The gas surge

Fracking has ignited an energy revolution, with still-uncertain consequences for climate and the environment

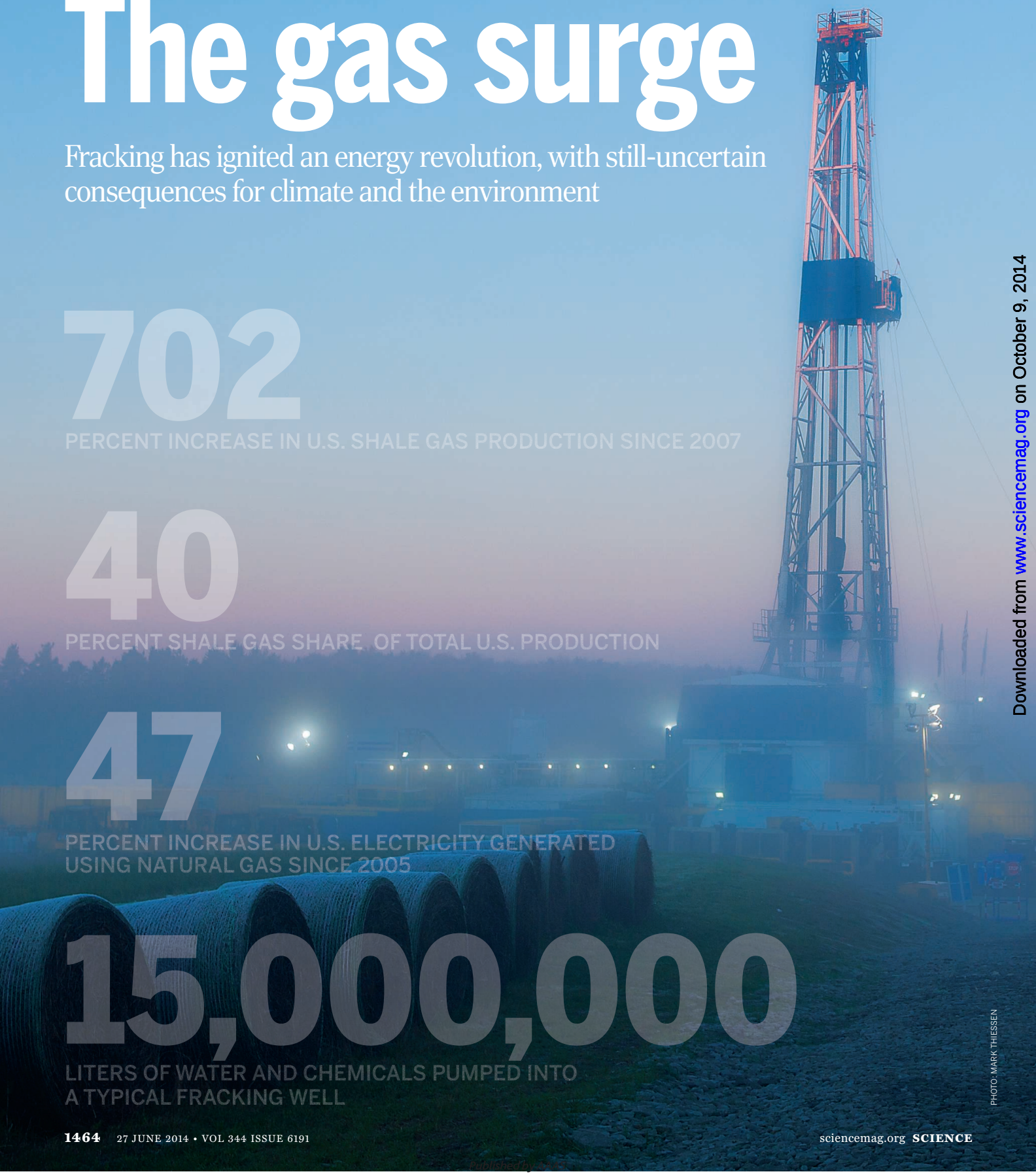


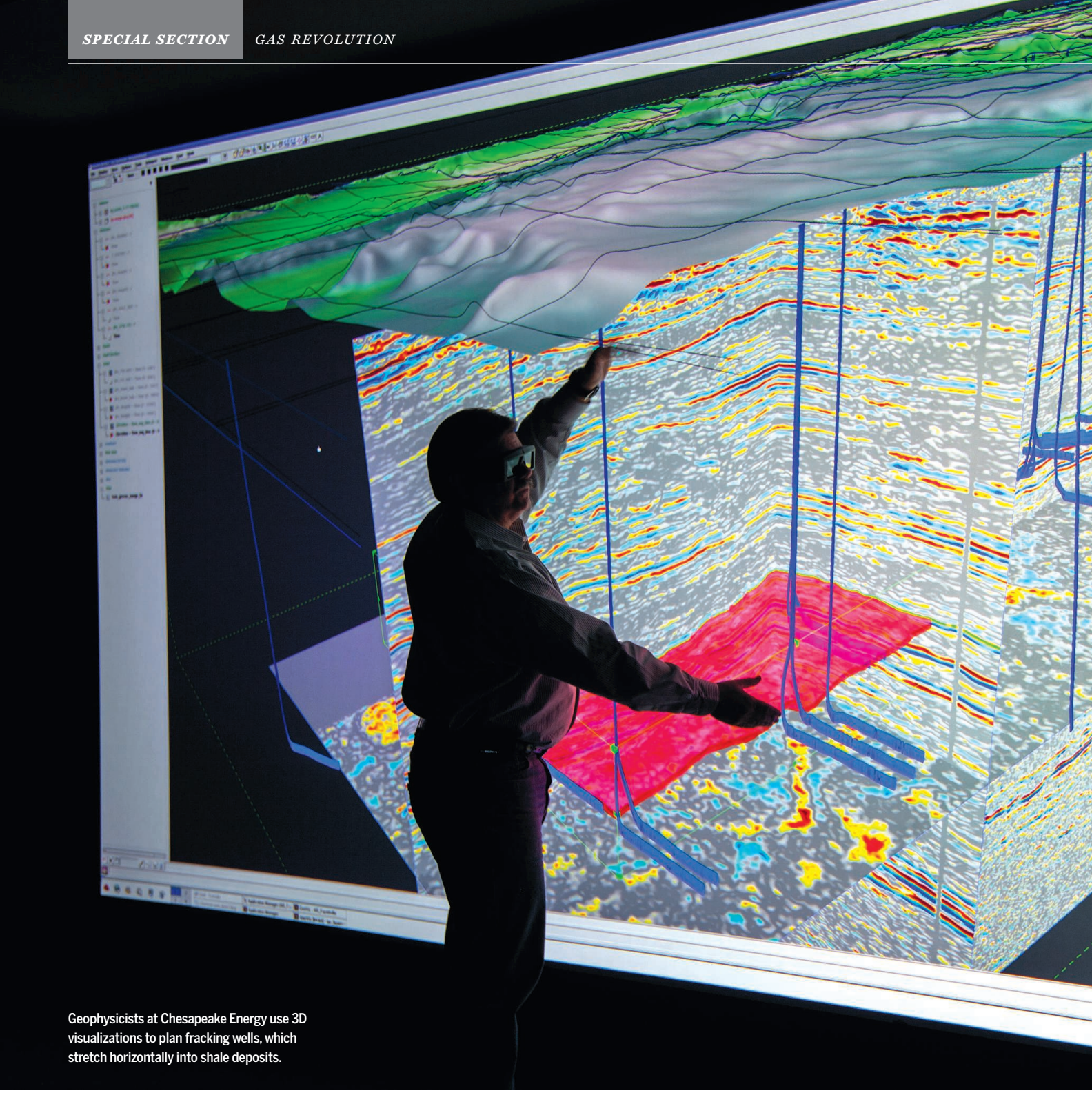
PHOTO: MARK THIESSEN

Nearly 70 years ago, a small group of engineers and geologists gathered at a dusty gas drilling site in southwestern Kansas to try an experiment. They pumped nearly 4000 liters of gelled gasoline and sand some 700 meters down a borehole into a thick bed of limestone, in hopes that the pressurized gunk would fracture the rock and release more natural gas. The "hydraulic fracturing" test failed. But success ultimately followed: Today, fracking, as it is known, is revolutionizing the energy industry, enabling firms to extract natural gas from a source once considered unpromising—vast deposits of shale, which is too dense for gas to flow freely (*Science*, 25 June 2010, p. 1624). By penetrating the shale with boreholes that bend horizontally, and then pumping in millions of liters of fluids and sand under high pressure, drillers can force open minute cracks that release valuable streams of gas.

Extensive shale gas deposits—or "plays" as they are

By **David Malakoff**

A fracking well in Pennsylvania taps shale gas deposits some 2 kilometers down.



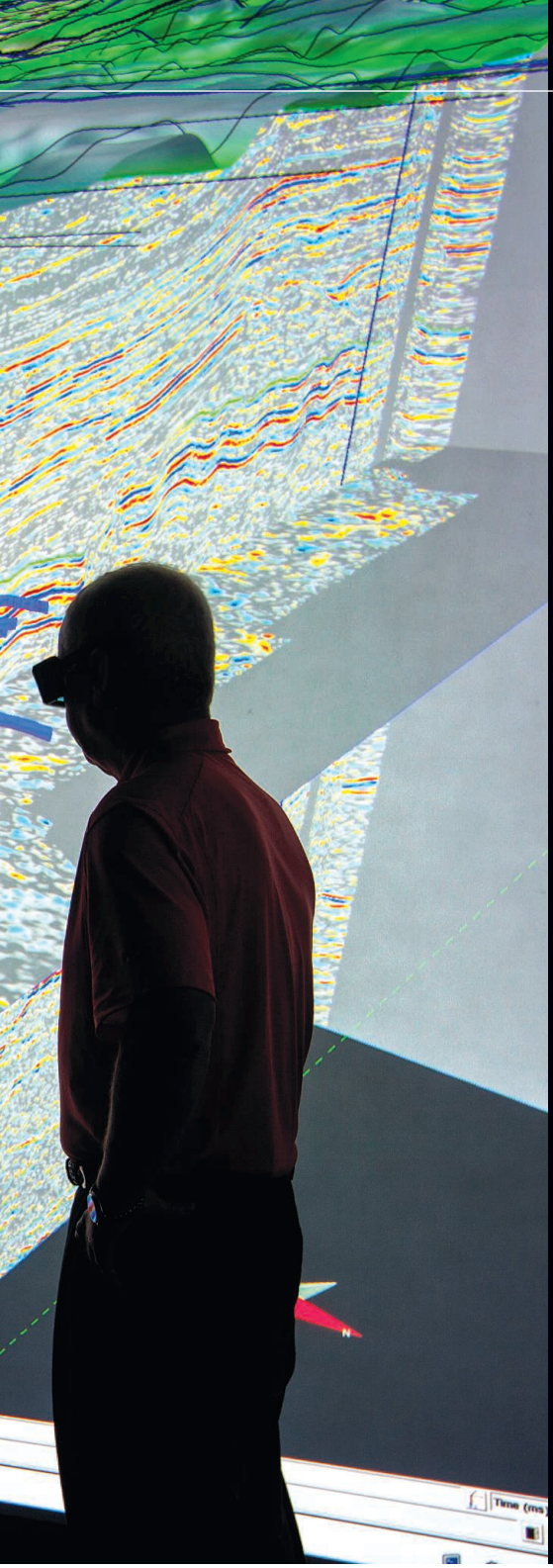
Geophysicists at Chesapeake Energy use 3D visualizations to plan fracking wells, which stretch horizontally into shale deposits.

PHOTO: MARK THIESSEN

known in the industry—are found around the world (see map, p. 1467). So far, however, the shale gas boom is largely confined to the United States, where over the past decade companies have drilled thousands of fracking wells into once obscure geological formations, including the Marcellus Shale in Pennsylvania, the Barnett in Texas, and the Haynesville in Louisiana. (In other shale plays, such as the Bakken in North Dakota, fracking is primarily used to produce oil.)

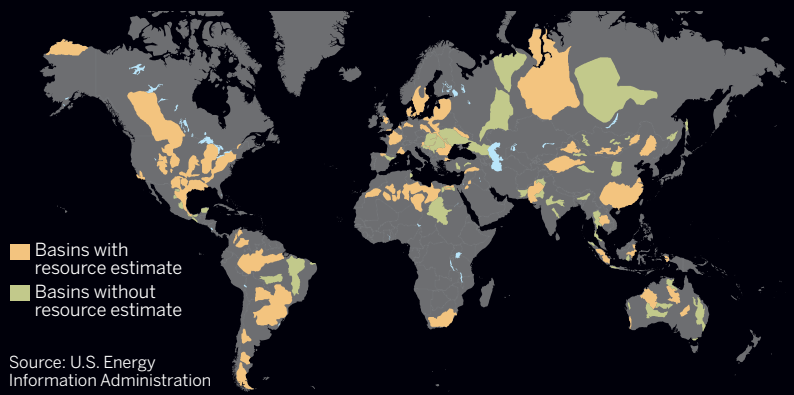
The resulting surge in natural gas is remaking U.S. energy markets—and causing economic ripple effects globally. Shale gas has made the United States the world's leading natural gas producer and now accounts for about 40% of U.S. production, up from less than 2% in 2001. The share is projected to grow to 53% by 2040, and natural gas prices have tumbled as abundance grows (see graphs, p. 1467). That's helped accelerate a shift away from coal to natural gas for generating electricity and prompted energy-intensive manufacturing firms to shift production from overseas factories to the United States, creating hundreds of thousands of jobs. The United States is also boosting natural gas exports to other nations—reversing its traditional role as an energy importer.

The shale gas shake-up has been accompanied by plenty of controversy—and new research—as the stories in this special section illustrate. Scientists are debating frack-



The world has vast deposits of gas-rich shale ...

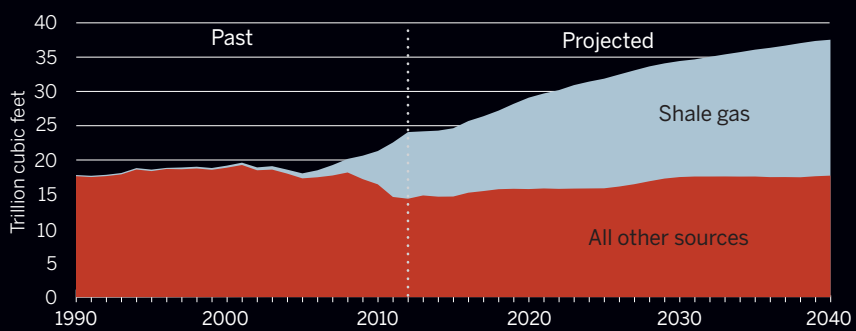
Six nations—the United States, China, Argentina, Algeria, Canada, and Mexico—hold an estimated 80% of documented shale gas deposits.



Source: U.S. Energy Information Administration

but so far shale gas has had the biggest impact in the United States ...

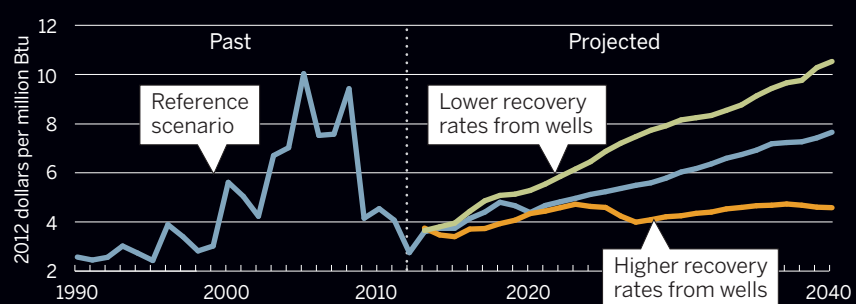
As other U.S. sources of natural gas decline, shale gas production is projected to expand and provide 53% of the total by 2040.



Source: U.S. Energy Information Administration, *Natural Gas Annual 2012*

where abundant supplies have helped reduce natural gas prices.

Future natural gas prices will depend, in part, on the future productivity of wells.



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2012*

ing's impact on water quality (see p. 1468) and whether the shale gas boom will help or hurt efforts to curb climate change (see p. 1472). They are also exploring potential links to human-caused earthquakes (*Science*, 23 March 2012, p. 1436), air pollution, and habitat fragmentation.

Basic researchers are also sizing up this new resource. They are searching for life deep in shale deposits (p. 1470) and potentially transformative ways to convert the methane in natural gas into liquid fuels and other chemicals (p. 1474). Some are examining the origins of shale gas, trying to determine whether it is primarily the product of methane-producing microbes or thermal breakdown of organic matter (see p. 1500). And analysts continue to debate just how much shale gas is really out there—and how quickly the current boom could turn bust.

For the moment, any downturn seems distant. Canada, which already gets 15% of its natural gas from shale, is ramping up production. China, Europe, and Russia are eyeing their essentially untapped shale deposits. Public opposition to fracking is growing in some nations, however, and drilling technologies that have performed well in the United States may not work well overseas, where the shale can have very different properties. One thing is clear: The shale gas revolution is still in its infancy, with plenty of growing pains ahead. ■