



## PART 1: NATURAL GAS AND THE MYTH OF DECLINING U.S. RESERVES

### Summary

With the application of new production techniques, the United States is looking at a significant increase in extractable natural gas reserves. This runs counter to the conventional wisdom of recent years, which held that the United States was finished as a major producer of natural gas.

Editor's Note: This is the first of a two-part series on U.S. natural gas reserves and their effect on energy policy.

### Analysis

In 2006, natural gas production in the United States appeared to be in permanent decline. Domestic production had flattened out below the 2002 peak of 693 billion cubic meters, after having briefly risen above a plateau that began in 1997. Continuing decline seemed inevitable, while there was every indication that consumption would remain in the range of 650 billion cubic meters per year, where it had registered since 2000, if not rise higher.

New field discoveries, and new reservoir discoveries in old fields, dropped off dramatically after the natural gas industry took a hit from the recession in 2001. Most important, the outlook for natural gas reserves looked bleak -- proven reserves had peaked as far back as 1967 at 8.29 trillion cubic meters, and although reserve estimates climbed throughout the early 2000s, they never reached higher than 4.6 trillion cubic meters.

In other words, the big picture seemed to show a dwindling American energy source that would have to be replaced by imports from Canada, Mexico and overseas (especially in liquefied form) and supplemented by other domestic energy sources.

But in 2006 the picture changed. A combination of high prices and cheap credit provided ample incentive to increase production. U.S. natural gas wellhead prices rose by 274 percent from 2002 to 2008. At the same time, a freewheeling finance sector made it possible to upgrade equipment and facilities and undertake new exploration and drilling projects. Natural gas production expanded by 4 percent in 2007 compared to 2006 and by 6 percent again in 2008, reaching a new record of 736.7 billion cubic meters. As a result, imports in 2008 fell to their lowest level since 1997, and imports of liquefied natural gas (LNG) fell by 54 percent from the previous year. New field discoveries ticked up in 2005 and 2007, and reserves were upgraded by 12.6 percent to 6.73 trillion cubic meters.

But coinciding with these shifts in the price and the financial environment was a combination of new technology and new applications of existing technology that made production from unconventional sources -- most notably shale formations -- logistically possible and economically feasible for the first time.

### New Production Techniques

Conventional natural gas reservoirs are formed when natural gas migrates from "source rocks" upward until it is blocked by an impermeable substance such as a layer of salt or limestone, which traps it and forms the reservoir. In traditional production, the well is drilled through this cap to access the underlying hydrocarbon. But while a conventional reservoir can be extensive, it is only a small and isolated accumulation compared to the greater source rocks beneath. These sources are

dense deposits of rock rich in organic matter, such as shale, that have relatively small pores and narrow cracks that restrict gas flows, essentially storing gas and not allowing it to rise. Unconventional natural gas sources include tight sands (gas stored in deposits of sandstone or limestone), coal-bed methane (traditional coal seams) and shale (a fine sedimentary rock made from sea mud millions of years old).

Natural gas producers have long sought to tap these lower layers of source rocks, but early attempts at producing natural gas from unconventional reservoirs were frustrated by the density of the formation and the low ratio of natural gas gained to the volume of rock that had to be worked. Coal seams have been tapped since 1989, but gas reserves from this source have leveled off and production has fallen. Tight sands and shales are the most expensive sources from which to extract natural gas, and the energy price environment of 2006-2008 made possible the application of key technologies that rendered shale gas accessible for the first time.

Two major developments made it possible to extract from shale formations. First came hydraulic fracturing, or "fracing" (pronounced fracking), which originally was developed in the 1980s. The chief problem with drilling down into layers of source rock is that its density makes it difficult to extract any natural gas. The solution is to pump "slick water" (water mixed with sand or another granular material) at a high pressure down into the well, forcing the source formation to fracture. The sand serves as a "proppant," propping open the cracks after the water is withdrawn and preventing them from closing back up, thus easing the pressure within the formation and allowing natural gas stored within to flow naturally into the well. This technique has led to higher output, roughly doubling the amount of gas that can be extracted per well. When natural gas prices rose to \$6-8 per 1,000 cubic feet (28.3 cubic meters) in 2005-2008, companies became able to employ fracturing treatments on a scale large enough to make it commercially viable.

Second came horizontal drilling, a technique pioneered in the 1990s. Instead of sending a well straight down into a traditional reservoir, developers would drill the well down into the source rock and then turn it horizontally and drill at an angle so as to extend the well along the elongated layer of source rock. A particular horizontal well could extend sideways for up to a mile, all the while expanding the area of contact with the source (creating wells that are about three times more productive than their vertical counterparts).

When horizontal drilling was combined with fracturing in the early 2000s, massive new volumes (sometimes up to 35 percent of a formation, depending on geological particulars and other factors) were suddenly available for extraction from shale formations that had been declared depleted decades prior or which could never have been tapped in the first place. All that was needed was the energy price spike in 2006-2008 to make widespread use of these techniques economically feasible. These techniques were first applied at the Barnett Shale in north Texas, which had long been considered exhausted but was revitalized with surprising success. Then they were brought to bear on the gigantic Marcellus Shale that underlies the Appalachian Mountains. Other formations with major reserves include Fayetteville, mostly in Arkansas; Haynesville, Louisiana, which is only gradually being developed but is claimed to be the fourth-largest natural gas field in the world; and Woodford Shale, mainly in Oklahoma.

Other technical advances have included the use of GPS and seismic imaging, which enhance the ability to make measurements of subterranean formations from the surface, better position wells, and more accurately aim the fracturing treatment. Producers are no longer limited to conventional traps but can range along an entire shale formation -- which can cover vast distances, as in the case of the Marcellus Shale that runs from eastern Mississippi to eastern New York.

As producers made breakthroughs in production from shales and other source formations, they steered away from less feasible alternative gas sources, such as gas hydrates. Gas hydrates are ice-like solids of natural gas trapped inside a crystalline structure and that fill up sedimentary layers forming giant gas traps, usually under water or in permafrost. Because they are most likely the single greatest source of organic carbon in the world (much larger than all known fossil fuels combined) and contain massive amounts of natural gas per deposit, they have been scouted out by some players in the natural gas industry as an alternative energy source. Yet energy firms lack the technical ability to break down these hydrates and extract the gas, and the economic challenges are

immense. Hydrates produce little energy per unit, are stored in less permeable sedimentary deposits and would require lots of heat in cold places to release the gas.

With new techniques also came new revelations regarding the amount of theoretically extractable natural gas reserves. The U.S. Energy Information Administration (EIA) estimated that in 2007, proven natural gas reserves from shale formations rose by 50 percent, reaching 9 percent of total U.S. reserves of 7.56 trillion cubic meters. (Coal-bed methane reserves, the other major unconventional source, though under production since 1989, rose 11.5 percent in 2007, also equaling 9 percent of total U.S. reserves.) Thus, total reserves translate to about 11 years of U.S. consumption at 2008 levels, and the EIA estimates only count proven reserves, which in turn take into account a relatively small number of sites.

Estimates of total unproven reserves range anywhere from 32 trillion cubic meters to 62.3 trillion cubic meters -- potentially enough to feed United States consumption for 50 to 100 years or more (although the higher estimates come from studies funded by a hopeful natural gas industry). And many of these estimates assume that natural gas producers will not discover any new formations with extraction potential, which is unlikely. Current estimates are also unreliable because production technologies are still in early stages of development and have not been universally applied. More use and experience plus continued technological innovation are likely to push natural gas producers beyond current capabilities and enable them to access still greater portions of formations.

Moreover, most of the companies involved in unconventional production are small independents (in keeping with the history of the natural gas sector in the United States), which tend to be particularly good at applying and inventing new technology. So far, new production techniques have been applied only to a handful of basins -- none of which have been exhausted -- and there are several more formations to exploit. All of this paints a promising picture for the new extraction techniques.

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