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## THE REVOLUTION IN NATURAL GAS

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Five years ago, it seemed that the United States would remain hopelessly dependent on imported oil, and experts were projecting a similar trend for natural gas. Expensive imports of liquefied natural gas (LNG) were expected to be required indefinitely to replace the diminishing production of domestic conventional natural gas. Instead, there has been a completely unexpected explosion in reserves and production of oil and gas from unconventional resources – shale and tight sand – now approaching 30% of domestic natural gas consumption. Rotary steerable drilling and hydraulic fracturing, technical advances largely due to private industry, have made this increase possible. Drilling pads operating in many states now support several wells drilled to significant depth with lateral pipe extending up to 5 km. Millions of gallons of water, mixed with sand and some chemical, are injected at high pressure through precise perforations of the wellbore, creating fractures in the rock that stimulate production of the trapped fluid.

The benefits to the United States are enormous. Natural gas prices have declined by half, lowering the cost of home heating for consumers. Employment has increased by many tens of thousands, and the now the expectation is that North America will become an exporter, not an importer of natural gas (and oil) in the coming decades. Natural gas is rapidly replacing coal in the electricity sector, which brings many environmental advantages, especially significantly lower carbon dioxide emissions per kilowatt-hour of



electricity. Natural gas is an important feedstock for the chemical industry so its availability and low cost are a boon to this sector.

The tremendous growth in unconventional oil and gas production has begun in North America. Drilling rigs and drilling activity is much greater in the United States and Canada than anywhere else. In the United States, unlike any other country, underground oil and gas resources belong to the private landowner rather than the state, which gives exploration and production tremendous private financial incentive. Hydraulic fracturing and field practice know-how resides with investor-owned oil companies that are aggressively pursuing unconventional oil and gas opportunities, while national-owned oil companies remain focused on their abundant conventional domestic reserves. However, shale and tight sand resources are widely spread around the world: in Latin America, North Africa, China, Russia, and Europe. Over time, there is likely to be a massive increase unconventional oil and gas production that will increase the diversity and supply of these resources.

There are two key economic uncertainties. Presently, there are three natural gas markets in the world, where the price of natural gas is wildly different: \$4 per thousand cubic feet (MCF) in North America, \$10 per MCF in Europe, and \$15 per MCF in Asia. The abundance of natural gas may well lead to greater trade through LNG tankers and progressively longer pipelines that could lead to a global market and price of natural gas such as now exists for oil. A global market price for natural gas would dramatically change the nature of energy markets, especially in the large emerging economies in Asia.

There presently exists the largest gap in history between the price of oil and the price of gas on an energy equivalent basis in North America: \$90 per barrel oil is roughly four times more expensive than natural gas at \$4 per MCF. Thus, there is a tremendous economic incentive to develop new technologies that will permit natural gas to displace higher cost liquid fuels in commercial applications. The transportation sector presents the greatest opportunity, as compressed natural gas would compete favorably against motor gasoline fueled light-duty vehicles. Many firms are exploring “gas to liquids” technology that converts methane into liquid fuels. It is most unlikely that the present discrepancy between the price of natural gas and oil can be sustained for many decades in the face of technical change.

The geopolitical implications of the natural gas revolution greatly favor US foreign policy interests. The increase in low-cost unconventional oil and gas resources shifts market power from supplier to consumer countries. North America with its expanded production levels and potential as a net exporter will have much greater influence in world oil markets. Many countries that possess the largest proven reserves of conventional natural gas, such as Russia and Iran, are experiencing a dramatically adverse wealth effect. Sharply lower



oil and natural gas prices mean lower revenue for producing countries such as Russia, Venezuela, and Saudi Arabia that has the possibility of destabilizing the economies and governments of those countries. Friends, such as Canada and Australia, that have undertaken high-cost oil and gas production projects, may also suffer. In sum, natural gas markets around the world will experience rapid and large changes, which will require companies to be agile and states to adapt diplomacy and trade policy rapidly.

The greatest threat to expansion of unconventional oil and gas production in North America and many other regions of the world is public opposition to real and perceived adverse environmental impacts of this activity. Presently, opposition and support is evenly split in the ten or so states that have significant drilling underway. All stakeholders understand the importance of strong regulation to protect public health, safety, and environmental quality. But even in the United States and Canada where the strongest regulatory structures are in place, there are important deficiencies in the scope and administration of regulations. Comprehensive regulations must address the main environmental concerns: (i) water quality, (ii) air quality, (iii) community and regional impacts, and (iv) induced seismicity. In the United States, serious tensions exist between the federal Environmental Protection Agency and the state regulatory agencies concerning responsibility for regulations and for inspection and enforcement. Since it is possible that hundreds of thousands of hydraulically fractured wells will be drilled in the next couple of decades, it is important that regulations be crafted and administered in a way that gains the public's confidence. Furthermore, other countries are sure to look to the United States to lead in environmental regulation. Hydraulic fracturing technology is advancing rapidly. Companies and regulators are accumulating valuable field experiences. So it is reasonable to believe that industry performance on key environmental indicators will improve over time. Progress would be surer and faster if industry adopted a more forward leaning policy based on measurement, reporting, and continuous improvement in its environmental management.

The prospects for much greater production of natural gas (and oil) from unconventional sources has potential to bringing significant economic and security benefits to much of the world. Realizing these benefits requires disciplined attention to managing undesirable environmental impacts. But other challenges remain: in particular, greater use of natural gas will slow but not avoid the greenhouse gas emissions that contribute to adverse climate change.



UNCORRECTED PROOFS