



The natural gas found within the Marcellus Shale formation in Pennsylvania is a clean-burning, abundant energy source. It provides economic benefits to communities across the state, with producers investing billions of dollars each year in leasing properties, drilling, infrastructure improvements and community development. From start to finish, drilling a Marcellus well is an investment in our communities' future.

## Geologic Testing

Long before the drill bit hits the ground, gas producers conduct rigorous geologic testing to determine the physical structure of the strata below. Using two- or three-dimensional seismic testing, geophysicists identify the location of the shale and determine an optimum site for drilling.

In two-dimensional seismic testing, large trucks move along the surface, producing shock waves that bounce off rock formations below. The waves are then reflected back to geophones strategically placed above ground. The vibrations are translated into electrical signals and sent to a recording truck where they are logged and later reviewed by geologists.



Geologists use a number of tools to study rock formations and locate those that have the potential to produce oil and natural gas. Technological advances have allowed the industry to become more efficient in exploring and producing energy from formations such as the Marcellus Shale.

A more technologically advanced system of seismic testing utilizes small charges placed in a grid formation about 20 feet below ground surface. The charges are fired in sequence and geophones record the vibrations. Similar to a doctor's sonogram, a computer analyzes the vibrations and shows three-dimensional images of the rock formations below, including the Marcellus Shale. Both seismic processes enable scientists to record data about the thickness, location, faults and other geologic features of the rock below.

## Leasing

Once a general understanding of regional geology is obtained, leasing agents develop oil and gas contracts with land owners interested in leasing their property for exploration and production. Land professionals research property titles in the deeds office at county courthouses and work with property owners to develop a sound agreement that gives the producer the right to explore for oil or natural gas on the property covered by the lease.

Typically, leases include a one-time payment or annual bonus payments for a set period of time. During this period, the gas producer has the exclusive right to explore for oil and natural gas. The second phase of the lease is entered when minerals are produced from the well, called royalty payments. These payments are based on the value of the oil and natural gas sold from the well, and continue as long as oil or natural gas is commercially produced.

Generally, leases include the ability for producers to construct access roads and production pipelines on a property to transport the natural gas from wells to processing plants and transmission pipelines. Landowners are encouraged to have an attorney review the lease and royalty documents before signing

## FAST FACTS

- Natural gas is the world's cleanest fossil fuel. When turned into energy, it produces 30 percent less CO<sub>2</sub> than oil and 45 percent less than coal, and generates virtually no sulfur dioxide, mercury or particulate matter.
- The active process of developing and completing a multi-well natural gas drilling location takes about one year. Once completed, the site is restored, with only a small amount of production equipment remaining. A completed natural gas well will produce energy for decades.
- In 2008, Pennsylvania had to import 75 percent of the natural gas it consumed annually. With increased development, the Commonwealth is expected to become a net exporter of natural gas by 2014.

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the agreements. Lease agreements are legal documents and can be long-term contracts if the oil and gas well produces commercially for many years.

## Site Preparation and Drilling

Preparing a drilling location is a process that includes the construction of roads to the pad site and the proper grading of the area where the rig and other equipment will be placed. Drilling pads and roads must be built and maintained to prevent erosion and sedimentation, including the installation of filter socks and erosion



Pennsylvania has leased some state lands for the production of natural gas, providing the Commonwealth with hundreds of millions of dollars in lease payments, and years of future royalty payments. Drilling from multiple-well pads allows natural gas to be extracted from large areas of public land while keeping the surface disturbance for pads, roads and pipelines to a minimum – in many cases, about two percent of the area where gas is being produced.

control blankets and the spreading of gravel on the pads to allow precipitation to drain properly.

Marcellus Shale gas wells can be drilled vertically or horizontally. Once the drill breaks through soil and the earth's crust, the first focus is reaching and protecting the water aquifers. As the drill makes its way through these water-bearing zones, compressed air is pushed down the drill pipe to lift and remove rock fragments from the wellbore. After passing the deepest water-bearing zone, the steel casing is supplemented by cement, that is pumped down the wellbore and then outside of the casing, keeping the well open and isolated from the rock and water around it. Steel pipes of increasingly smaller diameter, called casing strings, are used as the well is drilled to deeper depths – with each casing string followed by a protective layer of cement between the well and the surrounding rock. Each of these layers also provides additional levels of groundwater protection.

A vertical well is drilled to the Marcellus Shale and a final string of casing, either 4 ½" or 5 ½" in diameter, is cemented in place. A horizontal well is drilled vertically to a specific

depth above the targeted area of the Marcellus formation. The drill is then turned slowly to make a 90-degree angle, landing horizontally in the shale formation. The drill continues to move horizontally for several thousand feet, with the final string of casing cemented in place to the end of the well bore. It takes between 15 to 30 days of continuous drilling to complete a horizontal Marcellus well.

## Well Stimulation

Well Stimulation has been used by the oil and gas industry since the 1940s and has become a key element of oil and natural gas development worldwide. In fact, this process is used in nearly all wells drilled in the U.S. today. Properly conducted, it is a safe, sophisticated, highly engineered and controlled procedure.

Once the well has been drilled to its desired depth and horizontal length, a series of charges are fired into the well to perforate the steel casing and cement, creating small openings between the shale formation and the wellbore.

Next, a mixture of water, sand and a small amount of dilute chemicals are injected into the well under high pressure to prop open the shale, allowing natural gas to be released from the rock. The well stimulation fluid is flowed back out of the well, while the sand remains, allowing the gas to flow into the well. Some flowback water is returned to the surface soon after the well stimulation process and is collected in tanks or lined pits, where it is stored until it is either transported to a permitted disposal facility, or recycled and used at additional well locations.

Well stimulation can take several days and requires between 3 to 5 million gallons of water per horizontal well. Gas producers must receive permits from regulatory agencies for water withdrawals to maintain healthy stream flow, and protect water supplies and aquatic life.

The entire stimulation process is continually monitored to ensure the safety of the environment and the workers. Once completed, wells are typically "flared" to remove the flowback water, and then capped temporarily while pipelines and other production equipment is put into place.

## Site Reclamation

Producers go to great lengths to restore the landscape of the property as closely as possible to pre-drilling conditions. When drilling is complete, a small pad surrounding the well head is left clear for the placement of storage tanks, a gas well monitor or meter and other production equipment. The equipment is painted, clearly marked and maintained regularly by a well tender to ensure safety.

Although the natural gas well drilling process requires large amounts of heavy equipment moving to and from the well site during course of the drilling and completion processes, they are only short-term inconveniences. Developers work closely with local municipalities to post bonds or enter road agreements to ensure safe and adequate access to and from the site, protecting and improving local roadways both as needed during the drilling process, and following it, resulting in improvements to the local infrastructure.

## Environmental Protection

Every aspect of developing, drilling and completing a natural gas well is regulated by state and federal agencies responsible for Pennsylvania's land and water resources. The industry strives to not only meet the requirements of these regulations, but to achieve a higher standard of compliance and continue to improve the systems in place to protect the environment. Drill rig workers, supervisors and management personnel also complete training programs to remain current with environmental regulations.