Fracking's Future

Natural gas, the economy, and America's energy prospects

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FORUM

Supplies of natural gas now economically recoverable from shale in the United States could accommodate the country's domestic demand for natural gas at current levels of consumption for more than a hundred years: an economic and strategic boon, and, at least in the near term, an important stepping-stone toward lower-carbon, greener energy.

But even though natural gas is relatively "clean"—particularly relative to coal burned to generate electricity—the "fracking" process used to produce the new supplies poses significant environmental risks. We must ensure that procedures and policies are in place to minimize potential damage to local and regional air quality and to protect essential water resources. We need to make sure that extraction of the gas (consisting mainly of methane, with small amounts of other gases) from shale and its transport to market does not result in a significant increase in "fugitive" (inadvertent) emissions of methane (CH_4)—which is 10 times more powerful as a climate-altering agent, molecule per molecule, than carbon dioxide (CO_2, the most abundant greenhouse gas). Further, we will need to recognize from the outset that cheap natural gas may delay the transition to truly carbon-free, sustainable solar- and wind-energy supplies that remain crucial in light of our worsening climate-change crisis.

The Gas Gift

Production and consumption of natural gas in the United States were in approximate balance up to 1986. Production then lagged consumption during the following 20 years; the deficit was made up largely by imports from Canada, delivered by pipelines. The situation changed dramatically in 2006 as companies using new drilling technologies moved aggressively to tap the vast supplies of previously inaccessible gas trapped in underground shale deposits. Natural gas extracted from such sources accounted for 10 percent of U.S. production in 2007, and rose to 30 percent of production by 2010—an enormous, swift change in our huge market. There are few signs that the trend is likely to reverse in the near future.

Partly as a result of that surge in supply, domestic natural-gas prices are now lower than at any time in the recent past. The spot price for natural gas traded on the New York Mercantile Exchange hit a record low of $1.82 per million British thermal units (MMBTU) last April 20—down 86 percent from a high of $12.69 in June 2008. Even at recent, somewhat higher prices, natural gas

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is now significantly cheaper than either diesel fuel or gasoline on an energy-equivalent basis: a little more than *one-tenth* the wholesale, spot prices of about $3 per gallon for those liquid fuels.

Lower-priced natural gas has had important consequences for the U.S. economy. Approximately one-quarter of primary energy (mainly coal, gas, oil, nuclear, and hydro) consumed in the United States in 2011 was supplied by natural gas. Electricity generation accounted for 31 percent of total natural-gas demand, followed by consumption in the industrial (28 percent), residential (19 percent), and commercial (13 percent) sectors. Natural gas is used as an industrial energy source in manufacturing products ranging from steel and glass to paper and clothing. It is the raw material for fertilizer, paints, plastics, antifreeze, dyes, photographic film, medicines, and explosives. More than half of all commercial establishments and residences are heated using gas, which is widely deployed as well for cooking and as fuel for water heaters, clothes driers, and other household appliances. Consumers have benefited directly from lower gas-utility bills, and industrial customers have benefited by switching fuels—as have chemical and other processors that use gas as a feedstock. Abundant, cheap natural gas has been of general benefit to electric-utility customers as power suppliers have substituted it for coal to fire their generators.

The shift from coal to gas in the electricity sector has also yielded an environmental bonus—a *significant* reduction in emissions of CO_2, because CO_2 emissions *per unit of electricity generated* using coal are more than double those produced using gas. Approximately half of U.S. electricity was produced using coal in 2005, but by last March, coal's contribution had dropped to an unprecedented low of 34 percent. Meanwhile, the U.S. Energy Information Administration (EIA) reported that domestic emissions of CO_2 during the first quarter of 2012 fell to the lowest level recorded since 1992. An ancillary benefit of the coal-to-gas switch has been a significant reduction in emissions of sulfur dioxide, the cause of acid rain, because many of the older coal-burning plants selectively idled by the price-induced fuel switch were not equipped to remove this pollutant from their stack gases.

Supply and Demand

A KEY QUESTION is whether the current low price for gas can persist.

Shales in different regions are characterized by variable combinations of hydrocarbons. Some are gas- (methane-) rich, described as "dry." "Wet" formations yield significant concentrations of condensable heavier hydrocarbons—such as ethane, pentane, and propane—referred to collectively as natural gas liquids (NGLs). Still others—notably the Bakken field in North Dakota—are gas-poor but oil-rich and are being developed primarily to extract that valuable resource. (In fact, only Texas outranks North Dakota now among U.S. oil-producing states.)

The hydrocarbon mix matters, because the break-even price for profitable extraction of natural gas from a dry shale well is estimated at about $5/MMBTU—about one and a half times the spot-market price in October. The bulk of the natural gas produced from shale today is derived from wet sources: marketing of the liquid products (which command higher prices) justifies the investments.

That means that the economic momentum of the shale-gas industry can be sustained for the long term only by decreasing production (ultimately causing prices to adjust—a process that may be under way as drilling diminishes at current prices) or by increasing sales of its product.

Increased use of natural gas for transportation could provide an additional domestic market, taking advantage of the significant price disparity versus gasoline or diesel fuels (as noted above). Doing so would require not only an investment in facilities to produce and deliver compressed natural gas (CNG), which is in limited use now, but also the introduction of vehicles capable of running on this energy source. Buses, taxis, and public vehicles (police cars, for example), suitably equipped, that could be charged at central stations would appear to provide an attractive early marketing opportunity. The benefits of such conversions would include reduced demand for imported oil, improved urban air quality, and a further decrease in CO_2 emissions.

An even larger opportunity may lie in exports. Natural-gas prices in Europe and Asia were five to seven times those in the United States during the first half of 2012; Japan is an especially eager consumer, given the wholesale closure of its nuclear-electric generating capacity in the wake of the Fukushima earthquake,

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Opposite: A hydraulic fracturing rig drilling for natural gas in eastern Colorado. Right: A wastewater holding pond for a fracking well in rural Pennsylvania—a state where several thousand wells have been drilled to extract natural gas from shale.

tsunami, and power-plant crisis in March 2011. But exports require multibillion-dollar investments in facilities for liquefaction of gas and in the ports through which liquefied natural gas (LNG) can be shipped. Exxon Mobil Corporation, the largest producer of natural gas in the United States, has taken steps to form a $10-billion partnership for LNG exports. If this and other investments proceed, and the prices realized for LNG are high enough to justify further shale-gas drilling, the U.S. economy could benefit from significant energy exports—and the importing countries might also realize environmental benefits. China, where coal is the principal fuel source, could profit in particular: a cleaner source of energy would mean less local pollution from coal (including emissions of particulates, sulfur, mercury, etc.). And the global environment would benefit overall from a reduction in—or lessened growth of—CO_2 emissions. (China became the leading source of such emissions in 2006.)

To date, then, we can say conclusively that a shift to natural gas from coal has changed the U.S. energy system in ways that yield economic and environmental gains. But there are serious environmental challenges associated with freeing that gas from the shale and distributing it to consumers.

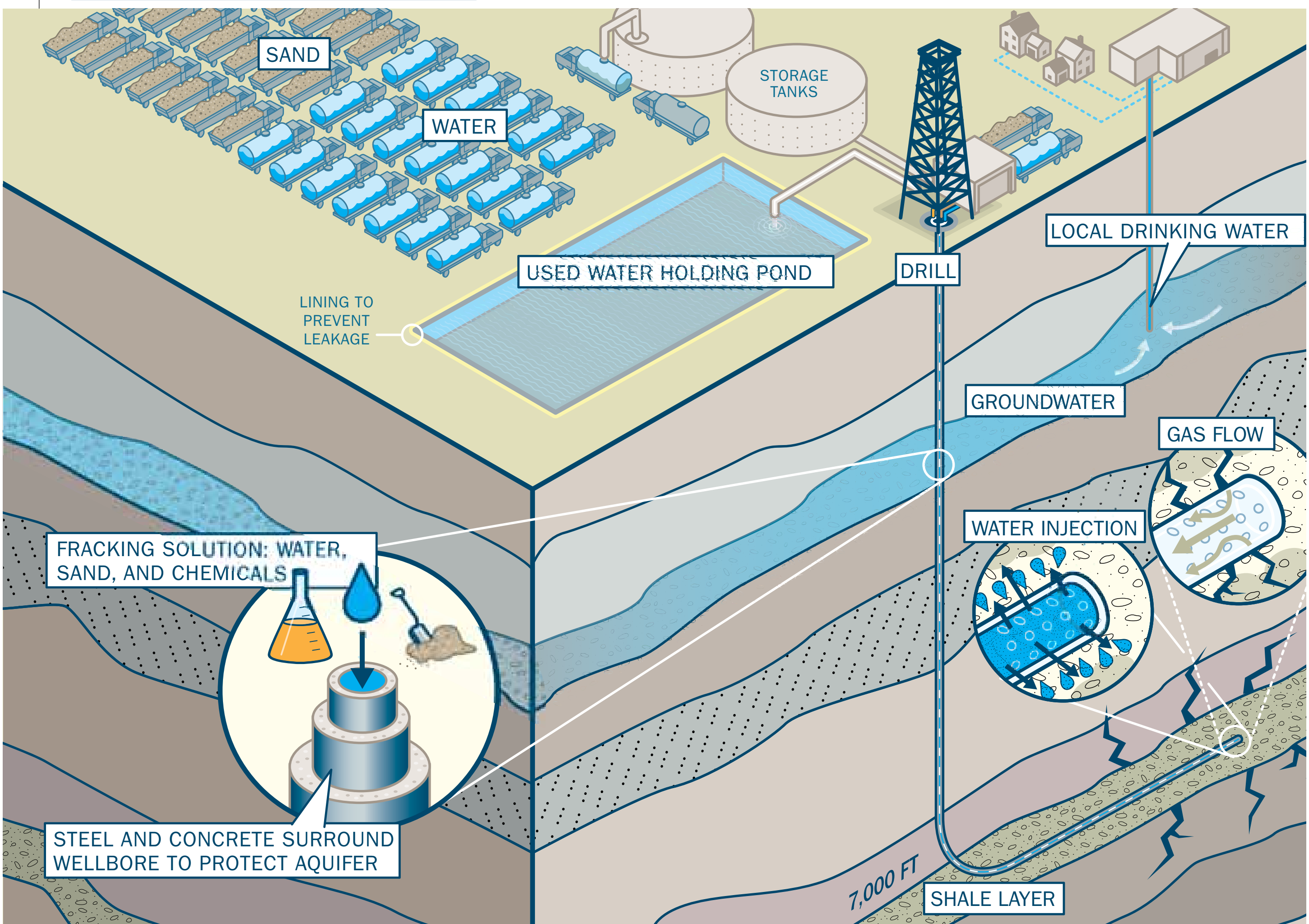
A Fracking Primer

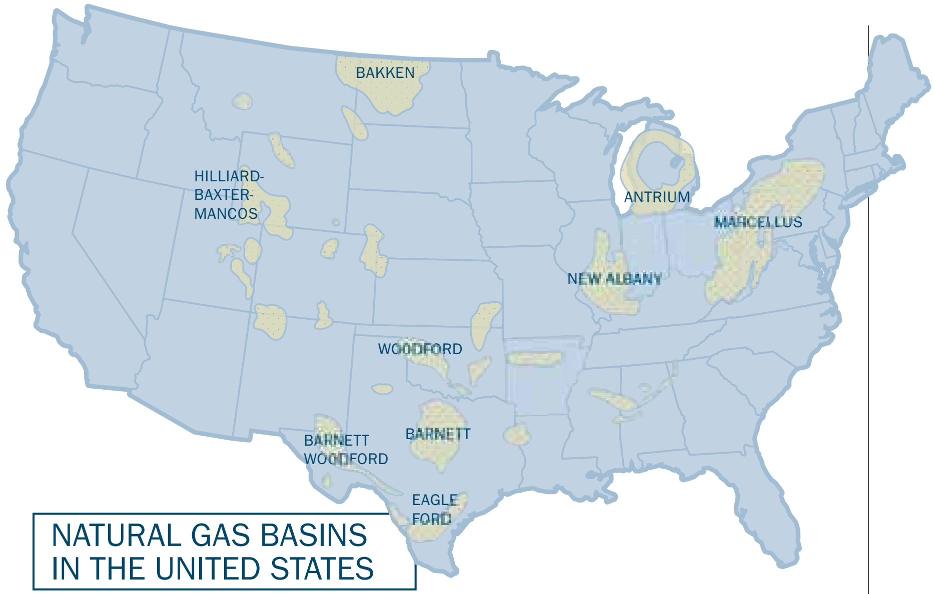
The first step in extracting gas from shale involves drilling vertically to reach the shale layer, typically a kilometer or more below the surface. Drilling then continues horizontally, extending a kilometer or more from the vertical shaft, and the vertical and horizontal components of the well are lined with steel casing, cemented in place. The horizontal extension of the casing is then perforated, using explosives; thereafter, water, carrying sand and proprietary chemicals, is injected into the well at high pressure. The water encounters the shale through the perforations, generating a series of small fractures in the rock (hence the nickname, "fracking"); the sand in the water keeps the cracks open, while the chemicals enhance release of gas from the shale. The injected water flows back up to the surface when the pressure in the well is released following completion of the fracking procedure. Then the well starts to produce natural gas.

As many as 25 fracture stages (per horizontal leg) may be involved

Careless releases of methane could more than offset the advantages otherwise realized by reducing emissions of carbon dioxide through substituting natural gas for other fuels.

DRILLING FOR NATURAL GAS





NATURAL GAS BASINS IN THE UNITED STATES

in preparing a single site for production, each requiring injection of more than 400,000 gallons of water—a possible total of more than 10 million gallons before the well is fully operational. A portion of the injected water flows back to the surface, heavily contaminated with the fracking chemicals and others it has absorbed from the shale. Depending on the local geology, this "return water" may also include radioactive elements.

Drillers developing a well must take exceptional care to minimize contact between the wellbore and the surrounding aquifer—often the source of nearby residents' fresh water. Serious problems have arisen in the past from failures to isolate the drilling liquids, including cases where well water used for drinking became so contaminated that human and animal health was threatened. It is essential that monitoring be in place to ensure the continuing integrity of the seal isolating the well from the aquifer even *after* the well has been fully exploited and abandoned.

A fraction of the contaminated water that returns to the surface is recycled and reinjected into the well to facilitate the next phase of the fracking process. But a larger proportion is stored temporarily in lined ponds on site for eventual transfer (most commonly by truck) to conventional water-treatment facilities. Care must be exercised to protect groundwater from spillage and to guard against potential leakage from the ponds. Moreover, the facilities to which the contaminated water is eventually transferred may be ill-prepared to deal with the challenges posed by its unusual chemical composition; for instance, conventional treatment facilities are not equipped to deal with radioactive materials—which under the circumstances could be transferred to the water bodies receiving the treated effluent.

Finally, careless drilling and production from fracked wells can result in fugitive emissions of methane from the shale below. Such inadvertent releases of methane could more than offset the advantages otherwise realized by reducing emissions of CO_2 through substituting natural gas for other fuels.

The International Energy Agency (IEA) recently proposed steps to ensure responsible extraction of gas from shale. If these procedures are implemented, the IEA concluded that the increase in production costs should be relatively modest—7 percent or less—and that the integrity of the environment could be protected. The IEA conclusions appear overly optimistic in the U.S. context: the costs for design and implementation of sensible regulations for the domestic shale-gas industry are likely to be significantly greater—but still tolerable. The problems are neither technical nor economic, but essentially political.

Beyond Shale Gas: Carbon-Free Energy

A recent study by the National Renewable Energy Laboratory (NREL) suggests that with suitably targeted investments, emissions of CO_2 from the U.S. power sector could be reduced by as much as 80 percent by 2050. The dominant source of electricity as envisaged in this analysis would come from a combination of wind and solar, with gas-fired plants called on to provide backup whenever the intrinsically variable source of power from wind and solar might not be sufficient to meet peak demand (on a hot summer evening, for example). Coal would be replaced initially by gas, continuing the trend observed over the past several years. Successful implementation of this strategy will depend critically, however, on future trends in relative prices for electricity generated using coal, gas, wind, and solar.

The break-even price for production of electricity using a modern coal-fired plant is about 5.9 cents per kilowatt hour. This means that coal cannot compete economically with gas under conditions where gas prices are lower than about $5/MMBTU, our estimate of the break-even price for production of gas from a dry well (at $5/MMBTU, the price for production of electricity from gas would be about the same as that from coal). Gas replaces coal as the fuel of choice in this case.

The cost for production of electricity using wind is about 8.0 cents per kilowatt hour. Wind therefore can compete with $5/MMBTU gas *only* if it can continue to benefit from the existing production tax credit (PTC), currently 2.2 cents per kilowatt hour. If gas prices were to rise above $8.3/MMBTU, wind would be competitive even in the absence of the PTC. The problem in this case is that generation of power from coal would be cheaper than that from either gas or wind.

Thus free-market forces alone may not be sufficient to grease the path to a low-carbon future. Should gas prices rise above $5/MMBTU, a carbon tax may be required to ensure a continuing competitive edge for gas relative to coal. Similarly, the PTC subsidy or similar initiatives—such as quotas for minimum contents of renewable energy in specific power markets (often on a state-by-state basis)—may be needed to ensure the continuing viability of wind and solar should gas prices persist below about $8.3/MMBTU. If we are to navigate safely and successfully to the future envisaged by the NREL, gas prices must be low enough to disenfranchise coal but not *so* low as to make it impossible for renewable sources to compete.

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