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Risks and Potentials of the Shale Gas Revolution

Consequences for Markets and the Environment

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The shale gas revolution, which until now has been mainly a North American phenomenon, is poised to go global. Geologists have long known about large quantities of methane trapped in shale rock, but it took favorable price signals and technological innovations to make it feasible to get shale gas out of the ground. Are European business elites and policy makers ready for these developments? What can be learned from the North American experience? If regulators allow it – and most importantly if industry finds it lucrative enough to pursue it in places such as Poland and Ukraine – the use of hydraulic fracturing as a technique for extracting natural gas from gas shale will carry with it consequences for the environment, the marketplace, and energy security, but the magnitude of those consequences is uncertain.

The geo-historical and geo-economic contexts of the shale gas revolution involve the interplay of four main factors: 1) the increasing scarcity of conventional hydrocarbon fuel sources in locations where markets are easily accessible and infrastructure is already in place; 2) the pinching of other fuel sources as part of the energy mix due to their environmental and/or economic costs, whether it be nuclear, coal, or oil; 3) technological advances as part of a larger technological revolution occurring to squeeze every last combustible carbon molecule out of the earth; and 4) policy decisions under the rubric of "security" that encourage "local" production to replace or reduce the need for supposedly less reliable "distant" production. The higher cost associated with extracting shale gas versus conventional natural gas is warranted in the eyes of producers because of the interplay of these factors.

Forerunner United States

Shale gas production in the United States has boomed during the last decade. In 2010, the total production amounted to more than 5 trillion cubic feet, and the US Energy Information Administration (EIA) predicts that this number will triple by 2035. Texas and Louisiana have traditionally been at the forefront of shale gas produc-

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tion, while production has been on the rise in other states such as Pennsylvania, Arkansas, Wyoming, and Oklahoma.

As a consequence, wellhead prices of natural gas in the United States have plummeted since July 2008, and the EIA expects them to remain below $5 per thousand cubic feet for at least another decade. The US Department of Energy recently announced that the share of natural gas in electricity production has risen during the past five years. The share of coal, on the contrary, has declined and is projected to be 825 million short tons in 2012, marking the fourth consecutive year that coal consumption for electricity generation will be below 1 billion short tons. While the EIA predicts an increase in coal consumption for electricity generation of 6 percent for 2013, due to an expected increase in prices of natural gas, shale gas will nonetheless save US households roughly $1,000 per year up to 2015, according to IHS Global Insight.

Cheap natural gas is also a stimulus for specific types of industrial activity. Abundant production of natural gas increases the production of natural gas-associated liquids such as ethane and propane, which in turn are used as input in petrochemical industries such as plastics. While natural gas is cheap, its by-products are as well, relative to petroleum-derived equivalents, making them cost-effective substitutes. Based on these developments, several chemical companies have announced expansion plans in the United States. These developments have motivated European multinational companies to lobby for development of European shale gas reserves, for competition with US counterparts has become exceedingly difficult.

Next to impacts on the US market for natural gas, effects on the ground are worth mentioning, for they are often an important argument for embracing the new technology. Shale gas extraction in states such as Pennsylvania and Texas has made once forgotten towns and villages blossom again: new roads have been constructed to facilitate intensive truck usage for water transportation, new hotels are being built to accommodate the workforce, and local businesses have witnessed growth in their turnover. Clearly, some of these benefits are undisputed, but empirical evidence for increases in local wealth has not been strong, among other reasons because the workforce only partly consists of locals who are working next to a highly specialized workforce often travelling from states with a long hydrocarbon history such as Texas, Louisiana, and Oklahoma. Recent academic contributions suggest that forecasts on jobs created by developing the Fayetteville and Marcellus shale gas formations may have been too optimistic.

Low prices of natural gas are not a blessing for everybody. To give an example, current low wellhead prices are reported to have dramatically slowed investments in drilling activities because companies are currently losing money on their investments. It has fuelled a lengthy debate about whether or not the United States should export some of its abundant natural gas in order to restore the balance between supply and demand. So far, only one company has been granted unrestricted permission to export, while seven others have been put on hold. Opponents of natural gas exports argue that US gas should be exclusive for domestic consumption in order to safeguard what is widely called “energy security.” Still, it is difficult to imagine that the United States will ban exports indefinitely.

Overall, the primary regulatory authority for shale gas is at the state level. One area in which federal regulation has been adopted is air quality. In April 2012 the federal Environmental Protection Agency (EPA) used its authority under the Clean Air Act to regulate emissions from drilling activity. From 2015 onward, gas producers have to abide to federal rules for natural gas wells that are hydraulically fractured. These rules demand that these companies apply what have been called “reduced emissions completions,” for example the application of capture technology to avoid having damaging gases such as volatile organic

compounds or methane come into the air. But many other contentious issues remain unresolved, for example the disclosure of chemicals being used in the hydraulic fracturing process, drinking water protection (with long-term studies on causal relations between fracking and drinking water contamination pending), and wastewater treatment.

Shale gas extraction is therefore not embraced in all parts of the United States. New York sits atop the most promising shale gas play of the country (Marcellus shale) together with Pennsylvania and Ohio. Unlike its neighbors, New York has been reluctant to extract any natural gas to date and is not expected to concede any time soon. Further to the east, Vermont has legally banned shale gas extraction from under its soils.

Impacts on global markets

Outside North America, no shale gas is being commercially extracted as of writing. According to the EIA, large reserves can be found around the world, most notably in China, Argentina, South Africa, and parts of Europe. While these estimates suggest that China could be the world's largest shale gas producer – with a potential of 1,275 trillion cubic feet (compared to 862 tcf in the United States in this same assessment) – it remains to be seen whether geological conditions in fact allow for a business case that validates extraction. It is impossible to tell how much of the natural gas reserves that are trapped in shale rock layers worldwide can in fact be commercially extracted. In addition, many questions remain regarding sufficient water availability, necessary infrastructure expansion, correspondence with regulations, and so on. And then, of course, unanticipated events can disrupt things, as we saw with the disaster at Fukushima and its impact on what was proclaimed by some to be a "nuclear Renaissance."

Dramatically increased domestic US production has turned the world's largest consumer of natural gas into a potential exporter. But it remains to be seen what impacts possible future US shale gas exports will have on international gas markets. Although current record low prices in the United States would suggest that this natural gas would be competitive on global markets, this is not necessarily the case. Unlike oil, natural gas is not traded on a global market, but rather regionally, although liquefied natural gas (LNG) is slowly changing that traditional picture.

In Europe, price competition will determine whether US natural gas can compete with traditional pipeline gas from countries such as Russia, Norway, and LNG from, for instance, Qatar. Some studies suggest that US-produced shale gas will in fact prove to be too expensive for this competition.

So far, the effects of US shale gas production have exclusively been indirect. Thus, LNG that was designated for the United States has since found its way to other markets, most notably European and Asian ones. In Europe, this has led to partial renegotiations of long-term contracts with, for instance, Russian Gazprom, for the difference between spot-market prices of natural gas and prices in long-term contracts had grown so large that big consumers insisted on revising existing contracts. As such, the interdependence between Russia and the EU in terms of natural gas is expected to change. It is no secret that the Russians are not excited about large-scale shale gas extraction, given their currently dominant market position and the threat from shale gas in the form of increased competition. Yet, the end of Russian dominance in European gas supplies, as predicted by some, is neither likely nor desirable. It is unlikely because it remains to be seen whether large-scale shale gas extraction will take place in Europe, and furthermore whether shale gas extracted in other parts of the world is mostly consumed there or not. It is a safe bet that the majority of European gas will be imported and that prices will dictate that a substantial part of this gas will come from Russia. The

end of Russian prominence in the energy sphere would be undesirable because, currently, more than half of its state income is generated from exports of natural gas and oil. Abrupt shifts in this pattern could have substantial domestic repercussions.

Environmental considerations

The environmental concerns most often cited are: 1) the carbon footprint of shale gas, especially during the production process; 2) anthropogenic seismicity; 3) water consumption and contamination; and 4) land use and landscape issues. What has been most concerning in North America is the fact that regulators and academic researchers were caught off guard by the shale gas revolution and have been playing catch-up since. It is not surprising that European regulatory and academic communities stand to learn from the North American experience. Indeed, this exchange is already well underway.

When extracting natural gas from the ground and moving it, some gas inevitably leaks into subsurface spaces or into the atmosphere. There have been widely publicized instances in the United States of fugitive methane contaminating groundwater in production areas and subsequently finding its way into households via domestic water wells. But it is often difficult to link methane in households to shale gas production because methane is long known to penetrate wells naturally through processes of subsurface migration. Another concern is the impact of fugitive methane emissions on the climate. While touting the United States' reduced carbon dioxide emissions as a result of increased fuel-switching to natural gas from coal, proponents of shale gas often neglect to point out that methane is 20 times more potent in terms of its global warming potential than CO_2 (albeit with a much shorter half-life in the atmosphere).

The unknowns of the implications of the shale gas boom on the climate have to do with unreliable measurements of how much gas is actually leaked during the life-cycle – from the wellhead, through the pipeline, up to the combustion chamber – and how this compares to leakage rates from conventionally produced gas. It is also still hotly debated to what extent cheap gas is replacing coal, with its higher carbon footprint, as a fuel source, or whether it merely stimulates additional consumption. Though IEA chief economist Fatih Birol announced last spring that carbon emissions in the United States had dropped by 450 million tons over the last half decade – due to, among other things, shale gas extraction and its application in electricity generation – the IEA also predicts that, in the longer run, large-scale shale gas extraction and usage will only have a marginal net effect on greenhouse gas emissions.

Puncturing the surface of the earth and pumping liquids under pressure thousands of meters deep carries the risk of inducing seismic activity (anthropogenic seismicity). It is worth noting that much of what is understood about induced seismicity comes from a renewable energy technology: geothermal. In the case of shale gas, mostly the re-injection of wastewater for disposal has been linked to seismic activity, though typically at levels imperceptible to humans. Since anything from mining to reservoir impoundment has been associated with seismic activity, the key policy consideration here will likely be the proximity of fracking operations to human populations, military installations, or sensitive habitats.

The most pressing environmental concern, especially for those local communities where wells would be located, is the potential surface and groundwater contamination. The most common method of hydraulic fracturing uses a cocktail of mostly water (4-6 million gallons) mixed with sand and chemicals pumped under high pressure into the well to release the methane trapped in the shale layer. Normally, this mixture only leaves the dedicated pipe in the shale layer itself, separated by hundreds of meters of impermeable rock from groundwater. The mixture is re-captured at

the surface and either recycled or treated and disposed of. But if the well casing is improperly sealed with concrete, as it sometimes is, then the fluid can leak. There have also been numerous instances of fracking fluids being spilled at the well site. The EPA is currently conducting a large-scale study of groundwater in regions where fracking operations are underway. The report is scheduled to be released in 2014, with preliminary results being made available in late 2012.

As with any mining activity, shale gas development impacts landscapes. Well pads are unsightly, and during the development stage, loud. Pipelines must be built to carry the gas to markets, and separate facilities for dehydrating and pumping gas must be constructed. Local roads are burdened with additional traffic, including heavy trucks carrying drilling equipment, fracking fluids, etc. The local reception to such activities is undoubtedly different in rural Texas or Alberta (both with long traditions of hydrocarbon development) than in more densely populated areas of the northeastern United States or, potentially, parts of Europe.

Prospects for the European Union

It is too early to tell whether domestic European shale gas production will take off and – if it does – whether this gas can compete with cheap Russian, Norwegian, Algerian, and Dutch gas, which is abundantly available on the market. However, significant shale gas reserves have been reported in the European Union, most notably in Poland, France, and Norway (with estimated and also questioned reserves of 187, 180, and 83 trillion cubic feet). Yet, given the absence of experience with shale gas extraction in most parts of the world, and given the number of affiliated uncertainties, reserve estimates should be treated with considerable caution. To illustrate this, in spring 2012 the Polish Geological Service published a study in which it lowered its earlier estimates of recoverable reserves that had been published by the EIA a year before. Instead of several centuries of natural gas at current consumption rates (the EIA estimate was 5.3 trillion cubic meters), Poland would "only" possess a handful of decades of natural gas consumption (around 0.5 trillion cubic meters). In contrast to the United States, actual shale gas extraction in Europe is still in the embryonic phase. A replication of the US shale gas revolution has been questioned, with reference to, for instance, less favorable geological conditions, lack of a well-developed onshore service industry, and the possible lack of public support due to the absence of local financial benefits.

In Poland, a handful of wells have been drilled. Companies are currently examining cores to establish the quality of gas and calculate at what costs it can eventually be extracted. So far the results have been mixed, with Exxon Mobil ending its exploratory operations in Poland in June 2012 after two of its exploratory wells generated disappointing results. Shale gas producers in the United Kingdom restarted their operations in spring 2012 after a year-long pause due to further research on human-induced seismic activity that was initiated following two small earthquakes of 1.5 and 2.3 on the Richter scale, which were directly linked to local hydraulic fracturing operations. Local gas company Cuadrilla implemented a "traffic light system" in order to monitor seismic activity near its exploratory wells in Lancashire. Countries like Germany and the Netherlands are awaiting further research, particularly on environmental concerns that have been linked to shale gas extraction, whereas France and Bulgaria have put outright bans on hydraulic fracturing. According to French officials, hydraulic fracturing brings too many uncertainties and, moreover, local benefits are too meager. Bulgarian authorities in January 2012 were so enthusiastic to put a ban on shale gas extraction that they made low-pressure hydraulic fracturing for conventional drilling impossible in the process, an unintended consequence that was rectified in June 2012. Czech Republic officials argued

in fall 2012 that their current regulatory framework is not geared to safeguard shale gas extraction in an environmentally viable fashion. They are therefore considering a ban on shale gas explorations until June 2014. The following section will turn to the case of Poland – the only country in the European Union where shale gas extraction is broadly embraced by policy makers and business elites alike, and the country where medium-term shale gas extraction is most likely to occur.

Poland: Following the US example?

The jury is out on whether shale gas will be produced in Poland. This is obvious, but easily forgotten in a country where euphoria has risen to great heights ever since the EIA first published information about extractable shale gas reserves in the country in the spring of 2011. Ever since, the Polish national natural gas company PGNiG and a handful of foreign companies have been active in establishing the certainty of these preliminary findings. So far, the results have been mixed, with several companies reporting that examination of selected cores from the subsurface of the earth has been very promising, whereas others (i.e., Exxon Mobil) have halted their activities after several wells generated disappointing results. Despite this news, Polish policy makers keep moving at full speed to have domestic natural gas flowing through their country.

There are several substantial hurdles to be overcome for commercial shale gas extraction to really kick off. First, there need to be convincing arguments for making the investment in shale gas – the most prominent of which is energy security and revenue generation through levies. Needless to say, that goes for governments worldwide, yet timing and communication of proper arguments in these matters are crucial. Moreover, it is not quite clear whether the argument of energy security really holds, as Russia has been a reliable supplier of both natural gas and oil to Poland in the last four decades. Finally, the argument that Polish consumers pay "too much" for their natural gas, as has often been claimed, appears to be false. According to EC data from late 2011, Polish households pay €0.0552 per kWh for their natural gas, which is less than what consumers pay in Austria, Belgium, Denmark, France, Germany, Hungary, Ireland, Italy, Netherlands, Portugal, Slovenia, Spain, and Sweden. If we examine charges for natural gas that industrial users have to pay out per kWh and we focus on certain parts of Central and Eastern Europe, we find that industries in Slovenia, Slovakia, Czech Republic, Germany, and Hungary in fact pay higher charges than their Polish counterparts do.

On a more practical but rather crucial note, Poland must still make substantial investments in infrastructure in order to prepare its gas market for substantially more natural gas. With only 15 percent of its primary energy resources consisting of natural gas (the rest being domestic coal and imported oil), it is no surprise that Polish energy infrastructure is not geared toward large-scale usage of natural gas. To give some examples, about half of the Polish households are not connected to gas distribution networks, while the bulk of gas transport systems are located in the southwest of the country and not in the north and east, where most of the potential shale gas reserves are located. Interconnection facilities with neighboring countries are not impressive regarding their capacities and they are not always two-directional. Inspired by shale gas euphoria, the Polish national transmission system operator, GazSystem, admittedly has been investing to reconstruct Poland into a gas country. Typically, "Brussels" is often engaged to co-fund these operations. The existing interconnector with Germany in Lasów was upgraded to a maximum capacity of 1.5 billion cubic meters (bcm) starting in January 2012. To the south an interconnector was launched in September 2011 on the border with the Czech Republic at Cieszyn with a capacity of 0.5 bcm, albeit not two-directional at this

moment. Next to these projects, interconnectors with Lithuania and Slovakia are under study, as is the so-called Baltic pipeline, which would link Poland with Denmark. Ironically, the Danish have an interest because they would like to be connected to Russian gas, whereas the Polish want to diversify away from Russia and have more direct access to Norwegian gas. On top of these investments, Poland is also constructing an LNG plant with a capacity of 5 bcm on its northern shores at Świnoujście. Currently, no analysis is available about what investments are needed to make large-scale domestic consumption of natural gas possible. But it is safe to assume that the Polish grid operator will be occupied for most of this decade facilitating large-scale shale gas extraction, albeit for exports or domestic consumption.

Outlook: Uncertainties and risks

The bottom line is this: shale gas is neither panacea nor cataclysm. It is a hydrocarbon fuel source, extracted by companies seeking to earn profits and using technologies that have advanced in recent years but are certainly not new. It has become a political hot button because of its perceived – often overstated – impacts on markets, ecology, and energy security. The shale gas revolution is a symptom of where we are in the carbon economy. The petroleum and natural gas that each of us consumes – every minute of every day in various ways – must be extracted using increasingly complex technological systems involving ever more intricate, deep-water/deep-earth punctures. This is what one would expect at the beginning of the endgame of the carbon economy. Each hydrocarbon molecule is harder to coax out of the ground than the last, and only technological prowess and innovation sustain the ravenous appetite for fuels our societies have in North America, Europe, Oceania, and increasingly Asia, Africa, and Latin America. As the recently deceased American ecologist and activist Barry Commoner so succinctly put it 40 years ago, there is no free lunch when exploiting natural endowments – and that applies to shale gas, too.

Shale gas is often referred to as an "unconventional" fuel source, in contrast to the conventional natural gas collected in underground pools that humans have been tapping with relative ease for at least a hundred years. But "unconventional" could also be used to describe the policy approach that this development requires. It is being developed in many places that lack experience with oil and gas extraction, and in the case of Poland, in a place that is now subject to the European Union's mediating role in regulating the development. It uses technologies and approaches that entail more environmental concerns than conventional gas extraction. And it has the potential to upend the conventional arithmetic of interdependencies between Europe and Russia, with both positive and negative potential consequences.

There are a number of legitimate concerns and uncertainties that have been linked to shale gas extraction. While some of these uncertainties are clearly out of our sphere of influence, most notably geological realities, for others it is worth examining what developments have taken place so far in the United States, which functions as an environmental and policy laboratory for shale gas extraction. The most pressing issues in the United States are currently twofold: how to effectively regulate legitimate environmental concerns that have been linked to shale gas extraction, and how to create a market structure that is geared toward the long-term, stable supply of this carbon resource, without having detrimental effects on renewable energy policies throughout the country.

Regarding the first issue, the track record of the United States has not been impressive. While most federal initiatives on environmental regulations have so far failed or are awaiting longer-term research (in the case of water contamination), results on the state level are also mixed. To date, the obligatory disclosure of both the quality

and quantity of chemicals used in hydraulic fracturing operations has been rare. The only area in which federal rules have been accepted is air quality, with regulations requiring gas companies to apply so-called "green completion" technologies during operations in order to minimize methane emissions. These regulations only take effect in 2015, and until then companies are required to minimally flare (burn) emissions instead of venting them (letting them escape into the atmosphere).

Regarding the second issue, the United States is currently struggling with the enormous amount of natural gas that is being produced. While most end-consumers and some manufacturing and chemical industries currently appear to be reaping the benefits of this development, it remains to be seen whether current market structures will be favorable in the medium term, for the difference between demand and supply is just too large. One of the decisions to be made is whether large-scale and unrestricted exports of natural gas can be allowed. This has led to an emotional debate about energy security, independence, and a possible rise in costs for US citizens and companies. Another related issue that US policy makers face is how to safeguard the transition to a low-carbon economy, since at the moment cheap natural gas is pushing all alternatives out of the market, including renewable energy.

Furthermore – and here international collaboration is required – it seems that the local reduction of carbon emissions that has been linked to US shale gas production is displacing the problem of these emissions instead of solving it. While coal consumption for electricity generation in the United States has been in decline in favor of gas-fired power generation, the United States is still producing enormous amounts of coal. As a consequence, this coal is sold on alternative markets and has resulted in higher shares of coal-fired electricity in Western Europe for a number of years now. Furthermore, there are reports of enormous investments being made in the western United States to facilitate large-scale coal transport and shipment to Asian markets. As such, the net positive effects of shale gas extraction that have been quoted can and should be questioned, without additional global carbon policies in place.

This revolution will continue to impact the global natural gas landscape, but precisely where and how it will play out depends as much on the policy decisions taken in places such as Poland and the EU, China, and elsewhere as it does on geological realities.

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