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THE GAS PROMISE

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Chapter 3

The Gas Promise

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Natural gas is a manic depressive industry that is prone to wild swings in mood. For decades, drillers had few incentives to hunt for gas. The industry was a niche backwater to the much more lucrative business of drilling for oil. Then, starting in the US in the late 1980s, a host of regulatory and market reforms opened the market and created a vibrant and highly competitive industry that was flush with new supplies. A decade later analysts swung back to depression as US supplies ran short and most experts envisioned a future heavily dependent on imports via liquefied natural gas (LNG) from overseas. The countries that expected to be the world's big gas suppliers—such as Russia, Algeria and Qatar with massive gas resources underground—even made the first moves to set up a cartel that might corner supplies and drive up prices much as OPEC has tried to do in oil. Policy makers braced for a nasty and brutish future as the country, they assumed, would depend on foreigners natural gas just as it did for most of its oil.

For the last few years the US natural gas industry has swung back to euphoria. A surge of new supplies, mainly from shale deposits unlocked through innovations in "fracking" and horizontal drilling, has created a revolution. At the turn of the millennium just one percent of US gas came from shale; by 2011 that share had risen to 30%.[2] US gas prices, which averaged just over $9/mmbtu in 2008, plunged below $3. Low prices

[1] Many thanks to Linda Wong for research assistance, to the Global Agenda Council on Energy Security for discussions, and to Jim Jensen, John Deutsch, Jan Kalicki and David Goldwyn for their comments.
[2] IHS Global Insight (USA) Inc. 2011. *The Economic and Employment Contributions of Shale Gas in the United States*. Prepared for America's Natural Gas Alliance. Washington DC.

have been good for consumers, but they also drive the next mood swing within the industry. Investors who made big bets on LNG imports because they assumed that gas within North America would be scarce and expensive are now exploring the opposite business strategy: exporting American gas as LNG to the rest of the world.[3]

This chapter explores the origins and implications as innovations in shale gas, along with LNG, affect the rest of the world's gas industry. I'll look not just at the impacts on economies but also on the impacts on the natural environment and geopolitics. Throughout, I make one central argument. Analysts and industrialists alike are prone to focus on what's new in gas and manically extrapolate the latest trends into the future. The innovations in shale gas are real and profound. However, so far the revolution is mainly an American affair that is still short-lived. A lot could go wrong, especially as firms try to deploy shale gas technologies in the rest of the world. Thus many of the plausible implications of this revolution for energy security and geopolitics—for example, new gas supplies could make Europe much less dependent on Russian gas exports and also force Russia to reform its stodgy gas industry—are still not yet evident. However, the environmental benefits are already clear. Low gas prices in the US along with tighter regulation of coal have allowed a massive shift toward gas in the US electric industry, leading to much lower US emissions of gases that cause global warming and possibly even greater reductions in the future. The potential economic effects of inexpensive gas are also clear. Within the United States, inexpensive shale gas is creating large numbers of jobs in gas production as well as in the industries that are

[3] NERA Economic Consulting. 2012. *Macroeconomic Impacts of LNG Exports from the United States.* Washington DC.

intensive users of gas—leading industrialists in Japan, Europe and other locales where gas is a lot more expensive to focus on how they, too, can enjoy the benefits of cheap gas.

I will also argue that, on balance, there is a compelling US interest in having this innovation spread quickly and globally. The U.S. might benefit a bit if it kept cheap gas at home, but the global environmental and security benefits of a truly global gas revolution are much greater. A coherent US policy strategy must start with the realization that most of what will determine the fate of the gas revolution depends on national investment and drilling policies in dozens of other countries. There's a lot that U.S. policy makers could do to impede the shale gas revolution but little they can do to push it faster than it will spread on its own. Where the US can perhaps have the greatest impact is in helping countries adopt the right regulations while, at the same time, opening the US market to foreigners who will learn about shale-based technologies and spread those innovations into their home markets. The most difficult test for a gas-friendly policy strategy lies with China. The potential for China to clean the air by switching from coal to gas is huge, but Chinese investors face many political obstacles to participating in the North American gas market and learning, practically, how to deploy shale and other unconventional gas technologies.

The Gas Industry in Historical Context

For most of its history, gas has been a poor stepchild in the oil industry. Found accidentally while drilling for oil, it was a problem to be managed while hunting for the real liquid prize. Gas was a nuisance because it was flammable, often highly pressurized and difficult to handle and transport. Until large networks of gas pipelines along with credible users of gas emerged, the easiest thing for drillers to do was to flare the gas.

That practice is still widespread today. For example, in the Bakken area of western North Dakota where there is extensive drilling for shale oil, more than one-third of the gas produced alongside the oil is flared.[4] While there are many programs to help governments cut flaring and venting, worldwide about 5% of annual global gas production is wasted this way.[5] On your next night flight over the Persian Gulf, an epicenter of flaring, look down and you'll see the luminescent result.

Because building pipeline networks and lining up customers who will use gas is a risky affair, in most of the world large gas networks have arisen only through active intervention of government through tight regulation, long-term contracts and state-ownership. State intervention reduced risk but it made for a dull industry with few incentives to find new sources of supply as well as new customers. All that changed in the US and a few other countries as market-oriented approaches to economic management rose in prominence starting in the 1970s. Along with other pivotal industries such as airlines, trucking and telecommunications, the US deregulated its natural gas. It forced the dismantling of long-term contracts, separating the trading of gas from the more monopolistic business of actually operating pipelines, and it created markets where gas could be traded freely. In time, the price for gas arose through "gas on gas" competition rather than through indexing to other fuels such as oil.

New markets along with new technologies helped inspire new uses for gas—especially in electricity. Cheap gas helped fuel a boom as electric utilities and speculators built many new gas-fired electric power plants. In the late 1990s, in fact,

4 Reuters. 2012. "Inside U.S. Oil." July 30, https://customers.reuters.com/community/newsletters/oil_us/IOA_Jul_30_2012.pdf; Krauss, Clifford. 2011. "In North Dakota, Flames of Wasted Natural Gas Light the Prairie." *The New York Times*, September 26.

5 Farina, Michael F. 2011. *Flare Gas Reduction: Recent global trends and policy considerations.* GE Energy, Global Strategy and Planning.

84% of total new electric generation capacity built in the US was designed to burn gas.[6] A new business model in the electric industry—so-called independent power producers (IPPs)—loved natural gas because gas-fired electric plants were cheaper and easier to build than coal plants, lowering the fixed capital needed to enter the industry. Low capital requirements and competitive gas markets meant that gas plants would be easy to switch on and off as needed to compete with other sources of electricity. These market-oriented trends also fueled the gas industry's manic tendencies. Rapid growth in gas-fired electric generators during the 1990s led analysts and investors to extrapolate a future where US gas consumption would keep soaring; huge demand for gas and the expectation that U.S. domestic supplies would run short led inexorably to the conclusion that massive amounts of LNG would be needed to fill the gap. Indeed, the US gas market was so competitive, and the assumption that the US was the market of last resort for LNG supplies, led many LNG suppliers to evaluate all new projects on the basis of whether they could compete in America.

While these market-oriented reforms happened in the US and a few other regions—notably in England and Wales—the shift to markets was slow or stillborn in the rest of the world. That's because most countries put state-owned enterprises in charge of gas and electricity and the incumbents understandably didn't want change. Even in continental Europe, where reformers passed strong laws requiring market competition, true progress toward competitive gas and electric markets has been slow. In fact, scholars who have studied and compared market liberalization around the world find that most gas and electric market reforms get stuck in a middle ground where governments

[6] EIA. 2011. "Today in Energy." July 5. www.eia.gov/todayinenergy/detail.cfm?id=2070.

pass laws requiring competition but don't dismantle the state enterprises and contracts that would allow for genuine competition except (if at all) around the margins.[7]

The failure of market reforms in most countries and the cost of moving gas long distances combine to explain why there isn't really a global gas industry. Rather, there are many hundreds of local markets that are, at best, loosely coupled. Unlike oil, which is easy to move once on a ship, physical arbitrage of gas is a lot trickier. At distances of more than one or two thousand miles pipelines are not economical. Transport at greater distances requires liquefied natural gas (LNG), which is an expensive proposition as well. The countries that historically have been the biggest buyers of LNG—Japan initially and now Korea as well—have been willing to pay almost anything for gas because they have essentially no fossil fuels at home. For them, a global gas market exists in the sense that gas moves planetary-scale distances, such as from Doha to Tokyo, about 7,500 miles by ship. But the paramount desire for energy security and the need to avoid disrupting uncompetitive local monopolies has made Japanese buyers of LNG uninterested in truly competitive markets that might see their cargoes redirected to other countries. It also helps explain why gas prices in Japan are about five times those of the U.S. today. Overall, in 2011 just 10% of global gas consumption moved as LNG.[8] The contrast with oil, which has been a global commodity for decades, is striking. While the oil market suffers from some fragmentation because only a few refineries (mainly in the Persian Gulf and Asia) are designed so they can process any kind of crude, as a practical matter

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7 My colleagues and I have studied this phenomenon in electric utilities, foreign investment in IPPs, oil supply, gas, and now coal. Everywhere we look the same patterns of partial reforms emerge. Victor, David G. and Thomas C. Heller, eds. 2007. *The Political Economy of Power Sector Reform: The Experiences of Five Major Developing Countries.* Cambridge: Cambridge Univ. Press; Woodhouse, Erik J. 2006. "The Obsolescing Bargain Redux? Foreign Investment in the Electric Power Sector in Developing Countries." NYU J. Int'L Law & Politics 38(102): 121-246; Victor, David G., Amy M. Jaffe and Mark H. Hayes, eds. 2006. *Natural Gas and Geopolitics: From 1970 to 2040.* Cambridge: Cambridge Univ. Press; Victor, David G., David R. Hults and Mark C. Thurber, eds. 2012. *Oil and Governance: State-Owned Enterprises and the World Energy Supply.* Cambridge: Cambridge Univ. Press; Victor, David G. and Richard K. Morse. 2009. "Living with Coal." *Boston Review* (Sept/Oct).

8 Walker, Andrew. 2012. "The Global LNG Market – A look back and a look forward." *LNG Industry* (Summer).

nearly every country's oil market pulses to the same global economic forces. That's not yet true for gas.[9]

Whether gas becomes a truly global commodity and the geopolitical effects of the global gas trade will depend centrally on the United States—the world's largest user of natural gas and the epicenter of most innovation in the industry. And while many factors will shape the US industry, two clusters of innovation will play central roles.

One, much in the news today, is new methods of production such as fracking of shale combined with horizontal drilling. While these technologies have entered the public mind only recently, in fact the key innovations have had a much longer gestation period. Starting in the middle 1970s the US federal government partnered with the gas industry to conduct R&D; the key innovations emerged in the middle 1980s at Mitchell Energy, a Texas gas company that worked for another decade to perfect by the late 1990s an innovative drilling technique called 'slick water fracturing' that made fracking economical.[10] Almost another decade passed before other companies helped deploy the best combinations of technologies at the scale needed to have a substantial impact on US gas supply and prices. As late as 2007 most analysts expected that the US would be short on home produced gas and would need to import from Canada (by pipeline) and abroad (by LNG); by 2010 almost no analyst believed that vision because the effects of massive home-produced shale were apparent.

While shale gas has proved to be the newest, most visible major source of gas, in reality there are many diverse sources of gas. Tapping some will require little or no

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[9] For an overview of the industry and projections, in particular see MIT. 2011. *The Future of Natural Gas.* An Interdisciplinary MIT Study, MIT Energy Initiative.

[10] Trembath, Alex, Jesse Jenkins, Ted Nordhaus, and Michael Shellenberger. 2012. "Where the Shale Gas Revolution Came From: Government's Role in the Development of Hydraulic Fracturing in Shale." Breakthrough Institute Energy & Climate Program, The Breakthrough Institute. See also Yergin, Daniel. 2011. *The Quest: Energy Security and the Remaking of the Modern World*. New York, Penguin Press.

innovation, such as the massive conventional gas resource in Russia, Iran and Qatar as well as big new finds in places such as Mozambique. Beyond shale, other unconventional sources of gas include coal bed methane—a cutting edge technology two decades ago that, now, is widely understood and still accounts for nearly one-tenth of US gas production.[11] China is making big bets on this gas source and is likely to scale it up before it turns to shale. Massive new gas plays in the Arctic are now coming into focus. Today's story may be shale gas in America, but the next new thing in gas might well be geography or technology that are quite different in a few years time. Looking over the horizon in a decade or more we could be focused on a cluster of innovations that make it economic to produce natural gas from methane hydrates, and even further into the future may be innovations in ultra-deep natural gas. Indeed, there is quite a lot of evidence that the planet is geologically awash in methane.

The other, equally important, cluster of innovations concern transportation of gas. LNG is particularly important because it allows truly global interconnection of gas markets. The idea that gas could be compressed, cooled and put on tankers for long haul travel has been around for a long time. The first LNG cargo sailed in 1959 from the US Gulf Coast to Britain. Britain soon imported LNG from Algeria, the first commercial LNG train. The US entered into the LNG business as an exporter from the Cook inlet (in rural coastal Alaska) to Japan—a project that shipped its first cargo in 1969. After the Arab oil embargo—when the cost of oil that powered much of Japan's electric grid soared—Tokyo poured money into LNG projects, gold plating them in exchange for a guaranteed supply. The Pacific basin, huge in size and dominated by Japan, became the

[11] EIA. 2010. "Annual Energy Outlook 2011." Summary presentation, U.S. Dept of Energy.

world's largest LNG trading zone. LNG was a boring, uncompetitive, costly industry dominated by Japanese buyers.

A project in Trinidad, conceived in the 1990s, helped eliminate gold plating by allowing flexibility in where the gas was sold—when prices were higher in Spain the ships sailed there, but when prices were more dear in the large US market the ships went to America.[12] The Atlantic basin, because it was smaller and linked some competitive national gas markets (notably the U.S.) invited this form of destination flexibility that is still slow to appear in Asia. As volumes of LNG from swing suppliers such as Qatar that sit between the Atlantic and Pacific basins grow then gradually these basins are likely to yield a more global market with global prices net the cost of the shipping. The Atlantic basin is approaching that point; the Pacific is still far away.

Putting innovations in gas production together with innovations in LNG helps explain why today's gas revolution is so interesting. Big new supplies, such as from shale, could cut the cost of gas while diversifying the sources of supply. Even countries that don't have shale gas of their own (or don't create the regulatory environment that encourages shale supplies) will feel the effects of the shale revolution if LNG connects competitive gas markets globally.

Before turning to the many consequences that could flow from this revolution, it is important to remember that these trends arise in an industry that is prone to wild swings in mood. A lot could unfold in ways that even the best analysts don't anticipate. A few years ago the best forecasting arm of the US government—the Energy Information Administration, whose forecasts are benchmarks for many energy contracts—took a

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12 Shepherd, Rob and James Ball. 2007. "Liquefied Natural Gas from Trinidad & Tobago: the Atlantic LNG project." In *Natural Gas and Geopolitics: From 1970 to 2040*, eds. David G. Victor, Amy M. Jaffe, and Mark H. Hayes. New York: Cambridge University Press.

careful look back over sixteen years of forecasting and assessed its performance. While EIA excelled in a few areas, one of their worst track records was in forecasting gas prices. As shown in figure 1, when gas prices were low the EIA models assumed they would stay low and rise gradually with depletion. When they were high, the assumption was that prices would fall with time as new supplies and imports (notably via LNG) came online. As is typical with resource depletion models, the forecasts were driven mainly by real world events rather than a deep capacity to predict the kinds of fundamental changes in markets that have come with shale gas.

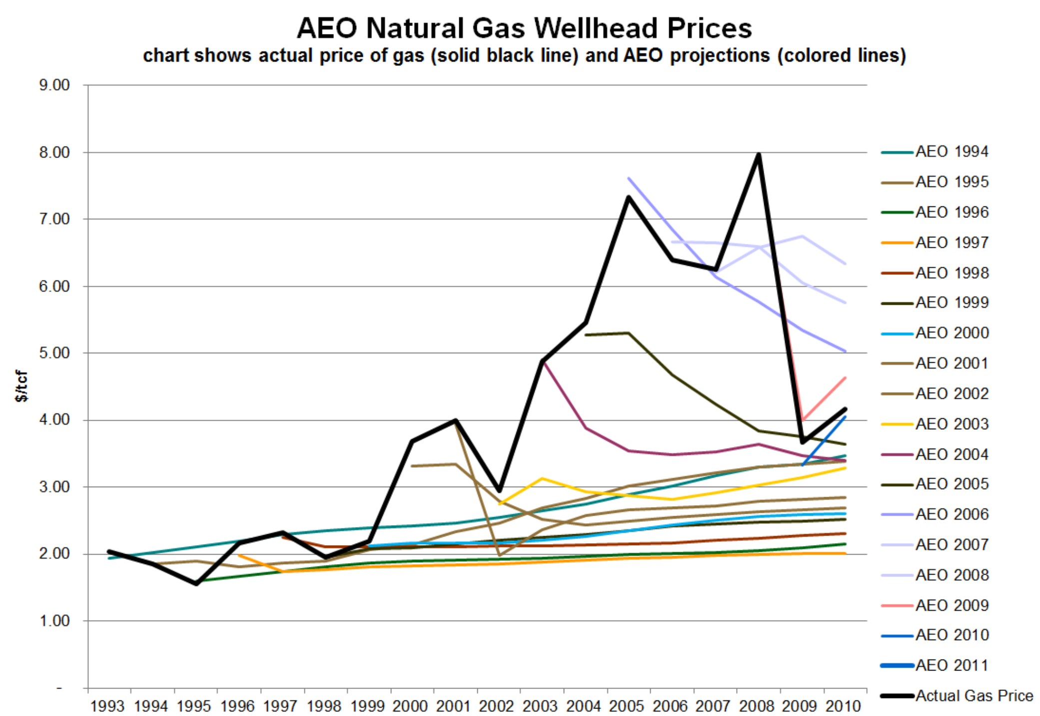

Figure 1 (Source: EIA. 2012. *AEO Retrospective Review: Evaluation of 2011 and Prior Reference Case Projections*. Washington DC: U.S. Dept of Energy.)

The history of exuberance, despair and error by the best forecasters is a warning that much can change in unpredictable ways.

Security, Geopolitical and Ecological Consequences

Large transformations in energy are rare and they usually unfold slowly. The shale revolution, by contrast, is moving with striking speed in the US even as its fate globally remains quite uncertain.[13] Through diffusion of the technology or trade in gas via LNG, the effects of new shale supplies could be felt globally and quickly. Looking to the future, the consequences could be many. I focus on three: energy security, geopolitics and the environment.

Energy Security

Energy security is one of those terms that is particularly popular because it has no precise meaning. For me, it means reliable provision of energy services at manageable cost. Reliability allows investors and energy users to plan around their energy systems; manageable cost allows them to do more in life than buy energy. Almost any system can be made nearly perfectly reliable at nearly infinite cost—witness the elegant and reliable power supply on the international space station, for example—but manageable costs are much harder to combine with reliability. As a practical matter, energy security has two main flavors because, as economies mature, energy bifurcates into two main applications: transportation and electricity. Figure 2 shows this bifurcation for the US economy, but most modernizing economies follow similar patterns.

[13] Deutch, John. 2011. "The Good News About Gas: The Natural Gas Revolution and Its Consequences." *Foreign Affairs* (Jan/Feb): 82-93.

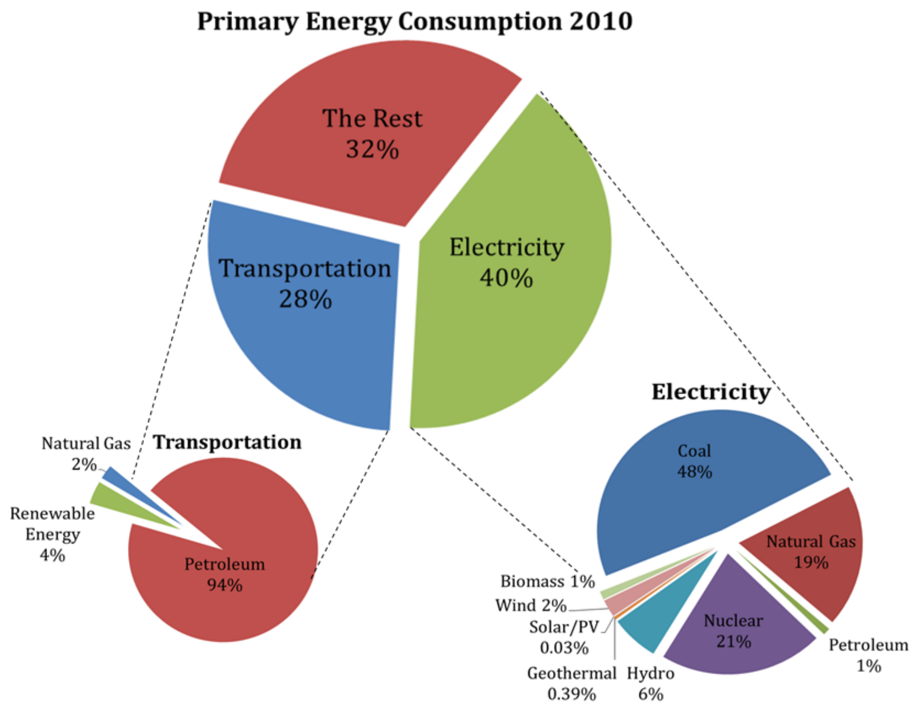

Figure 2 (Source: EIA. 2011. *Annual Energy Review 2010*. Washington DC: U.S. Dept of Energy.)

In transportation, oil is king and so far has no serious rivals. In the US, oil powers 94% of all transportation services. The balance comes mainly from a small role for biofuels blended with gasoline. Oil's dominance is hard to change because oil-based fuels are liquid at most temperatures and have a high energy density, which means that relatively little space and weight in cars, trucks and airplanes are required to store fuel. When refilling a car at the local gasoline station the process takes just about 3 minutes and transfers energy at a rate of 6 MW/hr; by contrast, the best electric vehicle charging systems transfer at rates one hundred times smaller. There's no shortage of innovative visions that could change that, such as with much better battery-based electric storage and new charging systems.[14] So far, though, these are visions more than practical realities.

[14] Chu, Steve and Arun Majumdar. 2012. "Opportunities and Challenges for a Sustainable Energy Future." *Nature* 488(7411): 294-303.

The other flavor of energy security is electricity. Electricity is an energy carrier, not a fuel. In theory, other energy carriers, such as hydrogen, could work as well, but the "hydrogen economy" is more the work of dreamers than practical people. (Full disclosure: the first academic paper I ever wrote was about hydrogen-fueled aircraft. It was something fun to think and write about in graduate school but never amounted to anything practical.) Electricity is king because it is extremely flexible, mostly safe, pristine clean at the point of use, and relatively easy to make reliable.[15] Since most people live in cities there is a special premium on energy carriers that can be wired directly to the final user while moving pollution and other externalities of power production far outside the urban area. In 1900 less than 2% of the world's primary energy was carried as electricity to its final users;[16] by 2010 that fraction has risen to more than 35% and is likely to keep going up.[17]

How could the gas revolution affect these two flavors of energy security? In transportation, gas has made few inroads. In some countries that are rich in gas and worried about dependence on imported oil there are special incentives to switch vehicles to gas, but in practice that switching is rare except in fleet vehicles (e.g., taxis, buses and delivery trucks) that return to the same filling stations every night. So long as oil remains a tolerable rival, the coordination problems in switching infrastructures--in this case, from liquid fuel refilling stations to natural gas, along with switches in storage tanks and pipelines—are likely to outweigh the benefits for nearly all users.

Because infrastructure coordination is so difficult I doubt there will be much switching from oil to gas unless the price differentials are massive. Already today in the

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[15] See Charles Ebinger and John Banks, "Global Electrification," chapter 19.
[16] Smil, Vaclav. 2000. "Energy in the Twentieth Century: Resources, Conversions, Costs, Uses, and Consequences." *Annual Review of Energy and the Environment* 25: 21-51.
[17] ExxonMobil. 2012. *2012 The Outlook for Energy: A View to 2040.* Irving, Texas: ExxonMobil.

US the price per unit of energy of oil-based fuels is more than seven times that of natural gas; before the surge in shale gas supplies around 2006 gas was only about half the price of oil.[18] (This severe decoupling of oil and gas prices is not yet evident in most of the rest of the world where gas and oil prices are much more closely linked—often explicitly linked in contracts.) Despite the sevenfold price advantage for gas there is little switching from oil to gas in the US except in some fleet vehicles. There are programs to build infrastructure (e.g., LNG along transcontinental highways, which is particularly promising for long haul trucks that can easily store LNG and whose fuel bills are so huge that they have a strong incentive to make the move), but none of this is likely to make much dent in oil. There are also interesting visions (though far from realities) that see liquid fuels made from gas that can "drop in" to the existing gasoline infrastructure, of which methanol is today's leading contender. When it comes to imagining ways to get off oil, technicians are bubbling with visions but the realities are many fewer.

That leaves energy security of the electric flavor, and here the gas revolution is likely to be much bigger news. The challenge for gas, however, is that it is just one of many rivals and each fuel brings its own challenges for energy security. In 2012 India suffered two massive blackouts linked, in part, to under-investment in coal supply infrastructure and power plants; China, too, has suffered energy insecurities linked to coal when the network of mines, coal transporting railroads and power plants couldn't grow as quickly as demand for electric power. Boosting gas might help these countries create more reliable power supplies, but in reality gas requires a costlier infrastructure than coal. Both countries are investing in gas, and both see energy security mainly coming from better coal supply systems and a bigger network of coal-fired generators. In part,

[18] Jensen, James. 2009. *Fostering LNG Trade: Developments in LNG Trade and Pricing*. Brussels: Energy Charter Secretariat.

electricity security comes from storing fuel, which is much costlier for gas than coal. A typical coal plant has a pile of coal worth 30 days sitting on hand requiring little more than a plot of land and gravity to hold it in place. Most gas-fired electric plants have little storage and rely on real-time delivery of their fuel and contracts for storage. Other electric generators face even greater challenges with storage, such as wind (which doesn't always blow) and solar (which suffers at night or on cloudy days). Even at small market shares, these intermittent and highly variable renewable supplies have actually made some electric grids less secure.[19]

Cheap gas is already having a big impact on the shares for coal and gas in the US electric system. In 2010 coal accounted for nearly half of US electric supply (see figure 2). Over the next two years that share dropped to one-third and is now at parity with gas. In my twenty years of studying energy systems I have never seen such a huge shift in major fuels over such a short period of time.

So far, however, this dramatic shift to gas in the American electric grid has had little net effect on energy security. Cheap gas has kept retail electric prices today a bit lower than they would be otherwise, and dependence on gas will allow utilities to avoid costly upgrades for older coal-fired power plants to comply with tighter new environmental regulations. (Thanks partly to cheap gas, in the coming decade utilities will retire perhaps one-fifth of the coal fleet rather than upgrade these units.[20]) Most utilities, however, see growing dependence on gas as a threat to energy security because of the fuel's history of price volatility and the difficulty of creating stable long-term

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[19] See Talbot, David. 2012. "The Great German Energy Experiment." *Technology Review,* July/August; Keil, Gunther. 2011. "Germany's Energy Supply Transformation Has Already Failed." EIKE. See also Katzenstein, Warren, Emily Fertig, and Jay Apt. 2010. "The Variability of Interconnected Wind Plants." *Energy Policy* 38: 4400-4410.

[20] EPRI. 2012. *PRISM 2.0: The Value of Innovation in Environmental Controls*. Summary Report. Palo Alto, California: Electric Power Research Institute.

pricing for gas supplies. Gas that is cheap, even if just for some periods of time, can reduce diversity in power networks since it undercuts the financial viability not just of coal but also new nuclear and renewable energy projects. Already these patterns are evident in parts of the US grid that have moved most extensively to gas—such as the Northeast—where gas for power plants competes with other uses like home heating and the gas supply network can't meet all needs during periods of maximum demand.

Geopolitics

The gas revolution could affect the political behavior of importers as well as exporters. If gas importers feel more secure then they might behave differently politically—Germany or France, for example, might be less beholden to Russia if they had more diverse and less costly gas supply options. So far, however, the revolutions rooted in shale gas supplies and LNG haven't yet had much impact on energy imports anywhere in the world. In the US the shale revolution has mostly offset declines in domestic supplies—total US gas imports (most of which come via pipeline from Canada) have barely changed over the last decade. Of the countries that depend most on imported LNG for gas—Japan (92% of gas is imported as LNG in 2010) and South Korea (more than 98% of gas imported as LNG)—neither has much shale at home. Japan, with nearly all its nuclear reactors shut in the aftermath of Fukushima, has actually become more dependent on imported gas (and other fuels) in recent years.

Looking to the future, a shale revolution along with expanded supplies of LNG could have the most immediate geopolitical impacts in Western Europe. Today, about one-quarter of Europe's gas comes from Russia at prices indexed partly to oil, which makes European gas three or four times the cost of gas in the United States. This huge differential (which is reflected, as well, in electricity tariffs) has led energy intensive European industries already lament their competitive disadvantage just as a host of gas-intensive industries, such as the production of ammonia, are investing in large expansions in the U.S. With weak economies across the OECD, one of the few spots of bright news for economic growth comes in the form of low U.S. gas prices. So far, the political implications of this are only evident within countries—with gas-intensive firms inside the major OECD countries pressuring their governments to keep cheap gas at home (in the U.S.) or emulate American policies and cut local energy prices (in Europe and Japan).

Even small new shale supplies at home along with extra LNG that Americans don't need to import could help lower prices and force the whole European gas supply industry to become more competitive. So far, however, that's an imaginary future. The shale revolution is starting to take off slowly in the UK. In France environmental groups have created a ban on fracking before anyone has even learned much about the country's potential. New shale plays in Poland and Ukraine are just now beginning, with possibly large but still unknown potential for production. Overall, it appears that European shale gas resources are much smaller than those already being developed in North America, but exploration in Europe remains at an early stage. One of the central lessons from the US shale revolution is that what's needed isn't just drilling technology but also a host of regulatory rules (e.g., well spacing requirements) and market conditions (e.g., ownership of underground resources and access to pipelines) that still don't exist in most of Europe.

If the gas revolution washes into Europe the biggest effects will be felt by Europe's gas producers, especially in Russia. Russia's prized position as supplier to Europe is based on a legacy of long-distance pipelines and the country's massive conventional gas resources. In turn, Russia has earned from $42 to $60 billion/year in the last six years selling gas mainly to Europe. Lower prices could radically cut those revenues just as Russia faces much higher costs for new fields and pipelines. Producing and transporting gas from possible new Russian projects off Murmansk or on the Yamal peninsula (both places with lots of gas underground but a sketchy investment climate above ground) are barely economic today even with high gas prices.   The shale revolution could seal that gas underground. Fewer exports and lower prices give less surplus cash for other things the Russian state (which taxes gas exports and has a controlling interest in the gas pipeline monopolist Gazprom) might want to do. A Russia forced to live on a smaller state budget is probably one that will encourage other kinds of economic activity, will seek trade with other countries, and is probably less hostile to western interests. Exactly that happened in the late 1990s when low oil and gas prices forced fiscal probity on the Russian state and helps explain why Russian foreign policy was less aggressive. Beyond Russia, it is likely that lower export revenues will also cut into transit fees charged by Belarus and Ukraine—countries already under pressure as Russia and its customers build costly pipelines around these sometimes erratic transit points. Looking to Asia, where there are bold Russian plans to export gas and electricity, Russian suppliers face competition from LNG (e.g., from Australia) and China's own fledgling gas industry. While the need to compete with cheap gas is terrible news for Russia, the exact effects on Russian politics and industrial policy are not easy to predict. The demise of Gazprom as a monopoly—which is probably essential if Russia is to become more competitive as a gas supplier—has been forecast many times and yet to happen. The Russian state might insulate itself from the loss of gas export revenues since it earns much more selling oil abroad than selling gas.

Elsewhere in the world, the shale gas and LNG revolutions could help lower surplus revenues and thus dampen the "resource curse" that has distorted the politics of other gas exporting nations, such as Indonesia and Bolivia. It will also underscore a maxim that has long explained investment patterns in the gas industry (and to a lesser degree oil): what matters for gas production isn't just resources under ground but also the context "above ground" that determines whether firms will make the capital intensive, long-lived investments typical of big gas export projects. That maxim explains why Trinidad is a powerhouse of LNG exports in the Atlantic basin but just 80 miles away Venezuela sits on huge gas resources yet exports none. It also helps explain why firms operating in Qatar have aggressively tapped the world's largest gas field—the "north dome" in the middle of the Persian Gulf. But on the Iranian side of that same field there is almost no drilling. A more competitive global gas industry, linked with more cost-effective LNG and supplied with a more diverse array of shale-based producers will make this maxim even more important. Huge amounts of gas will be left underground in the parts of the world that are hostile to modern gas investment strategies above ground.

Environment

In one area, the environment, the effects of the gas revolution are already tangible. Modern gas-fired electric power plants emit just two-fifths the CO_2 when compared with coal-fired plants for the same amount of electricity output. The big shift to gas has thus caused a plunge in emissions of CO_2, the leading human cause of global warming. Figure 3 illustrates the importance of this shift in the US where annual US emissions of

CO2 are perhaps 400 million metric tons lower than they would be if coal still accounted for nearly half of the US electric power sector. That's a huge number—about 8 percent of all US CO_2 emissions and about double the size of the effort that the EU has made to comply with the Kyoto protocol.[21] This outcome could be ephemeral if gas prices rise. Indeed, at this writing (Spring 2013) some utilities are switching back to coal as the price of natural gas has risen, and around the world costly gas has been a boon to coal-fired power generation. Today's American love affair with gas doesn't, of course, reflect a serious national global warming policy, and it won't deliver the 50% to 80% reduction in emissions needed by most nations so that they collectively stop global warming. But it is a big step in the right direction that also buys time for deeper cuts.

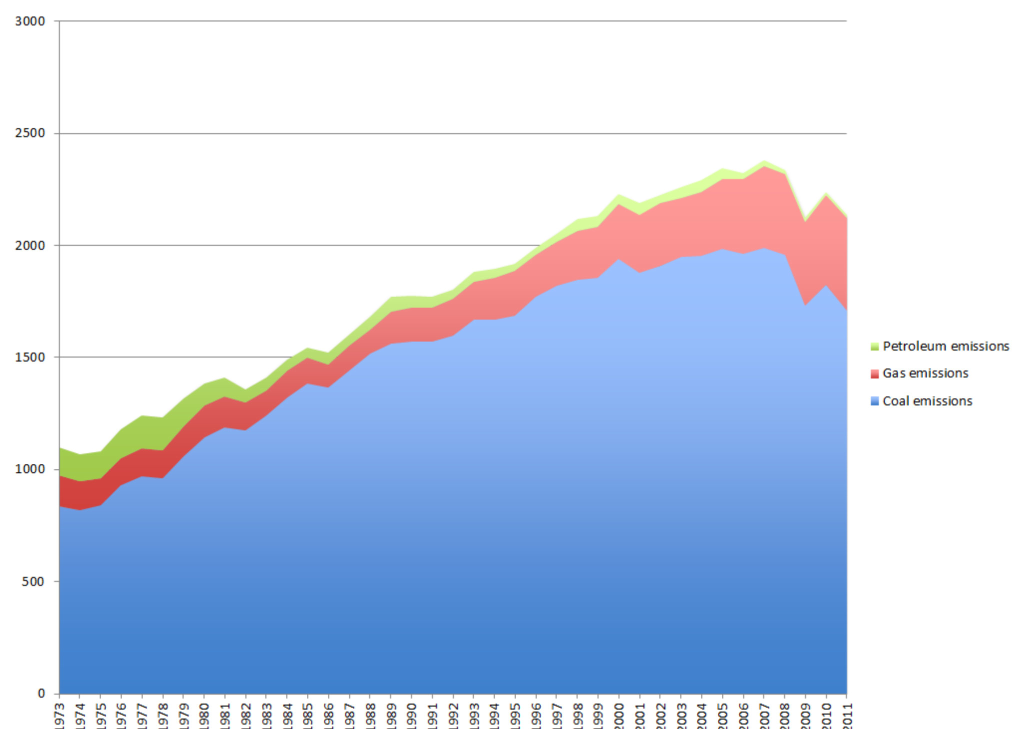

Figure 3 (Source: EIA. 2012. *June 2012 Monthly Energy Review*. Washington DC: U.S. Dept of Energy)

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[21] For more on the real effect of Kyoto see Victor, David G. 2011. *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet.* Cambridge, UK: Cambridge Univ. Press. For more detail on the impacts of gas on greenhouse gas emissions see National Petroleum Council. 2011. *Prudent Development: Realizing the Potential of North American's Abundant Natural Gas and Oil Resources*. Washington DC: NPC, chapter 4.

Shale gas isn't automatically all good news for the environment, however. Fracking has raised concerns about pollution of underground water supplies, triggering of small earthquakes and even air pollution from all the trucks and drilling activities. Major concerns have arisen over the one to seven million gallons of water typically used to open a single well with fracking.[22] There's some evidence that gas fracking could lead to higher emissions of methane (the main component of natural gas but also a strong global warming gas), which could offset some of the global warming benefits from a dash to gas. There's a huge literature amassing about how such challenges can be monitored and managed.[23] With best practices the impacts on water and on leakage of methane will prove easy to manage.

Conclusions and Implications

Looking to the future, what could be done to accelerate the gas revolution and help it spread globally? That question is on many minds these days, especially in the US, which has been at the center of the gas revolution and has a big stake in its success elsewhere in the world. New gas supplies and lower prices could help reduce world dependence on gas suppliers such as Russia. It could enrich US firms that have perfected the technology and also make it easier for countries around the world to cut emissions of

[22] E.g, Nicot, Jean-Philippe and Bridget R. Scanlon. 2012. "Water Use for Shale-Gas Production in Texas, U.S." *Environmental Science & Technology 46: 3580-3586.*

[23] SEAB. 2011. *Shale Gas Production Subcommittee Second Ninety Day Report.* Secretary of Energy Advisory Board, Shale Gas Production Subcommittee, U.S. Dept. of Energy, November 18; also, John Deutch 2012. "The U.S. Natural-Gas Boom Will Transform the World." *The Wall Street Journal*, August 14. http://online.wsj.com/article/SB10001424052702303343404577514622469426012.html; Bloomberg, Michael R. and George P. Mitchell. 2012. "Fracking is Too Important to Foul Up." *The Washington Post*, August 23. www.washingtonpost.com/opinions/fracking-is-too-important-to-foul-up/2012/08/23/d320e6ee-ea0e-11e1-a80b-9f898562d010_story.html.

warming gases—an outcome that would benefit the entire planet, including the US, by lessening the rate of global warming.

Traditional foreign policy tools won't be very useful. What matters most for the spread of the gas production and transportation technologies will be the internal regulations that other countries adopt. At present, most of the world is not yet open for fracking. Some countries have banned the practice (e.g., France). More common is the lack of regulatory and market frameworks that would encourage private firms (who are the experts in the technology) to take risks. For example, huge shale deposits in Argentina and Mexico are unlikely to be tapped much. Argentina recently nationalized the only competent gas company in the country and has a record of expropriating foreign investors. Mexico's constitution forbids private actors from most oil and gas drilling, and political gridlock has made this impossible to change, although several recent Mexican administrations (including the current one) have sought greater political and economic space for foreign investment in tandem with Mexican partners. Across China and India—two coal rich countries that could clear the air and cut warming emissions if they used more gas—a host of market barriers make shale and other promising gas sources hard to exploit.[24] The US can't change the fundamentally national prerogatives, but it can do three things to help tip the balance.

First, the US must continue working to ensure that its industry—which is the model for a global shale gas revolution—offers a good example. That means, especially, monitoring and managing the environmental side-effects of shale production so that the U.S. doesn't offer salient examples of what could go wrong with the technology.

[24] Jane Nakano, David Pumphrey, Robert Price Jr. and Molly A. Walton, 2012, *Prospects for Shale Gas Development in Asia*, CSIS. China's own assessments of its energy future see a much larger role for gas and a larger role for low-emission technologies generally. See Han Wenke and Yang Yufeng, 2012, "China Energy Outlook," Beijing, China Energy Research Institute, executive summary (Mandarin and English), 46 pp.

Second, the US should help where it can with direct technical assistance in the writing of regulations and other support for countries that seek it. (Such a program is already under way in the State Department.) I suspect, though, that most of the world's promising shale gas markets—such as in China or Poland—are unlikely to need or want much foreign assistance.

Third, the US can also make sure that is own shale gas market is open to foreign investment so that foreigners can learn (and Americans can benefit from the influx of capital). The pivotal player is China, which today uses more coal than the rest of the world combined. Inexpensive, clean alternatives to conventional coal offer the best way for China to clear its air and lower its emissions. Foreign companies can play a role—and many are already in the early stages of shale gas exploration in China—but as a practical matter, nothing will happen at scale in China's energy system without the country's state-owned national champions centrally involved. Yet when those companies try to invest in North America they find themselves entangled in security reviews—such as under the Committee on Foreign Investments in the US and similar reviews in Canada—that unwisely block the spread of this important technology. Wariness about theft of intellectual property and unfair contracting is understandable, but those legitimate worries have been an excuse to meddle in commercial transactions that, if allowed to proceed, would advantage the country over the long term.

The gas revolution is fundamentally the product of commercial incentives. So far, the stars are aligning in ways that could transform energy security, geopolitics and the energy system's impact on the environment in ways that almost nobody predicted even five years ago. Government, especially in the U.S., can help industry and other stakeholders focus on the long-term transformative potential for these technologies—especially as the shale revolution spreads worldwide.