Overview of Shale Gas

Course No: P02-004

Credit: 2 PDH

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NATURAL GAS FROM SHALE:

Questions and Answers

Natural gas production from "shale" formations (fine-grained sedimentary rocks with relatively low permeability that can be rich sources of petroleum and natural gas) is one of the most rapidly-growing trends in U.S. domestic energy exploration and production. In some cases, this fast expansion has resulted in natural gas drilling and production activity in parts of the country that have seen little or no activity of this type in the recent past. "Natural Gas from Shale" explains the basics, including what shale gas is, where it's found, why it's important, how it's produced, and challenges associated with production. Also included are a list of frequently asked questions, a glossary of major terms, and a list of resources and links for additional information.

U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

What is shale gas?

Basically, it is **natural gas** – primarily methane – found in shale formations, some of which were formed 300-million-to-400-million years ago during the Devonian period of Earth's history. The shales were deposited as fine silt and clay particles at the bottom of relatively enclosed bodies of water. At roughly the same time, primitive plants were forming forests on land and the first amphibians were making an appearance.

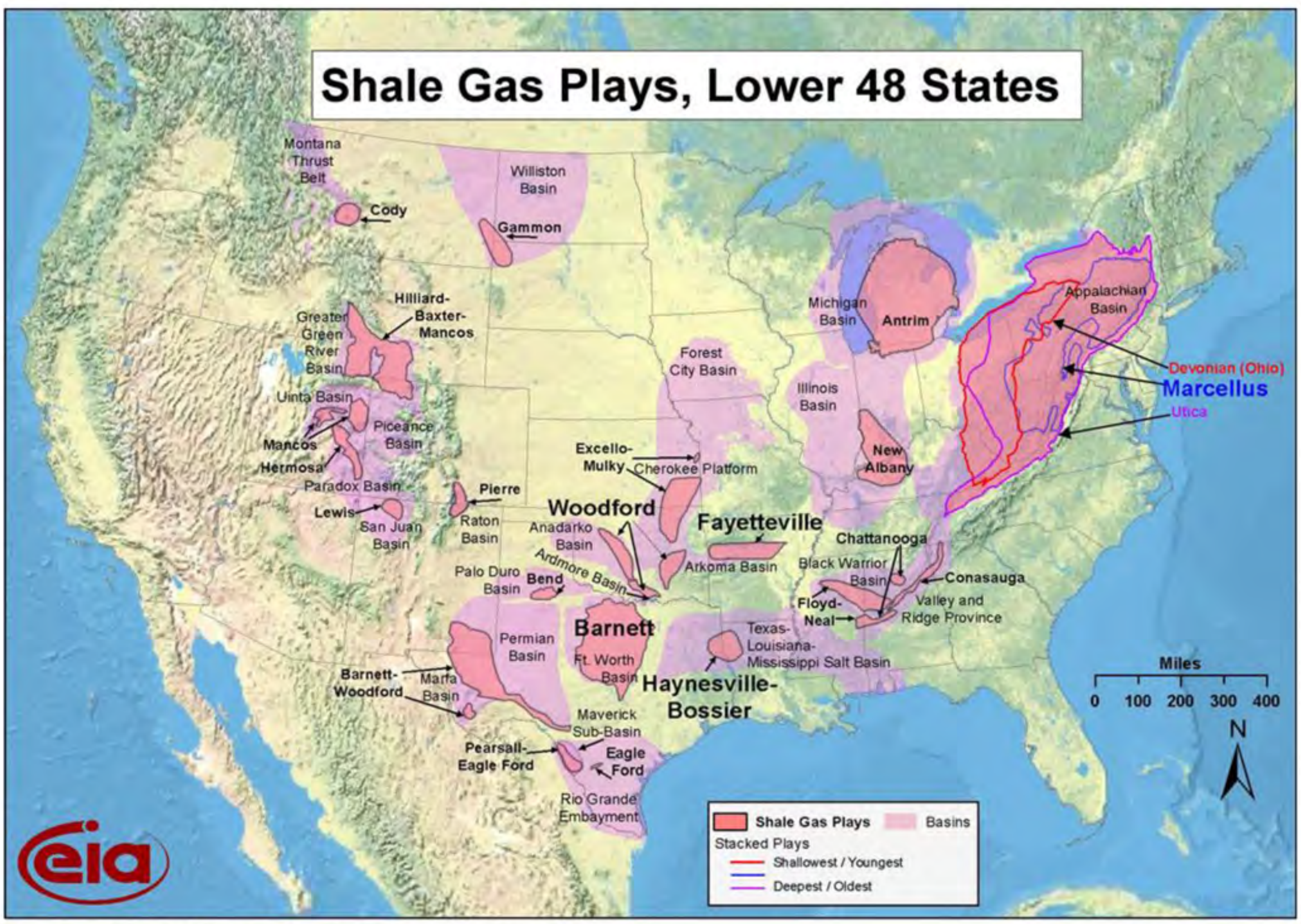
Some of the methane that formed from the organic matter buried with the sediments escaped into sandy rock layers adjacent to the shales, forming conventional accumulations of natural gas which are relatively easy to extract. But some of it remained locked in the tight, low permeability shale layers, becoming shale gas.

Many large shale formations were formed during the Devonian period of Earth's history, more than 300 million years ago.

This map shows what geologists believe the land looked like 385 million years ago during the Middle Devonian Period (with outline of today's states). Also indicated are the bodies of water that occupied the Michigan, Appalachian and Illinois basins, regions with thick layers of sedimentary rock containing fossil fuels, including shale gas. Credit: Ron Blakey, Colorado Plateau Geosystems, Inc.

Where is shale gas found in the United States?

Shale gas is located in many parts of the United States. These deposits occur in shale **"plays"** – a set of discovered, undiscovered or possible natural gas accumulations that exhibit similar geological characteristics. Shale plays are located within large-scale basins or accumulations of sedimentary rocks, often hundreds of miles across, that also may contain other oil and gas resources.[1] Shale gas production is currently occurring in 16 states.



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

Map source: U.S. Energy Information Administration

1 U.S. Government Accountability Office, Report to Congressional Requesters, "Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks," page 14, GAO-12-732, September 2012.

Shale Gas, Horizontal Drilling and Hydraulic Fracturing Development Technological Highlights

1800s

1821
First commercial U.S. production of natural gas from shale from a shallow dug pit in Fredonia, N.Y.

1860s to 1920s
Natural gas, including shale gas from Appalachian and Illinois basins, is limited to use in cities close to wells.

In 1947, Standolin Oil (Amoco) conducted the first experimental fracturing in the Hugoton field in southwestern Kansas. Photo: JPT Online, Society of Petroleum Engineers, http://www.jptonline.org/index.php?id=481

1930s

1930s
Technology developed to lay large pipelines to transmit gas to northeastern cities; first horizontal well is drilled.

1940s

Late 1940s
Hydraulic fracturing first used to stimulate oil and gas wells. First experimental hydraulic fracturing treatment pumped in 1947 in Grant County, Kansas. First commercial use occurs in 1949 in Stephens County, Okla.

1950s

1950s
Hydraulic fracturing becomes commercially accepted process. More than 100,000 individual hydraulic fracturing treatments performed by 1955.

Marcellus Shale outcrop in Highland County, Va. Photo: James Coleman, U.S. Geological Survey

1970s

1970s
Development of downhole motors – a key component of directional drilling technology, accelerates. DOE sponsors R&D to improve shale and other unconventional gas extraction.

1980s

1990s

1980s to 1990s
Partnering with DOE and the Gas Research Institute, Mitchell Energy combines larger fracture designs, rigorous reservoir characterization, horizontal drilling and lower cost approaches to hydraulic fracturing to make drilling in Texas's Barnett Shale economical.

2000s

2000s
2003-2004 – Led by the Barnett Shale play, about 2 billion cubic feet (Bcf) of gas per day are produced from U.S. shales; operators begin exploring the Marcellus shale play in Pennsylvania. *2005-2010* – Gas production from Barnett Shale grows to about 5 Bcf daily; development of other major shale plays begins. *2010 – Present*: DOE research continues to promote shale exploration, development and environmental protection.

Sources: U.S. Department of Energy, National Energy Technology Laboratory; U.S. Government Accountability Organization; "Economic Report of the President," 2012.

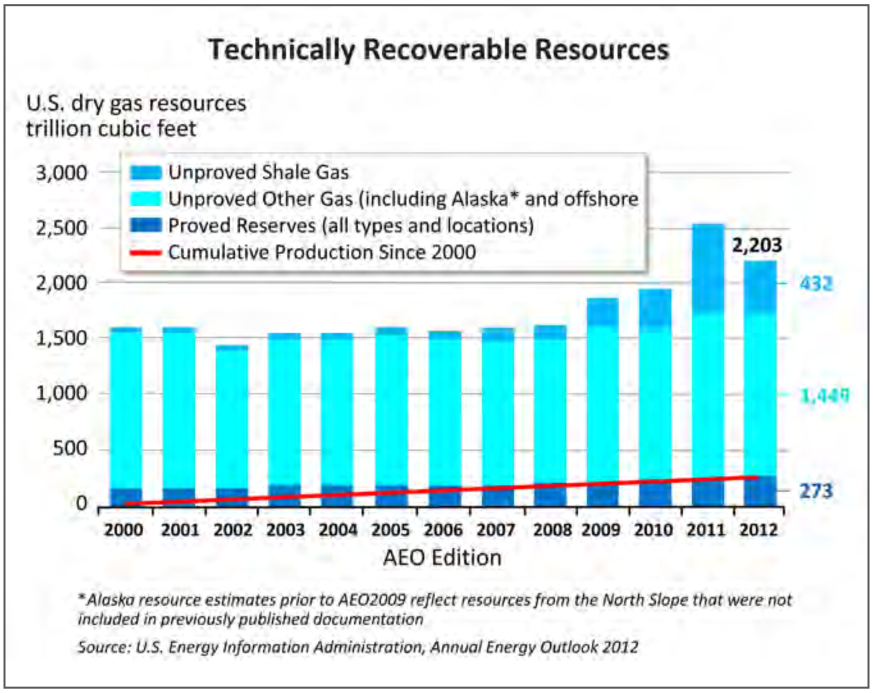
Photo: U.S. Geological Survey, New York Water Science Center

SHALE STAT: Between 1978 and 1992, DOE invested about $137 million in the Eastern Gas Shale Program, which helped develop and demonstrate directional and horizontal drilling technology.

Source: Economic Report of the President, February 2012, Chapter 8, page 256

Why is Shale Gas Important?

With the advance of extraction technology, shale gas production has led to a **new abundance of natural gas supply** in the United States over the past decade, and is expected to continue to do so for the foreseeable future. According to the Energy Information Administration (EIA), the unproved technically recoverable U.S. shale gas resource is estimated at **482 trillion cubic feet**.[1] Estimated proved and unproved shale gas resources amount to a combined 542 trillion cubic feet (or 25 percent) out of a total U.S. resource of 2,203 trillion cubic feet.[2]



Shale drilling site in Wyoming. Photo: David Mott, U.S. Geological Survey Wyoming Water Science Center, http://pubs.usgs.gov/fs/2012/3049/FS12-3049_508.pdf

U.S. shale gas production has **increased 12-fold** over the last decade and this trend is expected to continue through at least 2035 – rising from 5 trillion cubic feet per year in 2010 (23 percent of total U.S. dry gas production) to 13.6 trillion cubic feet per year in 2035 (49 percent of total U.S. dry gas production) – see *Annual Energy Outlook 2012*, page 3.

1 U.S. Energy Information Administration, "Annual Energy Outlook 2012," Table 14, Unproved technically recoverable resource assumptions by basin, page 57.

2 U.S. Energy Information Administration, "Annual Energy Outlook 2012," Shale gas provides largest source of growth in U.S. natural gas supply, page 93.

In general, increased domestic production of energy resources often results in larger supplies and lower prices, a reduced need for imports and enhanced U.S. energy security. Aside from these benefits, developing domestic shale gas resources means **additional jobs** when wells are drilled, pipelines are constructed, and production facilities are built and operated. Shale gas production also means **increased tax and royalty receipts** for state and federal governments, and royalty and bonus payments to landowners.

Developing domestic shale gas resources means additional jobs when wells are drilled, pipelines are constructed, and production facilities are built and operated.

Shale gas is having a beneficial impact on supplies and consumer prices for natural gas, as well as additional environmental benefits:

- Natural gas provides a quarter of overall U.S. energy;
- It is used to generate a quarter of the nation's electricity. Net generation from natural gas-fired power plants increased 35 percent between 2005-2012, coinciding with a continuous upsurge in shale gas supplies;
- Natural gas provides heat for 56 million residences and businesses;
- It delivers 35 percent of the energy and feedstocks needed by U.S. industry;
- Onshore consists of around 7,000 companies, including 2,000 drilling operators and hundreds of service companies;
- It directly employs over 2 million Americans who earn over $175 billion in labor income;
- Shale gas generates over $250 billion annually in government revenue via corporate income taxes; severance taxes; royalties on federal lands; sales, payroll, property, use and excise taxes;
- Combined with the continued displacement/retirement of coal power plants, greater shale gas use has helped the U.S. achieve approximately 70 percent of the CO_2 reductions targeted under the Kyoto Protocol as of 2012; and,
- According to a 2011 report, the shale gas industry supports more than 600,000 American jobs today (growing to 870,000 jobs by 2015) and contributes $118.2 billion to the nation's Gross Domestic Product.

Sources: National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," 2011, Executive Summary, pages 7 and 16; and Forbes magazine, "Surprise Side Effect of Shale Gas Boom: A Plunge in U.S. Greenhouse Emissions," December 7, 2012; IHS online, report available at http://www.ihs.com/info/ecc/a/shale-gas-jobs-report.aspx.

It Seems Like Shale Gas Came Out of Nowhere – What Happened?

Knowledge of gas shale resources and even production techniques has been around a long time (see *"Technological Highlights"* timeline). But even as recently as a few years ago, very little of the resource was considered economical to produce. Innovative advances – especially in **horizontal drilling**, **hydraulic fracturing** and other **well stimulation technologies** – did much to make hundreds of trillions of cubic feet of shale gas technically recoverable where it once was not.

The **U.S. Department of Energy's (DOE) Office of Fossil Energy**, along with industry partners, was heavily involved in the innovation chain, and helped to make some of these techniques, as well as protective environmental practices and data development, efficient and cost-effective.

SHALE STAT: In 1975, a DOE-industry joint venture drilled the first Appalachian Basin directional wells to tap shale gas, and shortly thereafter completed the first horizontal shale well to employ seven individual hydraulically fractured intervals. DOE integrated the basic core and geologic data from this well to prepare the first publically available estimates of technically recoverable gas for shales in West Virginia, Ohio and Kentucky.

Source: NETL, "Shale Gas: An American Success Story," page 5.

DOE researchers gathering data from one of a series of cored shale wells in the Appalachian Basin in the early 1980s.

How is Shale Gas Produced?

Shale gas formations are "**unconventional**" reservoirs – i.e., reservoirs of low "**permeability**."

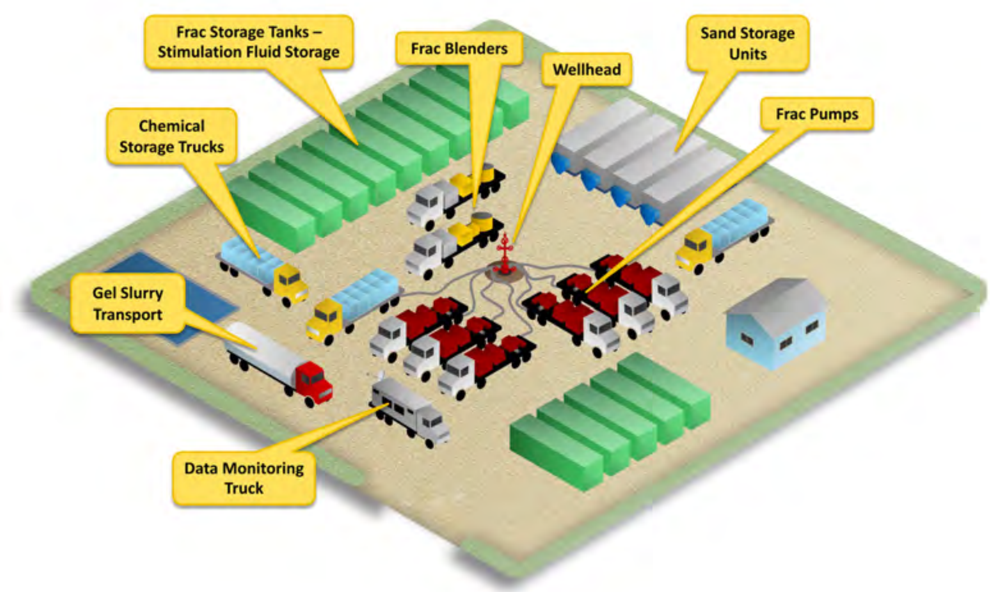
Permeability refers to the capacity of a porous, sediment, soil – or rock in this case – to transmit a fluid. This contrasts with a "**conventional**" gas reservoir **produced from sands and carbonates** (such as limestone).

Tight gas differs from shale gas in that it is trapped in sandstone or limestone, rather than shale formations.

The bottom line is that in a conventional reservoir, the gas is in interconnected pore spaces, much like a kitchen sponge, that allow easier flow to a well; but in an unconventional reservoir, like shale, the reservoir must be mechanically "**stimulated**" to create additional permeability and free the gas for collection. In addition to shale gas, other types of unconventional reservoirs include **tight gas** (low-porosity sandstones and carbonate reservoirs) and **coal bed methane** (CBM – gas produced from coal seams).

Hydraulic fracturing is a known technology and has been used for at least 60 years. It has helped produced more than 600 trillion cubic feet of natural gas and 7 billion barrels of oil.

Source: American Petroleum Institute, "Freeing Up Energy – Hydraulic Fracturing: Unlocking America's Natural Gas," July 19, 2010, page 4.

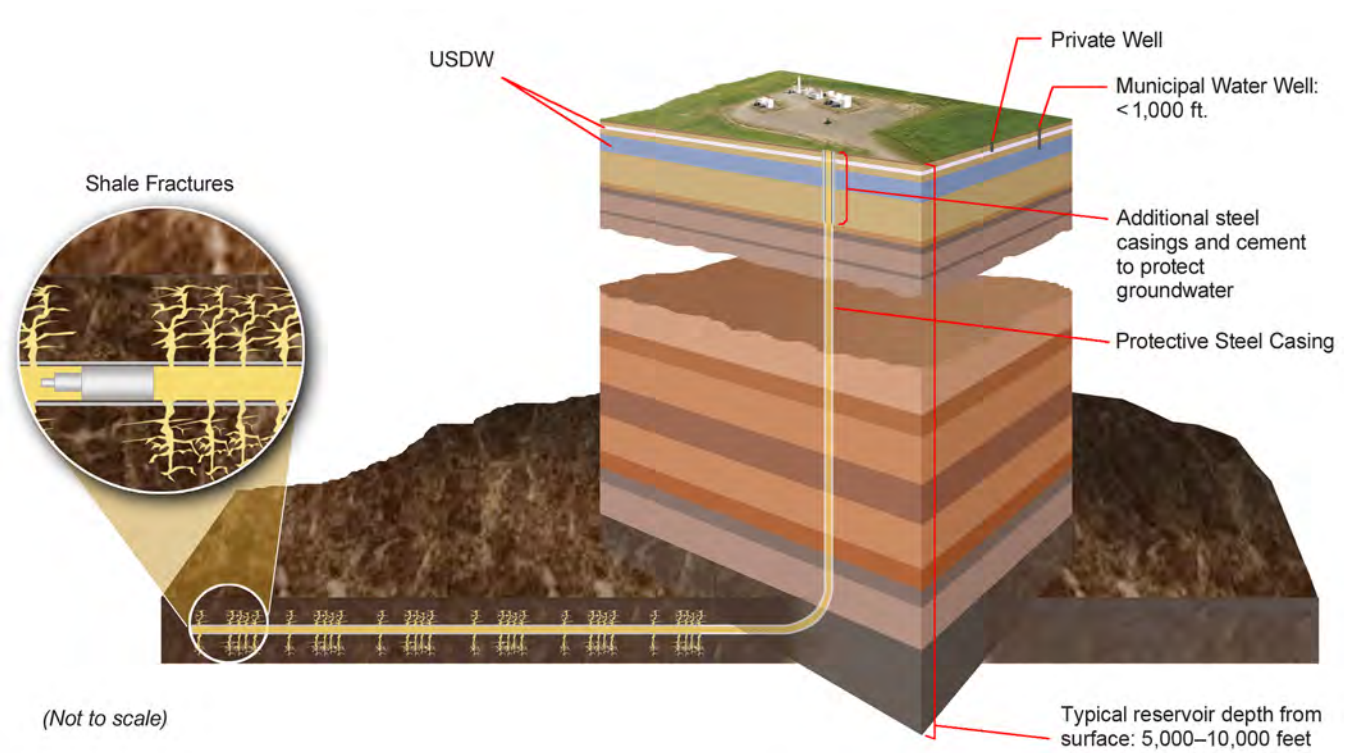


Representation of common equipment at a natural gas hydraulic fracturing drill pad.

For shale gas, **hydraulic fracturing** of a reservoir is the preferred stimulation method (*see graphic below*).

This typically involves injecting pressurized fluids to stimulate or fracture shale formations and release the natural gas. Sand pumped in with the fluids (often water) helps to keep the fractures open. The type, composition and volume of fluids used depend largely on the geologic structure, formation pressure and the specific geologic formation and target for a well. If water is used as the pressurized fluid, as much as 20 percent can return to the surface via the well (known as **flowback**). This water can be treated and reused – in fact, reuse of flowback fluids for subsequent hydraulic fracture treatments can **significantly reduce the volume of wastewater** generated by hydraulic fracturing.

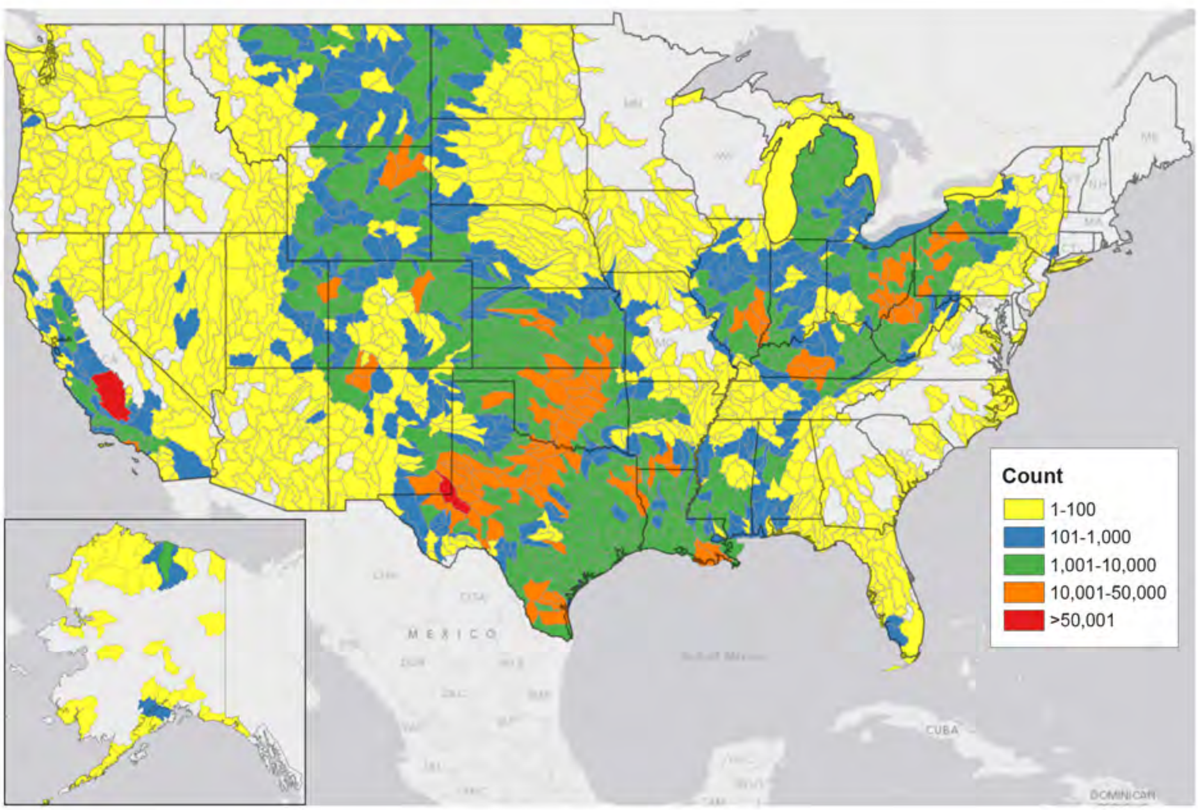
Fine-grained silica sand is mixed with chemicals and water before being pumped into rock formations to prevent the newly created artificial fractures from closing after hydraulic fracturing is completed. Photo: Bill Cunningham, U.S. Geological Survey



Producible portions of shale gas formations are located many thousands of feet below the surface, well below groundwater aquifers. Modern hydraulic fracturing technology involves sophisticated engineering processes designed to create distinct fracture networks in specific rock strata. Experts continually monitor all aspects of the process, which must comply with local, state and federal laws and regulations.

The hydraulic fracturing process was used in conventional limestone and sandstone reservoirs for decades before the onset of the shale revolution. But it was not until the 1970s that significant attempts to apply the technology to gas shale were made, pioneered by **DOE research** and demonstration project cost-sharing with industry in such ventures as the **Eastern Gas Shales Project** (1976-92).[1]

Another major technology often employed in producing natural gas from shale is **horizontal drilling** *(see graphic on previous page)*. The shallow section of shale wells are drilled vertically (much like a traditional conventional gas well). Just above the target depth – the place where the shale gas formation exists – the well deviates and becomes horizontal. At this location, horizontal wells can be oriented in a direction that maximizes the number of natural fractures intersected in the shale. These fractures can provide additional pathways for the gas that is locked away in the shale, once the hydraulic fracturing operation takes place.



More than 4 million oil and gas related wells have been drilled in the United States since development of these energy resources began nearly 150 years ago. At least 2 million of these have been hydraulically fracture-treated, and up to 95 percent of new wells drilled today are hydraulically fractured, accounting for more than 43 percent of total U.S. oil production and 67 percent of natural gas production.

Sources: U.S. Geological Survey Powell Center for Analysis and Synthesis (graphic), http://pubs.usgs.gov/fs/2012/3049/FS12-3049_508.pdf; "Hydraulic Fracturing – A Historical and Impact Perspective," presentation by Kent F. Perry, Gas Technology Institute, College Station, Texas, November 18, 2010, slide 33, http://www.rpsea.org/attachments/contentmanagers/3328/Natural_Gas_The_Path_to_Clean_Energy_Forum_Hydraulic_Fracturing_a_Historical_and_Impact_Perspective_Kent_Perry_111810.pdf; and National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," 2011, page 205.

1 See http://www.netl.doe.gov/publications/descriptions.html for a DVD archive of the DOE/NETL Unconventional Gas Resources Program, containing reports and logs related to the Eastern Gas Shales Project.

What Challenges are Associated with Shale Gas Production?

Developing any energy resource – whether conventional or non-conventional like shale – carries with it the possibility and risk of **environmental**, **public health**, and **safety issues**. Some of the challenges related to shale gas production and hydraulic fracturing include:

- Increased consumption of fresh water (volume and sources);
- Induced seismicity (earthquakes) from shale flowback water disposal;Chemical disclosure of fracture fluid additives;
- Potential ground and surface water contamination;
- Air quality impacts;
- Local impacts, such as the volume of truck traffic, noise, dust and land disturbance.

For more specifics about these challenges, see ***"Shale Gas Development Challenges – A Closer Look"*** fact sheets.

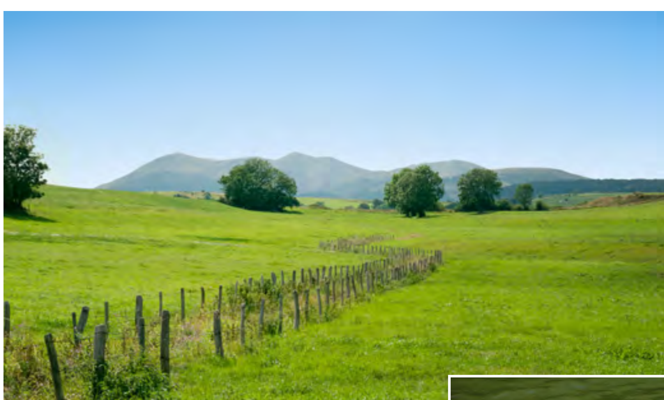
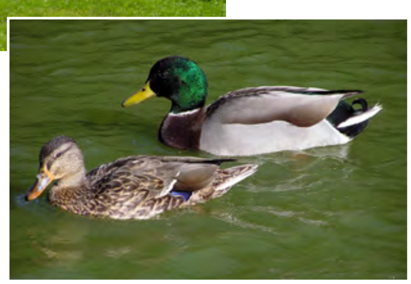


Photo: Doug Duncan, U.S. Geological Survey



Shale Gas Development Challenges – A Closer Look

Water

Key Points:

- As with conventional oil and gas development, requirements from **eight federal** (including the Clean Water Act) and numerous **state and local environmental and public health laws** apply to shale gas and other unconventional oil and gas development. Consequently, the fracturing of wells is a process that is **highly engineered, controlled and monitored.**
- Shale gas operations use water for **drilling**; water is also the primary component of **fracturing fluid**.
- This water is likely to come from rivers, lakes, ponds, groundwater aquifers, municipal supplies, reused wastewater, or recycled water from earlier fracturing operations. Operators are guided by all **applicable laws and regulations** in water acquisition.
- As much as **10 million gallons** may be pumped into a single well. Although this amount is relatively small when compared to other major water uses (such as agriculture), its cumulative effect could impact aquatic habitats or water availability, especially where water is a limited resource.
- A number of studies and publications caution that surface and **groundwater contamination remains a risk**; some studies document contamination from above-ground chemical spills, leaks, wastewater mishandling and other incidents. How significant these risks are over the long term is presently unclear and in need of continued study.

Although closely monitored at all stages, the fracturing of shale wells requires **large amounts of water**. However, this amount of water is considered relatively small when compared to other major uses, such as agriculture and industrial purposes.[1] Operators are pursuing a variety of techniques, including recycling and reusing produced water, to reduce freshwater demand. Research is under way to find improved methods of treating fracture flowback water so it can be reused more effectively. In some areas of the country, significant water use for shale production may affect the availability of water for other uses. The **National Petroleum Council** (NPC) has concluded some "widely publicized instances of water wells being contaminated by methane" are unrelated to hydraulic fracturing and due instead to drilling encountering "shallow geologic zones" containing natural gas, which migrated to drinking water aquifers and domestic wells *("Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources,"* page 195). Additionally, the Environmental Protection Agency is expected to release a report in 2014 that examines, among other things, hydraulic fracturing and potential drinking water impacts.

Left: The lifecycle of water associated with shale gas development. Water supply (top, usually either surface or ground water, is mixed with small amounts of chemical additives and pumped under pressure into the well. The water must be transported (bottom) and storage (middle) in impoundments occurs at or near well sites. After use the water is captured, reused, treated and discharged, or disposed of in an approved manner. More and more companies are utilizing tanks for storage to avoid potential problems of seepage and spillage.

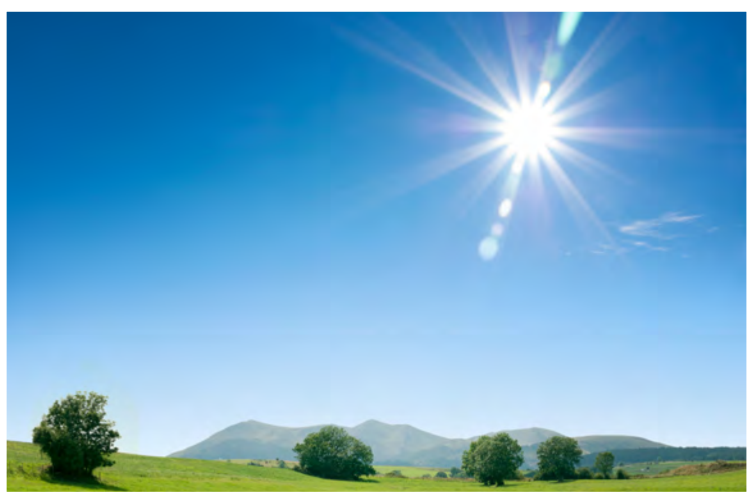
1 Massachusetts Institute of Technology, "MIT Study on the Future of Natural Gas," June 6, 2011, Chapter 2: Supply, pages 43-44.

Shale Gas Development Challenges – A Closer Look

Air

Key Points:

- Air quality risks from shale oil and gas development are generally the result of: (1) dust and engine exhaust from increased truck traffic; (2) emissions from diesel-powered pumps used to power equipment; (3) intentional flaring or venting of gas for operational reasons; and, (4) unintentional emissions of pollutants from faulty equipment or impoundments.[1]
- Natural gas is efficient and clean compared to other fossil fuels, emitting less nitrogen oxide and sulfur dioxide than coal and oil, no mercury and very few particulates. However, the drilling process potentially can release chemicals such as **benzene** as well as **methane**, a very reactive greenhouse gas. Data in this area is lacking and currently under study.
- The Environmental Protection Agency (EPA) in 2012 finalized **New Source Performance Standards** that set the first air pollution standards for natural gas hydraulic fracturing operations. The new rules, which also include performance standards for other modified oil and natural gas operations, are slated to become effective in 2015.[2]



1 Government Accountability Office, "Unconventional Oil and Gas Development: Key Environmental and Public Health Requirements," September 2012, page 33.

2 National Conference of State Legislatures, "Natural Gas Development and Hydraulic Fracturing: A Policymaker's Guide," June 2012, pages 3-4.

The sources of potential air emissions associated with shale gas production can occur at the drill site during drilling and fracturing, and at ancillary off-site facilities such as pipelines and natural gas compressors. The onsite emissions include **dust** and **diesel fumes**, **fine particulate matter** and **methane**.[3] Hydraulic fracturing operations use large amounts of horsepower, provided almost exclusively by diesel engines. **Volatile organic carbon compounds (VOCs)** from natural gas production are a primary concern because they can combine with nitrogen oxides (NOx) to form **smog** and contribute to elevated levels of **ozone** in the atmosphere. The contribution of shale gas activities to these levels is not well known and is being studied further. Methane is a strong **greenhouse gas** and might be released during the drilling, fracturing, flowback and production phases of shale gas development. Onsite **fugitive emissions** of methane may take place from other sources as well. Trucks are often used to transport water and/or fluids used in the hydraulic fracturing process. Where feasible, operators are increasingly turning to temporary surface **flowlines** to transport fresh water to impoundments and well sites, resulting in a subsequent decrease in truck traffic. Additionally, **multi-well pads** allow centralized water storage and management of flowback water, reducing truck transport. In an effort to both lower costs and improve environmental performance, some of North America's largest oil and gas field service companies are converting drilling rig and truck engines to run on liquefied natural gas (see The Wall Street journal, "Drillers Shift to Use of natural Gas," Dec. 25, 2012, http://online.wsj.com/article/SB10001424127887323291704578199751783044798.html?mod=WSJ_qtoverview_wsjlatest).

Left: Engine exhaust from increased truck traffic can be one of the air quality risks associated with development of shale gas. Photo: Doug Duncan, U.S. Geological Survey

Right: A dust release from a sand refill truck, identified by the National Institute for Occupational Safety and Health (NIOSH) as an inhalation health hazard. Photo: Centers for Disease Control and Prevention

3 The Energy Institute at the University of Texas at Austin, "Fact Based Regulation for Environmental Protection in Shale Gas Development," February 2012, page 27.

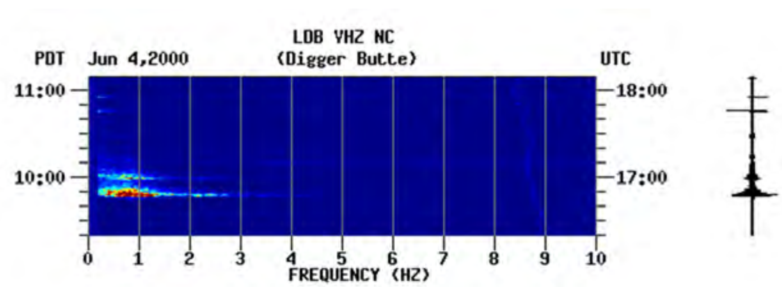
Shale Gas Development Challenges – A Closer Look

Induced Seismic Events (Earthquakes)

Key Points:

- **Induced seismic events** are earthquakes attributable to human activity. The possibility of induced seismic activity related to energy development projects, including shale gas, has drawn some public attention.
- Although **hydraulic fracturing** releases energy deep beneath the surface to break rock, studies thus far indicate the energy released is generally not large enough to trigger a seismic event that could be felt on the surface.[1]
- However, **waste fluid disposal** through underground injection can "pose some risk for induced seismicity."[2]
- According to the **National Academies of Sciences (NAS),** accurately predicting seismic event magnitude or occurrence is not possible, in part because of a lack of comprehensive data on the natural rock systems at shale gas and other energy development sites.
- NAS said further **research** is required to "better understand and address the potential risks associated with induced seismicity."

Image shows a teleseism which is a record of an earthquake made by a seismograph at a great distance. Source: U.S. Geological Survey



1 Government Accountability Office, "Unconventional Oil and Gas Development: Key Environmental and Public Health Requirements," September 2012, page 52.

2 The National Academies of Sciences, "Induced Seismicity Potential in Energy Technologies," 2012, Executive Summary, page 1.

Scientists have long understood that pumping fluids into or out of the Earth has the potential for inducing seismic events, including **earthquakes** that can be felt at the surface. A series of small seismic events in Arkansas, Ohio, Oklahoma and Texas over the past several years has drawn public attention to a possible link between earthquakes and deep wells used to dispose of hydraulic fracturing waste water. As presently implemented, scientists do not believe the process of **hydraulic fracturing** a well for shale gas production poses a significant risk for inducing felt seismic events.[3] Injection for disposal of **waste water** from the process, however, may pose some risk, although very few instances have ever been documented.

According to the **National Academies of Sciences** (NAS), the factor that appears to have the most direct consequence for inducing seismicity is **net fluid balance** – the total balance of fluid introduced into or withdrawn from the subsurface. But additional factors may also influence the way fluids affect the subsurface. “Energy projects that are designed to maintain a balance between the amount of fluid being injected and withdrawn, such as most oil and gas development projects, appear to produce **fewer seismic events** than projects that do not maintain fluid balance,” an NAS report says. “Future research is required to better understand and address the potential risks associated with induced seismicity.”

Scientists do not believe hydraulic fracturing activities are a significant cause of seismic events that can be felt at the surface. Waste fluid disposal, however, does pose some risk for induced seismicity. Future research is needed to better understand risks associated with induced seismicity, according to the National Academies of Sciences. Photo: Bill Cunningham, U.S. Geological Survey

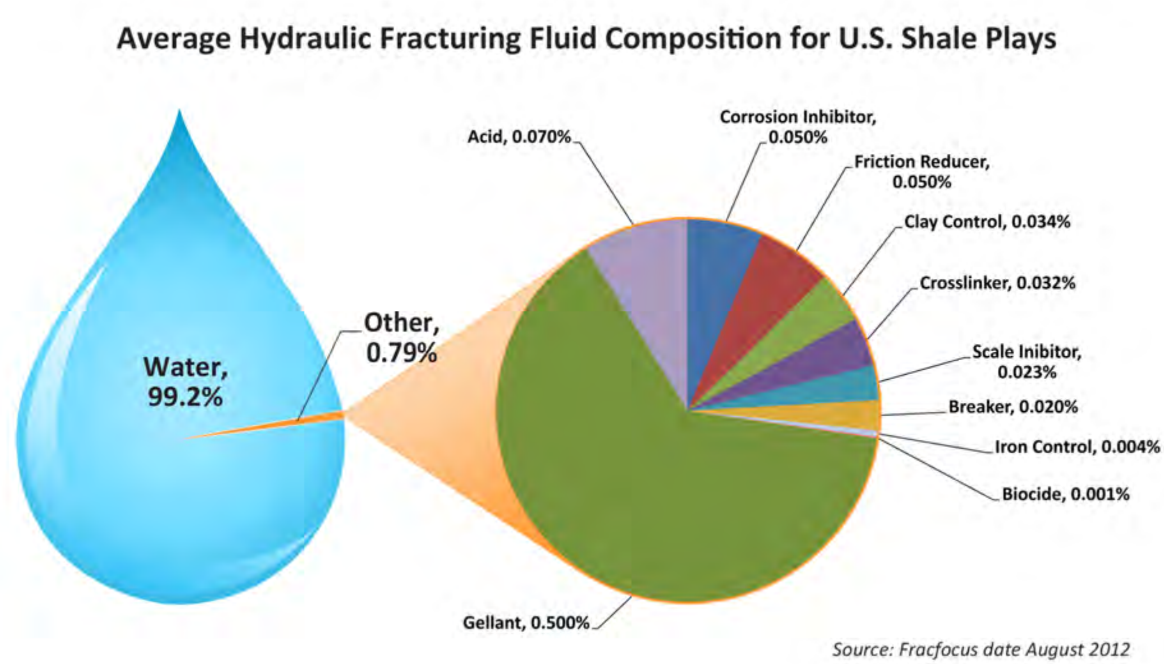
[3] Ibid.

Shale Gas Development Challenges – A Closer Look

Fracture Fluids

Key Points:

- Shale fracture fluid, or "**slickwater**," is largely composed of water (99%); but a number of additives are mixed in with it to increase the effectiveness of the fracturing operation. These additives vary as a function of the well type and the preferences of the operator.
- **Hydraulic fracturing fluids** can contain hazardous chemicals and, if mismanaged, spills could leak harmful substances into ground or surface water. However, good field practice, governed by existing regulations, "should provide an **adequate level of protection**" from fracturing fluid risks.[1]



Slickwater is mostly water, with a relatively consistent 0.5 to 2.0 percent comprised of additives.

Information Source: http://fracfocus.org/

1 Massachusetts Institute of Technology, "MIT Study on the Future of Natural Gas," June 6, 2011, Chapter 2: Supply, page 41.

- **Disclosure of additives** contained in these fluids is an important issue, which some states have addressed through legislation.
- **FracFocus**, a joint effort by the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC) and sponsored by the U.S. Department of Energy, is an online registry for companies to publicly disclose the chemicals used in hydraulic fracturing. As of November 2012, more than 30,000 well sites and 200 companies were registered on the site (http://fracfocus.org/), and eight states were using it for regulatory reporting.

Photo by: Daniel Soeder, USGS

Proper management and use of **fracturing fluids** is one of the keys to shale gas production environmental protection. These fluids are critical to the fracturing process – for example, a single well hydrofracture in the **Marcellus Shale** formation of the Northeastern U.S. may require **2 million to 5 million gallons** of fracturing fluid, an average of **25 percent** of which may be returned to the surface as **"flowback"** water (see *"Shale Gas Development Challenges – A Closer Look: Water*").[2] Fracturing fluids are primarily **water**, with a small amount of **chemical additives** and **sand**. Some additives used in fracturing fluid are known to be toxic, but data are limited for other additives.[3] If the chemical additives in fracturing fluid are not properly handled, they can pose a risk to surface and/or ground water. **FracFocus** (see above), a joint effort by the **Ground Water Protection Council (GWPC)** and the **Interstate Oil and Gas Compact Commission (IOGCC)** and sponsored by DOE**,** is an online registry for companies to publicly disclose the chemicals used in hydraulic fracturing.

Produced water and fracturing fluids returned during the flowback process contain a wide range of **constituents** (some of which occur naturally but others of which are added through the drilling and hydraulic fracturing process) and pose a risk to water quality if not properly managed. This water is typically treated to remove metal ions and other dissolved materials, and then **recycled** for future use, or released back into the environment via **discharge to rivers** (as authorized under the **Clean Water Act**), or **deep underground injection** (as authorized under the **Safe Water Drinking Act**). Regulations may also allow recovered fracturing fluids to be disposed of at appropriate commercial water facilities. Fracturing fluid that does not return to the surface during the well's production is confined by thousands of feet of rock layers and stays underground.

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2 "Water Treatment Key to Hydraulic Fracturing's Future," Rigzone, http://www.rigzone.com/news/article.asp?a_id=97222, retrieved on November 2, 2012.

3 Government Accountability Office, "Unconventional Oil and Gas Development: Key Environmental and Public Health Requirements," September 2012, page 41.

Shale Gas Development Challenges – A Closer Look

Surface Impacts (non-water)

Key Points:

- There are many local economic and energy benefits from shale gas development; there is also an inherent risk of increased traffic or other habitat disturbances that could affect residents, agriculture, farming, fishing and hunting.[1]
- Shale gas development can lead to socio-economic impacts and can increase demands on local infrastructure, traffic, labor force, education, medical and other services.[2] Federal and state laws are designed to mitigate the impact of these challenges.
- The rapid expansion of shale gas development and hydraulic fracturing has increased attention on potential effects on human health, the environment and local wildlife habitat. Vegetation and soils are disturbed where gas wells require new roads, clearing and leveling.
- The degree of surface impacts can be affected by many factors, such as location and the rate of development; geological characteristics; climatic conditions; the use by companies of new technologies and best practices; and regulatory and enforcement activities.
- Advanced horizontal drilling and hydraulic fracturing technologies increasingly allow energy companies to access far more natural gas with fewer wells and disturbed acres.

1 National Conference of State Legislatures, "Natural Gas Development and Hydraulic Fracturing: A Policymaker's Guide," June 2012, page 3.

2 National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," 2011, Tale 2-2, page 181.

A number of studies have begun to document potential impacts and risks of shale gas development, including increased **truck traffic** from construction of the **well pad**, **access road** and other **drilling facilities**; **noise** and **degradation of air quality** from truck traffic and heavy machinery needed for drilling and fracturing; possible human health issues from **silica sand** used in the hydraulic fracturing process (see *"Shale Gas Development Challenges – A Closer Look: Air"*); **degradation of water quality** (see *"Shale Gas Development Challenges – A Closer Look: Water"*); **erosion** from the earth-disturbing activities (clearing, grading and excavating) necessary for well development; and **wildlife and habitat impacts**, such as clearing land of vegetation, leveling the site to allow access to the resource, and construction activities.

The **Government Accountability Office** (GAO) notes that because shale development is relatively new in some areas, "the long-term effects – after operators are to have restored portions of the land to pre-development conditions – have not been evaluated. Without these data, the cumulative effects of shale oil and gas development on habitat and wildlife are largely unknown."[3] GAO also found that, in general, shale gas development impacts can vary significantly even within shale basins.

There are inherent risks of surface impacts with any type of energy development, including shale wells and hydraulic fracturing. Many of these impacts are temporary in nature, and federal and state laws and regulations are designed to mitigate harmful effects. Additionally, new technologies and sound operator practices can have a positive effect on lessening surface and other socio-economic impacts. Photo source: U.S. Department of Energy

[3] U.S. Government Accountability Office, Report to Congressional Requesters, "Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks," page 52, GAO-12-732, September 2012.

Shale Gas Development – FAQ

Q: *Is shale gas development regulated at the federal, state or local level?*

A: In many cases, all three. At a minimum there are eight federal environmental and public health laws that apply to unconventional oil and gas development, which includes shale resources; however, for some of these laws, key exemptions or limitations in regulatory coverage can affect applicability. There are at least 16 states that currently have or are expected to have shale gas development, and related laws and regulations. State law determines the extent of authority local municipalities may have; this authority will vary from state to state.

Q: *Who has the lead regulatory responsibility?*

A: States often have the lead role in regulating shale gas development activities; many federal requirements have been delegated to states. A number of states have been involved in overseeing oil and gas exploration and development for much longer than the federal government. Federal agencies have primary responsibility where the federal government owns or controls mineral rights or lands.

Q: *What exactly is regulated?*

A: Taking into account federal, state and local laws and regulations, virtually every aspect of exploration, production and site restoration activities, including well design, location, spacing, operation, water and waste management and disposal, air quality, wildlife protection, surface impacts, site closure and health and safety.

Q: *How can I find out what agency in my state is responsible for shale gas regulation?*

A: State agencies that regulate shale development environmental practices and monitor and enforce laws and regulations may be located in the Department of Natural Resources (such as Ohio), the Department of Environmental Protection (as in Pennsylvania), or some other agency. Sometimes multiple agencies are involved, having jurisdiction over different activities and aspects of development. For a list of regulatory agencies for states with oil and gas development, see Exhibit 26, page 28 at: http://www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf.

Q: *I am considering a mineral rights/oil and gas rights transaction and/or have concerns about shale gas drilling activity near my property; what should I do?*

A: Understanding the laws of your state is essential. Contact the state regulatory agency involved (see link above); for any transaction, get advice from an attorney who specializes in the area involved on how laws and regulations apply to your situation.

Q: *A company is constructing a new shale gas well on or near my property and will use hydraulic fracturing. Can't the gas be produced some other way?*

A: In most cases, no. In an unconventional reservoir like shale, the gas is often taken from the rock itself. So the reservoir must be "mechanically stimulated" to break apart the rock and release the gas. Hydraulic fracturing, a mature 60-year-old technology, is usually the most efficient and economical way to do this. That's why up to 95 percent of new wells drilled today are hydraulically fractured. Plus, technology and methods continue to improve; DOE is conducting research to develop technologies that reduce the volumes of water used.

Q: *What kind of noise and surface disturbance can I expect from development of a new shale well?*

A: There will be temporary disruption and impacts on the surrounding landscape, including increased truck traffic; clearing and construction of the well pad and access road; drilling activities; noise and potential air quality degradation from heavy machinery like bulldozers and graders; significant water use; and possible wildlife habitat fragmentation. The degree of surface impacts can be affected by many factors, including the location and rate of development; geological characteristics; climatic conditions; the degree of new technologies and best practices employed by the producing company; and regulatory and enforcement requirements and activities. Advanced technologies are increasingly allowing energy companies to access far more natural gas with fewer wells and disturbed acres.

Q: *Aren't shale fracturing fluids toxic?*

A: The make-up of fracturing fluids, or "slickwater," varies from one geologic basin to another, but in general, it consists of about 99 percent water and the remainder sand and chemical additives, some of which are potentially toxic if mishandled. The proper management and use of fracturing fluids is one key to environmental protection in regard to shale production, is enforced by laws and regulations, and is taken seriously by operators. Disclosure of fluid additives is an important issue which some states have addressed through legislation; FracFocus is an online registry for companies to disclose the chemicals they use in hydraulic fracturing (http://fracfocus.org/).

Q: *Will hydraulic fracturing endanger my water well?*

A: Both fracturing and horizontal drilling activities take place thousands of feet below drinking water acquifers. An earlier study by the Environmental Protection Agency (EPA) found no confirmed cases linking hydraulic fracturing to drinking water well contamination. EPA is currently updating this study with data specifically focusing on natural gas drilling in shale formations. The National Petroleum Council (NPC) concluded that certain highly publicized instances of water wells being contaminated by methane were unrelated to hydraulic fracturing and due instead to drilling encountering shallow geologic zones containing natural gas, which migrated to drinking water acquifers and domestic wells.

Q: *What happens to the waste water (flowback water) used in hydraulic fracturing?*

A: For most shale wells, hydraulic fracturing involves injecting under high pressure several million gallons of water, sand and a small amount of chemical additives. Some of this fluid mixture (10-20 percent) immediately returns to the surface via the well and is called flowback. Additional volumes can return over time as the well is produced, or remain absorbed in the shale formation. Well operators increasingly are recycling flowback, treating it and mixing with fresh water to reuse and significantly reduce the amount of wastewater. Flowback can also be treated and discharged to rivers or streams or disposed of (often through injection into deep formations) in an approved manner that complies with law.

Q: *What is "produced" water and how is it handled?*

A: Produced water is naturally occurring water found in shale formations; it generally flows to the surface during the entire lifespan of a well. How this often highly saline water is managed and treated depends on many factors – basically the options after treatment are deep injection back into the sub-surface; using it to return water to the local ecosystem; and recycling it for use in hydraulic fracturing operations.

Q: *Doesn't hydraulic fracturing cause earthquakes?*

A: According to a recent National Academies of Sciences (NAS) study, scientists do not believe the process of hydraulic fracturing a well for shale gas production poses a significant risk for inducing seismic events that are felt at the surface. Injection for disposal of waste water from the process, however, may pose some risk, although very few instances have ever been documented. NAS has recommended additional research to better understand and address the potential risks.

Q: *What is the role of the U.S. Department of Energy in regard to natural gas production from shale?*

A: DOE has a legacy of helping pioneer technologies and processes to improve shale and other unconventional gas extraction, as well as enhance environmental protection. DOE research continues to search for innovative solutions to shale exploration, development, production and environmental protection challenges.

Shale Gas Glossary

Acquifer – A single underground geological formation, or group of formations, containing water.

Antrim Shale – A shale deposit located in the northern Michigan basin that is a Devonian age rock formation lying at a relatively shallow depth of 1,000 feet. Gas has been produced from this formation for several decades primarily via vertical, rather than horizontal, wells. The Energy Information Administration (EIA) estimates the technically recoverable Antrim shale resource at 20 trillion cubic feet (tcf).

Appalachian Basin – The geological formations that roughly follow the Appalachian Mountain range and contain potentially exploitable shale gas resources. The U.S. Department of Energy (DOE) associates the Appalachian Basin with the Marcellus Shale, the Devonian Shale and the Utica Shale.

Barnett Shale – A newly developed major play within the Fort Worth Basin in Northeast Texas. Wells are in the 6,000-to-8,000 foot depth range and the EIA estimated technically recoverable resource is 43 tcf.

Borehole – The hole or shaft in the earth made by a well drill; also, the uncased drill hole from the surface to the bottom of the well.

Caney Shale – Located in Arkoma Basin of Northeastern Oklahoma; has only recently been developed following the success of the Barnett Shale in Texas.

Casing – Pipe cemented in an oil or gas well to seal off formation fluids and to keep the borehole from caving in. Smaller diameter “strings” of casing are cemented inside larger diameter strings as a well is deepened.

Clean Water Act – The federal law that regulates discharges into waterways.

Coal Bed Methane (CBM) – A form of natural gas extracted from coal beds. Along with tight and shale gas, CBM is considered an unconventional natural gas resource.

Conesauga Shale – Cambrian Age shale deposits located in north central Alabama currently being evaluated for development.

Conventional Natural Gas Reservoir – A geological formation in which the natural gas is in interconnected pore spaces, much like a kitchen sponge, that allows easier flow to a well.

Department of Energy – The federal agency whose Office of Fossil Energy (FE) and National Energy Technology Laboratory (NETL) have played a significant role in advancing research and development related to hydraulic fracturing, horizontal drilling, and improved environmental practices.

Devonian Shale – The general term used to describe the thick sequence of shales in the Appalachian Basin that has been produced for more than a century. Development was greatest in the 1930s-through-1980s, using vertical wells and explosive fracturing. However, any shale deposited during the Devonian geologic period (360 million to 406 million years ago) is considered Devonian shale.

Drilling Rig – Usually a large-standing structure employing a drill that creates holes or shafts in the ground for purposes of accessing and producing natural gas or oil from subsurface deposits.

Eagle Ford Shale – A newly discovered (2009) shale play located in several counties in south Texas. The average gross thickness of the shale is 350 feet and it produces from depths varying from 4,000 to 14,000 feet. Eagle Ford is the most active shale play in the world, with about 250 rigs operating at any single time and the technically recoverable resource is estimated by EIA to be 21 tcf.

Eastern Gas Shales Project – A program initiated by the U.S. Department of Energy in the late-1970s to evaluate the gas potential of – and to enhance gas production from – the extensive Devonian and Mississippian black shales located in the Appalachian, Illinois and Michigan basins of the eastern United States. The program not only identified and classified shales throughout the three basins, but also focused on developing and implementing new drilling, stimulation and recovery technologies to increase production potential. Between 1978 and 1992, DOE spent about $137 million on the program, which helped develop and demonstrate directional and horizontal drilling technology.

Fayetteville Shale – Newly developed shale deposit located in the Arkoma Basin of Arkansas, lying at a depth of 1,500-to-6,500 feet. Previously produced from vertical wells but all current wells are horizontal. Technically recoverable resource is estimated by EIA to be 32 tcf.

Flaring – The controlled burning of natural gas that can’t be processed for sale or used because of technical or economic reasons.

Flowback – Water used as a pressurized fluid during hydraulic fracturing that returns to the surface via the well. This occurs after the fracturing procedure is completed and pressure is released.

Floyd Shale – A shale deposit from the Mississippian geologic age located in the resource-rich Black Warrior Basin of Mississippi and Alabama.

Fossil Energy – Energy derived from crude oil, natural gas or coal. Shale gas is a form of fossil energy.

Fracturing Fluid – The primarily water-based fluid used to fracture shale. It is basically composed of 99 percent water, with the remainder consisting of sand and various chemical additives. Fracturing fluid is pumped into wells at very high pressure to break up and hold open underground rock formations, which in turn releases natural gas.

FracFocus – A joint effort by the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC) that is an online registry for companies to publicly disclose the chemicals used in their hydraulic fracturing operations. As of November 2012, more than 30,000 well sites and 200 companies were registered on the site (http://fracfocus.org/).

Fugitive Emissions – According to a study by DOE's Argonne National Laboratory, a primary air quality concern from natural gas production (including shale gas) is leaking and venting throughout the supply chain (see Hydraulic Fracturing and Shale Gas Production: Technology, Impacts, and Policy, September 10, 2012, page 5). These fugitive emissions can potentially result in releases of methane, the primary constituent of natural gas and a potent greenhouse gas (GHG). In addition, fugitive emissions of natural gas can release volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), according to the study.

Geological Formation – A body of earth material with distinctive and characteristic properties and a degree of homogeneity in its physical properties.

Gothic Shale – A newly exploited shale formation located in the Paradox Basin of Colorado. Only a few wells have been drilled, one testing to 5,700 mcf (million cubic feet) per day.

Groundwater – The supply of usually fresh water found beneath the surface usually in acquifers, which are a body of permeable rock containing water and supplying wells and springs with drinking water.

Haynesville Shale – Along with the Marcellus and Barnett, this is one of the major shale plays. Located in Northwestern Louisiana, Haynesville is a Jurassic Age formation where vertical wells were drilled as far back as 1905; but it was not considered a major natural gas source until the advent of directional drilling.

Horizontal Drilling – The process of drilling the deeper portion of a well horizontally to enable access to more of the target formation. Horizontal drilling can be oriented in a direction that maximizes the number of natural fractures present in the shale, which provide pathways for natural gas to escape once the hydraulic fracturing operation takes place. The more generic term, "directional drilling," refers to any non-vertical well.

Hydraulic Fracturing – The use of water, sand and chemical additives pumped under high pressure to fracture subsurface non-porous rock formations such as shale to improve the flow of natural gas into the well. Hydraulic fracturing is a mature technology that has been used for 60 years and today accounts for 95 percent of all new wells drilled.

Marcellus Shale – A large play that underlies most of the U.S. Northeast, the Marcellus is a Devonian-age shale that is estimated by the Energy Information Administration to contain at least 410 tcf of unproved, technically recoverable gas. Most of the play is at the 5,000-to-8,000 foot level below the surface and was long considered too expensive to access until advances in drilling and fracturing technology.

Natural gas – A naturally occurring mixture of hydrocarbon and non-hydrocarbon gases beneath the surface, the principal component of which (50-to-90 percent) is methane.

New Albany Shale – This Devonian to Mississippian age shale deposit is located in the Illinois Basin and has been a producer of natural gas for over 100 years. Most wells are shallow, between 120 and 2,100 feet; new drilling and completion technologies and competitive prices have resulted in energy companies revisiting old leases and drilling new wells. Estimated by EIA to contain 11 tcf of technically recoverable resources.

On-Site Water Treatment – A practice employed by many shale gas producers to facilitate reuse of flowback fluids. In this instance, mobile and fixed treatment units are employed using processes such as evaporation, distillation, oxidation, and membrane filtration for recycling and reuse. On-site treatment technologies may be capable of returning 70-80 percent of the initial water to potable water standards, making it immediately available for reuse.

Pearsall Shale – Located in the Maverick Basin of southwestern Texas. Located about 2,500 feet below the Eagle Ford Shale and is approximately 500-600 feet in thickness.

Permeability – The measure of the ability of a material, such as rock, to allow fluids to pass through it.

Produced Water – Naturally occurring water found in shale formations; it generally flows to the surface during the entire lifespan of a well, often along with natural gas. Produced water and flowback from natural gas extraction may be reused in hydraulic fracturing operations; disposed of through underground injection (see definition); discharged to surface waters as long as it doesn’t degrade water quality standards; or transferred to a treatment facility if necessary, processed and discharged into a receiving water body in compliance with effluent limits.

Proppant – A granular substance, often sand, that is mixed with and carried by fracturing fluid pumped into a shale well. Its purpose is to keep cracks and fractures that occur during the hydraulic fracturing process open so trapped natural gas can escape.

Reclamation – The clean up or restoring a well site to its pre-existing condition after drilling operations cease. Reclamation activities, which are governed by state, federal and local laws and regulations, can include soil replacement, compacting and re-seeding of natural vegetation.

Royalty – A payment received by a lessor or property owner from an oil, gas or minerals-producing company, based on the production of a well or other extraction process and market prices.

Safe Water Drinking Act – A federal law whose provisions also apply to shale production activities related to wastewater disposal through underground injection and discharge to surface waters.

Shale – A fine-grained sedimentary rock composed mostly of consolidated clay or mud. Some large shale gas formations were formed more than 300 million years ago during the Devonian period of Earth's history, where conditions were particularly favorable for the preservation of organic material within the sediment. Methane that remained locked in the shale layers is the source of today's shale gas.

Shale Gas – Natural gas produced from shale formations. Shale gas is widely distributed in the United States and is currently being produced in 16 states. Although data are being constantly revised, the Energy Information Administration currently estimates the recoverable U.S. shale gas resource is 482 trillion cubic feet; domestic shale gas production has increased 12-fold over the past decade and led to a new abundance of natural gas supply in the United States.

Shale Gas Play – A set of discovered, undiscovered or possible natural gas accumulations that exhibit similar geological characteristics. Shale plays are located within basins, which are large-scale geologic depressions, often hundreds of miles across, which also may contain other oil and natural gas resources. For a map detailing the location of major shale gas plays in the lower 48 states, see: http://www.eia.gov/oil_gas/rpd/shale_gas.pdf.

Surface Water – Water that is open to the atmosphere, such as rivers, lakes, ponds, reservoirs, streams, impoundments, seas and estuaries.

Tcf – Trillion cubic feet.

Tight Gas – Natural gas found in low-permeability sandstones and carbonate reservoirs. The rock layers that hold the gas are very dense, preventing easy flow.

Unconventional Natural Gas Reservoir – Coal bed methane, shale or tight gas, where the natural gas does not flow naturally to the well, but instead requires some form of extensive stimulation to generate economic flow rates.

Underground Injection Well – A steel and concrete-encased shaft into which hazardous waste is deposited by force and under pressure. The Environmental Protection Agency's (EPA's) Underground Injection Control Program (UIC) is responsible for regulating the construction, operation, permitting and closure of injection wells that place fluids underground for storage or disposal.

Utica Shale – An Ordovician age natural gas-containing rock formation located below the Marcellus Shale. The formation (also called the Utica-Point Pleasant in some areas) extends from eastern Ohio through much of Pennsylvania to western New York. It is currently being actively developed in eastern Ohio.

For Further Information . . .

American Petroleum Institute
http://www.api.org/policy-and-issues/hf.aspx

Bipartisan Policy Center
http://bipartisanpolicy.org/sites/default/files/BPC%20Shale%20Gas%20Paper.pdf

FracFocus Chemical Disclosure Registry
http://fracfocus.org/

Massachusetts Institute of Technology
http://globalchange.mit.edu/files/document/MITJPSPGC_Reprint_12-1.pdf

National Academies of Sciences
http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=13355

National Conference of State Legislatures
http://www.ncsl.org/documents/energy/frackingguide_060512.pdf

National Energy Technology Laboratory
http://www.netl.doe.gov/technologies/oil-gas/ngres/index.html

National Petroleum Council
http://www.npc.org/NARD-ExecSummVol.pdf

Natural Gas Subcommittee of the Secretary of Energy Advisory Board, Safety of Shale Gas Development
http://www.shalegas.energy.gov/

The Energy Institute at the University of Texas at Austin
http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf

The Penn State Marcellus Center for Outreach and Research
http://www.marcellus.psu.edu/

U.S. Department of Energy, Office of Oil and Natural Gas
http://www.fossil.energy.gov/programs/oilgas/

U.S. Energy Information Administration
http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

U.S. Environmental Protection Agency
http://www.epa.gov/hydraulicfracture/

U.S. Government Accountability Office
http://www.gao.gov/assets/650/647791.pdf

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