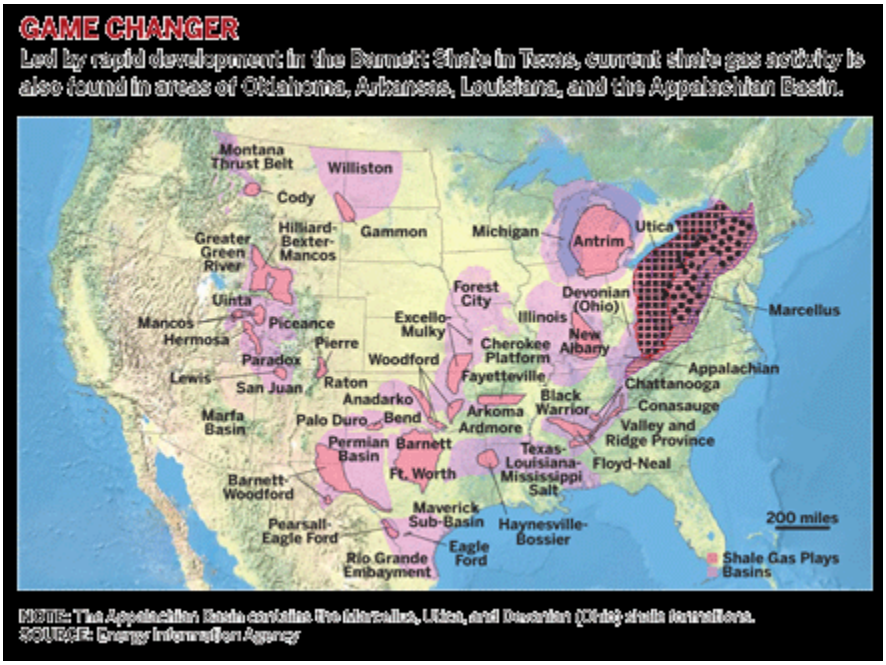

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Drilling Process Draws Scrutiny

‘Shale gale’ reshapes energy outlook, but critics fear environmental impact

Glenn Hess

The U.S. has a plentiful supply of natural gas—a clean-burning, efficient fuel that could help solve the nation’s energy problems, ranging from climate change to dependence on foreign oil, industry proponents contend.

But critics say this view is overly optimistic, because the technology for releasing gas embedded deep underground in massive shale fields has not yet been shown to be economical. Such technology could also contaminate water supplies with toxic drilling chemicals.

Geologists have long known that natural gas is abundant in shale rock formations running from the Appalachian Basin to the Rocky Mountains. But the resource has remained largely untapped because of the difficulty in extracting it. In recent years, however, advances in a technology developed decades ago by the petroleum industry to boost production at aging oil wells has helped unlock vast reserves of once-inaccessible natural gas.

Hydraulic fracturing is a process in which millions of gallons of chemically treated water and sand are pumped into the ground at extremely high pressure to generate fractures or cracks in shale rocks and release trapped gas.

More than 1 million wells have been completed in the U.S. using this technology since the 1940s, according to the American Petroleum Institute (API), the oil and gas industry's main lobbying group. Studies estimate that up to 80% of natural gas wells drilled in the next decade will require fracturing to remain viable.

In 2000, only 1% of America's natural gas was harnessed from shale rock. Today it's 20%, and it could be 50% by 2035, according to a new analysis by the consultant group IHS Cambridge Energy Research Associates (IHS CERA).

"This is simply the most significant energy innovation so far this century," IHS CERA Chairman Daniel Yergin says. "As recently as 2007, it was widely thought that natural gas was in tight supply and the U.S. was going to become a growing importer of gas. But this outlook has been turned on its head by the 'shale gale.' "

Recoverable U.S. gas reserves might now exceed the proven reserves of Russia, the world's largest natural gas producer, some experts say. In 2009, the Potential Gas Committee, a panel of U.S. industry specialists, found that the nation's estimated gas reserves had surged 35% since an assessment in 2007. The jump was the largest increase in the 44-year history of reports from the committee.

The U.S. now has about 2,074 trillion cu ft of technically recoverable natural gas resources—enough to meet domestic demand for more than a century at the current rate of consumption, according to the expert panel.

"New and advanced exploration, well drilling, and completion technologies are allowing us increasingly better access to domestic gas resources—especially unconventional gas—which, not all that long ago, were considered impractical or uneconomical to pursue," says John B. Curtis, a professor of geology and geological engineering at Colorado School of Mines.

Natural gas is the fuel of choice for a wide range of industries, including chemical manufacturing. In addition to its use in generating electricity, natural gas is also a feedstock for a variety of products, including petrochemicals, plastics, and fertilizers.

Industry officials are hopeful that the emergence of shale gas can be a game changer that stabilizes the often volatile price of the commodity by dramatically increasing the domestic supply.

Shale gas holds "great promise" for the manufacturing sector, says Calvin M. Dooley, president and chief executive officer of the American Chemistry Council, a trade group representing major U.S. chemical companies. "However, much remains to be done to bring these unconventional supplies to market quickly and reliably enough to ensure the end of high, volatile natural gas prices," he adds.

Although hydraulic fracturing has the potential to turn gas deposits in shale formations into an energy bonanza, the method is coming under increasing scrutiny. Environmental activists and some lawmakers are concerned that the drilling technique may pose a threat to drinking water. Consequently, they argue, the practice should be regulated by the federal government. Individual states currently monitor fracturing activities.

What worries critics are the chemical additives used in the process to reduce friction, kill bacteria, and prevent mineral buildup. The chemicals make up less than 1% of the overall solution, but some are hazardous in low concentrations.

“We have significant concerns not only about contamination of our water resources, but also depletion of the water table,” says Tracy Dahl, president of the North Fork Ranch Landowners Association in Colorado. “We have already seen significant impacts and expect more to come.”

Democrats have introduced legislation in the House of Representatives (H.R. 2766) and Senate (S. 1215) that would require energy companies to disclose the chemical ingredients used in their fracturing fluids without revealing the exact formula and to comply with regulations under the 1974 Safe Drinking Water Act, the main federal law that ensures the quality of Americans’ tap water (C&EN, Aug. 17, 2009, page 28).

The typical contents of fracturing fluids are widely known, but the specific chemical formulas usually are divulged only to state regulators and to emergency response personnel, such as firefighters. Drilling companies have balked at revealing the makeup of their proprietary mixtures, arguing it would put them at a competitive disadvantage.

But as energy firms seek to alleviate concerns about potential contamination, resistance to chemical disclosure is softening. In a statement filed last month with the U.S. Securities & Exchange Commission, ExxonMobil said it now supports disclosing the identity of the ingredients used in fracturing fluids at oil and gas production sites.

“While we understand the intellectual property concerns of service companies when it comes to disclosing the proprietary formulations in their exact amounts, we believe the concerns of community members can be alleviated by the disclosure of all ingredients used in these fluids,” the company said.

In an attempt to determine whether federal regulation of hydraulic fracturing is warranted, House Energy & Commerce Committee Chairman Henry A. Waxman (D-Calif.) has asked eight oil-field service companies to provide detailed information about the chemicals used in their drilling operations.

Hydraulic fracturing “could help us unlock vast domestic natural gas reserves once thought unattainable,” Waxman noted in a statement. “As we use this technology in more parts of the country on a much larger scale, we must ensure that we are not creating new environmental and public health problems.”

The inquiry, he added, will "help us better understand the potential risks this technology poses to drinking-water supplies and the environment, and whether Congress needs to act to minimize those risks."

The Environmental Protection Agency also intends to conduct a comprehensive research study of the effects of fracturing on water quality and public health. A committee of EPA's Science Advisory Board is expected to recommend a strategy for conducting the $1.9 million study by this summer. Agency officials have said they intend to have their initial research results completed by the end of 2012.

Fracturing "is simply the most significant energy innovation so far this century."

EPA reviewed various studies on fracturing in 2004 and concluded that the technology poses "little or no threat" to drinking water. Environmentalists dismissed the finding, claiming it was politically motivated and scientifically unsound.

"Independent, unbiased scientific inquiry into hydraulic fracturing is critical," says Amy Mall, a senior policy analyst for the Natural Resources Defense Council, a conservation group. "We're very pleased that EPA is doing this study. There are communities around the country that are very concerned because their water has been contaminated or could be contaminated."

In 2009, after receiving complaints about possible drinking-water contamination near the town of Pavillion, Wyo., EPA tested more than three dozen municipal and private water wells. The agency found traces of a variety of toxic chemicals, including 2-butoxyethanol, a foaming agent widely used in fracturing fluids. But officials could not say with certainty that the cause was nearby oil and gas production.

The industry maintains that fracturing has never been conclusively linked to drinking-water contamination and argues that federal oversight would add unnecessary compliance costs.

"We're hopeful and it's our expectation that EPA's study—if based on objective, scientific analysis—will serve as an opportunity to highlight the host of steps taken at every well site that make certain groundwater is properly protected," says Lee Fuller, executive director of Energy In Depth, an advocacy group for the oil and gas industry.

Industry reports claim that if federal regulations are applied to hydraulic fracturing, more than a third of onshore gas wells would be closed and oil and gas companies would spend $10 billion complying with the law in its first year.

"Adding layers of unnecessary federal regulations to hydraulic fracturing—which is tightly regulated by energy-producing states—could put our nation's energy potential out of reach," Fuller warns.

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Geochemistry: Hydraulic Fracturing Fluid Is A Chemical Soup

Elizabeth K. Wilson

The exact compounds and their proportions are currently rigorously guarded industry secrets and are tailored for each particular geological site. The website of Energy In Depth, a group representing U.S. oil and natural gas producers, makes public a general list of hydraulic fracturing fluid ingredients.

A recent review of the challenges of drilling at one of the U.S.'s most important natural gas reservoirs, the Marcellus Shale in Pennsylvania, also describes some of the components of these fluids (*Environ. Sci. Technol.*, DOI: 10.1021/es903811p).

"This is a hodgepodge chemical soup," notes Ronald G. Wilhelm, environmental scientist with the Environmental Protection Agency's Office of Radiation & Indoor Air, in Washington, D.C., and one of the study's coauthors.

Water makes up the lion's share—98 to 99%—of most hydraulic fracturing fluid mixtures, according to various sources. But once the fluid forces open a crack in the rock, something else in the fluid needs to keep it from collapsing. For that purpose, engineers use ordinary silica, or sand. Sand, with its fine grains, allows natural gas to seep through to the surface while holding the crack open.

To keep the sand suspended in the fluid, engineers add a variety of substances that increase the fluid's viscosity; gels such as guar gum or hydroxyethyl cellulose are one option. Isopropyl alcohol, which acts as a surfactant, is also used to increase viscosity.

This thick fluid has to move smoothly through pipes without clinging to the sides. Polyacrylamide, mineral oil, and even diesel oil add the needed slipperiness.

Various acids, such as sulfuric, hydrochloric, and citric, help dissolve minerals and protect the pipes from scale formation. The common antifreeze ethylene glycol, as well as dimethylformamide $(CH_3)_2NC(O)H$, helps prevent pipe corrosion, and ammonium bisulfite scavenges oxygen from the fluid.

Engineers must also contend with microbes because some organisms thrive in the warm, watery environment generated during fracturing, producing slimy masses that gum up and corrode pipes.

Engineers therefore treat the fracturing fluids with “biocides,” generally toxic compounds that are registered with EPA as antimicrobial pesticides. One commonly used compound, glutaraldehyde, $CH_2(CH_2CHO)_2$, a medical and dental disinfectant, kills microbes by cross-linking their proteins.

Researchers are looking for more environmentally friendly replacements for some of these chemicals, according to the recent review. For example, relatively nontoxic long-chain oily paraffins can be substituted for diesel oil, the authors of the *Environmental Science & Technology* paper say.

CHEMICAL COCKTAIL

Hydraulic fracturing of natural gas employs numerous compounds

COMPOUND	PURPOSE
Acids	Help dissolve minerals and initiate fissure in rock
Ammonium bisulfite	Removes oxygen from water to protect pipes from corrosion
Borate salts	Maintain fluid viscosity as temperature increases
Citric acid	Prevents precipitation of metal oxides
N,N-Dimethyl formamide	Prevents pipe corrosion
Ethylene glycol	Prevents scale deposits in pipes
Glutaraldehyde	Eliminates bacteria in water
Guar gum	Thickens water to suspend sand
Isopropyl alcohol	Increases the viscosity of fracture fluids
Petroleum distillates	Slick water to minimize friction
Polyacrylamide	Minimizes friction between fluid and pipe
Potassium chloride	Creates a brine carrier fluid
Sodium chloride	Allows a delayed breakdown of gel polymer chains

NOTE: Companies use proprietary mixes of chemical additives that include a subset of those listed. **SOURCE:** Energy In Depth