier hydrocarbons, like butane and propane, are removed. The hydrocarbon compounds, called natural gas liquids, are reprocessed and shipped to market for a variety of different uses.

Natural Gas Distribution



The U.S. natural gas pipeline system connects to pipelines in Canada and Mexico. (Image: EIA)

Natural gas is delivered to North American consumers through a network of underground pipes about 3 million miles long. As natural gas leaves the processing plant, it enters a compressor station where it is pressurized. As natural gas flows through the pipeline, friction reduces the pressure and slows the gas. This loss of pressure is made up at compressor substations every 50 to 100 miles. Valves are used to control pressure and cut off flow in an emergency such as a break in the line or a fire. Natural gas utilities odorize natural gas with mercaptan – which smells similar to rotten eggs – to help identify leaks.

The size of the pipeline is largely a function of the peak demand, which is set by the number of users and the time of year. The pipes must be large enough to handle enough natural gas to meet the needs of consumers during the high peak use periods – typically the winter months, when natural gas heating drives up usage.

As a pipeline nears a city, some natural gas is diverted through a city gate, where its pressure is reduced and it is measured and sold to the local natural gas company. The natural gas company distributes the natural gas through an underground network of smaller pipelines called mains. Still smaller pipes connect the mains directly to end users — homes, schools and businesses. There, the natural gas flows through meters which measure the exact amount of natural gas used. Learn more at *ingaa.org*, the website for the Interstate Natural Gas Association of America.

Natural Gas Storage

Some gas is not used right away. The gas companies save it in storage tanks or underground. Natural gas is most commonly stored underground and under pressure in depleted oil and/or natural gas reservoirs, aquifers and salt caverns. A depleted reservoir is a formation that has already produced its natural gas or oil. An aquifer is a porous and permeable formation which contains water under pressure. Salt caverns are developed in thick salt formations by mining a large space out of the salt.

Stored gas is used at times of increased demand, as in the winter to heat homes or in the summer when it is needed to generate electricity. Natural gas can be stored in tanks as liquefied natural gas or LNG. When chilled to -160 C (-256 F), natural gas changes to a liquid. LNG can be shipped overseas and can be used as a transportation fuel.

LNG Storage Tanks

NATURAL GAS USE

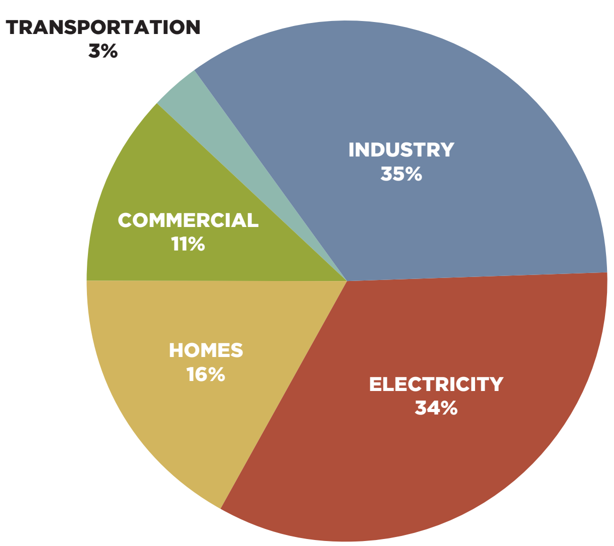
Natural gas is a popular energy source in North America for four main reasons. First, when natural gas burns, it introduces virtually no pollutants into the environment. Second, the delivery of natural gas is efficient, easy and convenient. Third, natural gas is safe and reliable. The underground natural gas delivery system has an outstanding safety record. Fourth, the cost of natural gas is significantly less than that of comparable fuels having equal British thermal unit (BTU) values (a BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit).

Natural gas is used as a fuel to produce steel, glass, paper, clothing, bricks and electricity. It is also used as a raw material for many products, including paints, fertilizer, plastics, antifreeze, dyes, photographic film, medicines and explosives.

About half of the homes in the United States use natural gas as their main heating fuel. Natural gas is also used in homes and businesses for cooking, heating water, drying clothes and outdoor lighting. See all the uses for natural gas in the interactive home at *naturalgashome.aga.org/main*.

Electricity from Natural Gas

In the United States, about one-third of our electricity comes from natural gas. (Source: *eia.gov*, accessed April 2018) In Canada, about nine percent of electricity is generated by natural gas. (Source: *nrcan.gc.ca*, accessed December 2018) Since 2000, a variety of factors have increased natural gas use in electric power plants, such as the competitive price, environmental public policies and increased supplies due to hydraulic fracturing.



U.S.A. Natural Gas Use 2017
(Source: *eia.gov*,accessed November 2018)

Burning natural gas with coal or oil in the same boiler (cofiring) can also reduce fossil fuel pollutants. A similar helpful use of natural gas is cogeneration: a process by which electricity and useful heat are produced from a single source, reducing both waste and pollution.

Natural Gas Vehicles

A major cause of urban pollution is the carbon monoxide produced by automobiles. Light-duty natural gas vehicles (NGVs) can reduce life cycle GHG emissions by 15 percent over gasoline vehicles. Many fleet vehicles, such as buses, already display the little blue flame to denote an NGV.

Natural gas vehicles perform about the same as gasoline powered vehicles in regard to energy consumption but outperform gasoline vehicles in cold weather starting and result in less engine wear over the life of the vehicle. Learn more at *afdc.energy.gov*.

The use of natural gas for transportation provides both environmental and durability benefits. The use of compressed natural gas (CNG) in bus and fleet vehicles and LNG in larger vehicles that need a longer range is expected to expand rapidly as a fueling infrastructure develops and supporting regulations are written.

CNG Fueling Station (Image: U.S. Navy)

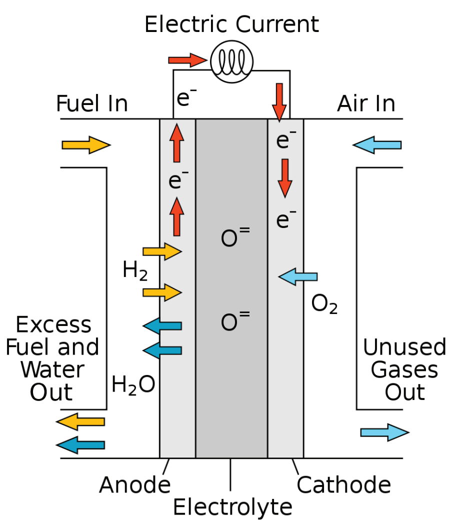
NATURAL GAS TECHNOLOGIES AND THE ENVIRONMENT

Scientists are discovering new uses for natural gas all the time. New technologies will help extend the life of natural gas and improve the environment.

The gas heat pump, a natural gas heating and cooling system, was a dramatic breakthrough in climate control and efficiency. Natural gas heat pump technology offers cooling at a cost savings over electric systems.

Commercial cooling offers an attractive alternative to electric air conditioning because of high electric costs and anticipated capacity shortages during peak demand periods. Using gas equipment for commercial cooling can greatly reduce electric peak demand and help defer the need to build more power plants. Natural gas cooling systems are environmentally preferable because these natural gas systems do not use any CFCs (chlorofluorocarbons) or HCFCs (hydrochlorofluorocarbons), which are required for all electric systems.

Fuel cells are high-efficiency devices for generating electricity directly from a hydrogen-rich fuel such as natural gas. These devices operate through an electrochemical process similar to a battery. Since the gas is not burned, fuel cells are quiet and virtually pollution free. They operate at elevated temperatures, generating waste heat that can be recovered for water, space or process heating.



Natural Gas Fuel Cell
(Image: U.S. Department of Energy)

Energy Impacts the Environment

Our society relies heavily upon energy, raising concerns about the sustainability of our energy sources and the environment. Human activities are believed to affect the composition of the atmosphere by the increased release of greenhouse gases (GHGs) such as CO_2 (carbon dioxide), CH_4 (methane) and gases that cause acid rain, such as SO_2 (sulfur dioxide) and N_2O (nitrous oxide).

Natural gas is considered the best fossil fuel for the environment. If done responsibly, its production does not seriously disturb the surrounding area and the site is quickly restored to its original state once production ends. The few pollutants present as it comes from the ground are removed before it enters the pipeline. Some natural gas does leak into the atmosphere from wells, storage tanks, pipelines and processing plants. These leaks were the source of about two percent of total U.S. GHGs in 2018, according to the U.S. EIA.

According to the U.S. Environmental Protection Agency, some concerns associated with overall natural gas and shale gas extraction, including hydraulic fracturing, are already well known. Possible impacts on the environment include:

- Stress on surface water and ground water supplies from the withdrawal of large volumes of water;
- Contamination of underground and surface waters from spills, faulty well construction, or by other means;
- Adverse impacts from discharges into surface waters or from disposal into underground injection wells; and
- Air pollution resulting from the release of volatile organic compounds, hazardous air pollutants and greenhouse gases.

(Source: *epa.gov/hydraulicfracturing#providing*, accessed February 2018)

When obtained and used responsibly, natural gas can help improve the quality of air and water, especially when used in place of other, more polluting, energy sources.

(Image: NASA)

NATURAL GAS PRICING, SAFETY AND CAREERS

Natural Gas Pricing

Natural gas is a popular commodity for consumers. It is used by homeowners, schools, businesses, factories and electric power plants because of its efficiency, cleanliness and reliability. Pricing is related to supply and demand. As a result, the market price of natural gas reflects an extremely tight balance between the two. The wholesale price of natural gas was relatively stable during the 1990s because supplies were in balance with demand. The price of natural gas went down from 2008 – 2015 due to a combination of increased efficiencies and supplies. With U.S. and Canadian demand for natural gas projected to continue to increase, energy efficiency and continued domestic supplies are vital to maintain gas prices.

811® Know what's below. Call before you dig.

Natural Gas Safety

Natural gas is a very safe energy source. It is lighter than air so it dissipates if a leak occurs. It has a higher combustion temperature than other fossil fuels and if the proper mixture of oxygen and natural gas are not met, combustion will not occur. To make sure your family is safe, call 811 before any digging project to avoid hitting an underground gas pipe. Make sure your family knows the scent of mercaptan and what to do if they smell it and think there is a gas leak.

For more information on natural gas safety, reference NEF's *Natural Gas Safety Poster* available at *nef1.org/store*. Learn more about natural gas, gas safety and find out how to participate in the Academy of Natural Gas Education, a free material distribution project, at *energysafekids.org*.

Careers in the Natural Gas Industry

The natural gas industry offers many kinds of jobs. Whether you like science and math, reading and writing, drawing, helping people or working outdoors, you can find a career that matches your interests. Some examples are: engineer, computer programmer, accountant, drafting technician, graphic designer, customer service representative, human resources manager, pipe fitter, meter reader and leakage inspector.

These jobs require an ability to communicate and work well with others. Most jobs require computer literacy and problem-solving skills.

Geophysicist: studies the earth to find prospective places to drill for natural gas.

Supply and Demand Analyst: looks at long-term weather forecasts to decide the amount of gas to deliver to homes and businesses and explores new technology which may impact the demand for natural gas.

Environmental Scientist: responsible to see that the well is drilled in a way that minimizes the total impact to the natural setting around the well. This scientist checks air and water quality, monitors wildlife and gives advice on restoration of the area for the life of the project.

Pipeline Engineer: decides on the size, strength and type of pipe that transports gas to your home or business. The engineer helps ensure the safety of the pipe and operations from the well to your home.

Petroleum Engineer: studies the production of a natural gas well. By determining the size of the reservoir rock, the petroleum engineer gives an estimate on how long the well can produce gas.

Installing New Natural Gas Pipelines
(Image: Real Clear Energy)

HOW TO BE MORE ENERGY EFFICIENT WITH NATURAL GAS

- Take a power shower! Short showers save water and the natural gas used to heat it.
- Have an adult check the temperature of your hot water and adjust it to 120 – 130 F, unless someone in your family has an immune system problem.
- Check around windows or doors for leaks and install door sweeps, weather stripping and caulk as needed.
- Keep doors and windows closed when the heater or air conditioner is running.
- Adjust the thermostat for the season. Adjusting it down in the winter and up in the summer even a degree or two can make a difference on your bill. A programmable or smart thermostat can save even more by automatically adjusting for when the building is empty.
- Check your natural gas provider's website to see if they offer a free or low-cost energy audit.

Programmable Thermostat

You can find more information on how to save energy at *energy.gov*.

Student Activity – Curtains for Efficiency

Conduct the following experiment to find one way you can help conserve energy in your home. You will need four thermometers.

1. Tape one thermometer to the inside of a window in your house. Tape a second thermometer to the window covering (curtains, blinds, etc.). Place a third thermometer outside on the window ledge and a fourth thermometer in the room.
2. Follow the directions for the season that best fits when you do the experiment.
   - For cold months: on sunny days, open the window coverings. Close the window coverings at night.
   - For warm months: close the window coverings during the day.
3. In the afternoon, record the temperatures of each thermometer. Find the difference in temperatures.
4. Repeat the procedure for four days, at the same time each day. Construct a line graph for each thermometer. Calculate the average temperature for each thermometer.

Share your findings with your family and discuss how window coverings can be used as an insulator to conserve energy.

About the National Energy Foundation
The National Energy Foundation (NEF) is a unique 501 (c)(3) nonprofit organization dedicated to cultivating and promoting an energy literate society since 1976.

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