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Shale Gas: Present Status and Expectations

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Questions have been asked about if and how policy-makers should respond to the opportunities and challenges posed by unconventional gas in general, and shale gas in particular. There are still divergent views about the role of natural gas, but there is a growing consensus that natural gas will play a central role in meeting energy demand to 2035. The 'golden age of gas' would be unthinkable were it not for liquefied natural gas (LNG). Although there is still some uncertainty regarding the size and economics of shale gas, there has been ample evidence that increased shale gas production in the US is changing the characteristics of global gas markets. It remains to be seen how far the shale gas revolution will spread globally. China is well placed to become the top producer outside the US, although some significant production will also take place in most other regions. Significant shale gas production has the potential to lower natural gas prices. Changes in global gas markets will have a fundamental impact on geopolitics and international security.

The goal of this paper is to examine recent trends in terms of the North American shale revolution, and chart its potential global implications. It begins by detailing the state of US natural gas and oil production, and goes on to examine countries with major shale gas reserves – with particular emphasis on China – before discussing the impact of, and future expectations for, the US shale revolution.

The US Shale Revolution: Present Status

The US natural gas industry has oscillated between supply concerns and supply optimism. For the past few years, the natural gas sector in the US has swung back to euphoria. Many recent articles have indicated that although the prospects for shale gas production in the US are bright, there is still some uncertainty regarding the size and economics of shale gas. The US shale gas industry is still in its formative stage. There are major questions still to be answered about the extent of the resource base, as well as the ability of the industry to develop it economically and safely. It also remains to be seen how the social and environmental debate will play out in different parts of the US.

J. David Hughes, geoscientist and author of *Drill, Baby, Drill: Can Unconventional Fuels Usher in a New Era of Energy Abundance?* has explained why shale production is not sustainable, while according to Deborah Rogers – financial consultant, founder of the Energy Policy Forum and author of *Shale and Wall Street: Was the Decline in Natural Gas Prices Orchestrated*, US shale gas and oil reserves have been overestimated by a minimum of 100 percent and a maximum of 500 percent. She concludes,

> … the recent natural gas market glut was largely effected through overproduction of natural gas in order to meet financial analyst's production targets and to provide cash flow to support operators' imprudent leverage positions.[1]

In her report, Rogers notes,

> … shale must be examined thoroughly and independently to assess the true value of shale assets, particularly since policy on both the state and national level is being implemented based on production projections that are overly optimistic (and thereby unrealistic) and wells that are significantly underperforming original projections.[2]

Similarly, Arthur Berman states that "despite operator claims of increasing efficiency, more wells are required to replace the same gas volume every year."[3] Essentially, he argues that the field is showing signs of depletion and that unsustainable capital expenditures will limit the capability to deliver on supply. He also states that shale oil wells are following the same steep decline rates and poor recovery efficiency observed in shale gas wells. In 2001, the annual decline rate for US natural gas production was 23%. He further notes,

> In 2012 annual decline rate was 32%. In 2001, when decline rates were 23% per year, 12 Bcf/d annual replacement was required to offset consumption of 54 Bcf/d. In 2012, 22 Bcf/d annual replacement was necessary to offset 65 Bcf/d consumption.[4]

At the time of writing there are growing expectations that potential barriers to further shale gas production in the US will be largely overcome and increased supplies will become available. US shale gas production has continued to grow, and domestic natural gas seems abundant. Total recoverable shale gas resources in the US are estimated at 20 tcm (trillion cubic meters). US production of natural gas increased 25 percent from 2000 to 2012.[5] US dry natural gas production will increase from 23.0 tcf in 2011 to 33.1 tcf in 2040.[6] The Energy

Information Administration (EIA) projects that it will account for 46 percent of United States gas supply by 2035.[7] Shale gas production is projected to grow from 7.9 tcf in 2011 to 16.7 tcf in 2040.[8]

According to the EIA, domestic production of dry natural gas reached an all-time high of over 65 billion cubic feet per day (bcfd) in July 2012.[9] Total domestic gas production in September 2013 was 82.16 bcfd. In the forecasts for 2015, the EIA predicted in January 2014 that US natural gas output in 2014 would increase on average by about 2.1 percent from 2013.

After incorporating tight gas and coal-bed methane (CBM), unconventional production accounted for nearly 60 percent of all production in 2010. The EIA expects this trend to continue at this fervent pace, with 50 percent of production coming from shale by 2035 and a total of 78 percent of production when accounting for other unconventional methods.

There has been some skepticism about the long-term productivity of shale gas wells. Most of the shale gas wells have been drilled in the past few years. US shale gas play breakeven prices have been a major discussion topic and source of disagreement among analysts and industry participants in recent years. While production costs of shale wells form a crucial determinant of the future trajectory of shale production, there is a notable absence of concrete per-well production costs in the public domain, as the range of production costs is so great. There are issues related to the rapid decline in the rates of initial flows, the low natural gas price environment, and slumping demand. US natural gas supply growth is outpacing demand growth, resulting in decade-low prices and peak inventory levels.[10] Since 2007, total supply increased by 25 percent while demand rose by only five percent.[11] One important result of the surge in natural gas production is that the natural gas price has plummeted. US natural gas prices plunged below $2 per 1 million British thermal units (mBtu) in April 2012.[12]

There have been numerous debates revolving around shale gas well economics and cost optimization. A recent report by the European Commission notes,

> It was therefore initially anticipated that depressed prices in the USA would ease indigenous production of gas, as the break-even extraction costs would no longer be covered by wellhead prices. However, contrary to this belief, the margins have improved as the technological learning curve has driven down per-well development costs. Moreover, gas producers' "sold production forward" on gas futures and the expectation of higher prices. This hedging strategy, propped up by a bullish forward price curve, helped to cushion producers from depressed gas prices in the second half of 2008.[13]

Liquid production from shale wells plays a key role in shale economics. Sustained growth in US shale gas production is explained by NGL (natural gas liquids) production. Regarding the impact of liquids on shale gas production costs, the European Commission report explains,

> An important issue to highlight when discussing shale gas production cots is the presence or absence of associated liquid hydrocarbons, in the form of natural gas liquids (NGLs) that need to be separated in a processing plant, such as butane, propane or ethane. Production and processing of such liquids can serve to lower per-unit production costs and raise the economic profitability of wells. Thus even if the proportion of total 'dry gas' production dwarfs total liquids production from a given shale well, the energy content and market price of the latter makes for a compelling business case to target liquid-rich shale plays. Moreover, there have been substantial recent additions to proved US 'wet' gas reserves – e.g. gas that includes lease condensates and natural gas plant liquids.[14]

So far, enhanced efficiencies have more than made up for initial depletion rates. Oil and gas companies have turned from dry gas production to the production of the liquids portion of shale gas formations [15] Associated gas production from liquids drilling could contribute 40–50 percent of new hydrocarbon production from liquids-producing wells.[16] Dry gas is produced as a by-product of development from still profitable liquids-rich shale plays. An average wet shale play in the US with 35 percent liquids content produces around 11,000 cubic feet of dry gas per barrel of natural gas liquid (NGL) produced.[17] Associated gas from liquids-rich shale plays is expected to triple from 2006 levels by 2020.

In 2012, Barnett natural gas production declined by 11.9 percent. Much of the more recent activity in the Barnett has been in the more liquids-rich portions of the play.[18] Liquids continue to comprise a larger portion of overall Eagle Ford production, growing from 27 percent in 2009, to 39 percent in 2010, 51 percent in 2011, 57 percent in 2012, and 61 percent through September of 2013.[19] Dry gas production in the Haynesville has since fallen by 23 percent to 5.6 bcfd in June 2013 from a peak of 7.3 bcfd in November 2011.[20] Marcellus production has grown rapidly in recent years, rising from less than 1.7 bcfd in January 2010 to 13 bcfd in December 2013, representing 14 percent of total US dry gas production in May 2013.[21]

Increased natural gas use for electric power generation is soaking up abundant natural gas. The extent to which the price of natural gas interacts with its supply and demand has been a subject of much speculation in the US. Over the long run, an increase in demand is likely to increase supply. US gas supplies will keep on rising, even in a relatively low price environment. Henry Hub closed 2012 without a single month averaging more than \$3.5/mBtu. Prices averaged \$3.73/mBtu for 2013 overall. Prices are now seen averaging about \$3.89/mBtu.[22] Most of growth in demand for gas in the US is expected to occur in the power generation sector. Industrial, residential and commercial sectors are considered mature markets with little growth prospects.[23] In the medium term, increased industrial activity and natural gas as a vehicle and shipping fuel will present itself as the primary outlet for natural gas. In particular, a significant penetration of NGVs (natural gas vehicles) as a result of favorable price differentials between natural gas and oil is expected.

In the European Commission report, authors argue that the surge in US shale gas production has also had impacts particularly on the US petrochemicals industry.

> As a result of this energy-intensive industry requiring a substantial amount of ethane and other natural gas liquids, its competitiveness is heavily dependent on the price of these liquids, as well as the price of competitive feedstocks more generally (such as propane, butane, and naphtha). In this context, increases in the ratio of the price of oil to the price of natural gas (from a low of 5.5:1 in 2003 to 15.9:1 in 2009) have been favorable for US exports of petrochemicals, plastics and other derivatives.[24]

Between 2015 and 2017, surging demand growth simultaneously in power, industry, and transportation should tighten the supply–demand balance. A new study by IHS CERA predicts that natural gas prices are likely to stay low for at least the next 20 years, with a long term annual average price of \$4–5 per mBtu.[25] IHS CERA expects the Henry Hub price of natural gas to remain in the \$4–5 per mBtu range as an annual average through 2035.[26]

Perhaps one of the most hotly debated issues is whether US LNG exports will become a reality and the impact on domestic prices of natural gas will hinder US LNG exports. Concerns about the effect of US LNG exports on the domestic price of natural gas began to mount in 2011 and 2012. Presently, numerous companies in the US and Canada are taking advantage of the arbitrage opportunity resulting from the current supply overhang of shale gas and the price differentials (“shale spreads”) between global gas markets. Exports represent an additional source of demand and might affect the domestic natural gas market in the US.

Various pricing studies have been conducted on the impact of US LNG exports. While there does not seem to be consensus on the exact price impact of US LNG exports, there does seem to be consensus that the US domestic price of natural gas will increase.

In January 2012, the EIA issued the first pricing impact study, which identified some potentially significant impacts. In the EIA study, 6 bcfd (46 mtpa) and 12 bcfd (90 mtpa) LNG export hurdles were used when identifying the effect on domestic US gas prices. The result was an assumed increase of $0.52/mBtu and $1.39/mBtu against the EIA reference case in the worst-case 6 and 12 bcfd scenarios, respectively.[27]

An independent assessment conducted by Deloitte MarketPoint LLC (DMP) found that any price increase resulting from US LNG exports would be minimal.[28]

Initially there was much skepticism about the prospects for US LNG exports. More recent studies have indicated a much brighter outlook owing to strong Asian demand and a widening of "shale spreads." Oil and gas companies have applied for new LNG export licenses with the US government in order to profit from the price disparity between the US and foreign natural gas prices.[29] Currently, the government is considering permit applications that total 20 bcfd, which if approved would make the US the largest natural gas exporter in the world. Currently approved US LNG projects add up to 65 mtpa:

> The US natural gas market has seen three non-free trade export approvals from the DoE in 2013, sending the total number of approved projects to four with a total export capacity of 6.37 bcfd.[30]

Table 4.1 Approved US LNG Projects

Project	Export Approval (Date)	Production Capacity	Start of Production
Sabine Pass	Approved (May 20, 2011)	17 MTPA	2015
Free Port	Approved (May 17, 2013)	10.8 MTPA	2018
Lake Charles	Approved (Aug. 7, 2013)	15.4 MTPA	2018
Cove Point	Approved (Sep. 11, 2013)	5.75 MTPA	2017
Freeport (Expansion)	Approved (Nov. 15, 2013)	3.1 MTPA	2019
Cameron	Approved (Feb. 11, 2014)	12.0 MTPA	2017
Total Applications		**274 MTPA**	

Source: Takayuki Sumita, "Challenges and LNG Policy in Japan," Paper presented at North East Asia Gas Pricing Gathering, March 23, 2014, Seoul, Korea.

How important a role could US shale gas play in providing Asia and Europe with gas, compared to Australian, Middle Eastern, East African, and Russian conventional gas? America will be an LNG export competitor with Qatar, Australia, Mozambique and Russia. The key growth market is Asia. Natural gas trade in Asia is in the form of LNG. Supplies to Asia will be under lucrative oil-indexed contracts. Russia and the Middle East retain the largest conventional natural gas reserves. Russia in particular possesses a vast potential for expanding and developing its conventional reserves. Qatar is becoming a crucial swing player feeding European and Asian markets. Qatar's strategy is to keep feeding European spot markets as a transitional step towards far higher markets in Asia. The future penetration of US LNG into Asia and Europe will depend on regional differences in conventional gas production and export terminal project costs. Ernst & Young suggests that projects at the high end of the supply curve – namely, many of the Australian projects – will become increasingly vulnerable.[31]

How much LNG can the US look to place into Asian markets over the next decade? As argued in the IHS CERA study mentioned above, natural gas prices in the US are likely to stay low for at least the next 20 years, with a long term annual average price of \$4–5 per mBtu. The cost of transportation varies widely. The International Gas Union suggests that North American LNG from the Gulf coast, priced at \$4–6 mBtu at Henry Hub, would be very competitive at between \$10 and \$12.9 delivered to Asia.[32] Similarly, as argued by Edward Morse et al., with liquefaction costs of about \$2.25/mBtu, a fuel surcharge to fund liquefaction of about 15 percent of the underlying gas price in the \$4–6/mBtu range, and transport costs of about \$1–1.5/mBtu, breakeven economics require a price of \$7.85 or higher for deliveries to Europe; therefore, with transport costs more than \$2 higher to Asia, the delivered breakeven for Asia is \$10.10 on a \$4 US gas price.[33]

Shale Developments outside the US

Shale gas is relatively evenly distributed around the world. The majority of regions will likely witness at least some level of production in the future. Governments around the world are in the process of assessing their own shale gas reserves to determine whether they can replicate the success of the US in their own country. The recent increase in unconventional gas production in the US has been underpinned by market forces as well as technological advancements. Can the US "shale gas revolution" spill over to other countries? China is well placed to become the top producer outside the US, although some significant production may also take place in most other regions. However, in most states, developing these shale resources could take time. No single region or country will produce enough shale gas to move from being a net importer to a net exporter. An independent assessment conducted by the Joint Research Center of the European Commission found that:

> The USA captures the lion's share of unconventional gas production in 2020 by producing 70% of the world's total. However, over time the US share declines to 30% as new entrants slowly enter the unconventional gas-producing market. In particular, East Asian markets see a surge in shale gas production after 2020 such that within 20 years these countries provide 28% of the global unconventional gas supply (with China alone producing three quarters of this figure). Other regions witness more moderate but steady growth: significant production takes place in Central/South America (9%), in Europe (8%), in Africa (7%) and in Canada (6%) in 2040.[34]

There is great uncertainty in unconventional gas resource estimates for the rest of the world. Even the estimates of unconventional gas resources in the US remain very uncertain. There is limited geological information available for a number of regions and countries anticipated to hold shale gas. The exclusion of shale resources in some regions such as Russia and the Middle East is justified because they are unlikely to be economically recoverable. Very few estimates are available of the recoverable resource of shale gas within Europe. Global estimates do not use the same definitions and are based on a number of different methodologies and assumptions.[35]

It is worth exploring the key factors that led to the shale revolution in the US and how these factors may influence a shale revolution in China and Europe. The shale revolution is more than just the result of applying the dual techniques of hydraulic fracturing and horizontal drilling. The US shale revolution is the product of a mature oil and gas drilling industry, replete with robust supply chains. The boom depended on a unique set of mineral rights that provided landowners with a financial incentive to invite drillers on to their land, on a deep pool of capital, and on a variety of small wildcatting firms willing to take on the risk of drilling exploratory wells. Property rights, mismatches between resource holder and landowner incentives, infrastructure, access to service capacity, geology, and access to capital are all issues that must be overcome outside the US. Geological infrastructure, regulatory and environmental factors are also at play.

China

China's recent push for domestic shale exploitation is driven by energy security concerns. Without timely development of shale gas, China could be facing a future in which more than 50 percent of its gas consumption would have to be met by imports:

> Self-sufficient in gas as recently as 2006, China now imports 25 percent of its total gas consumption, which will rise to 35 percent by 2015 and 50 percent by 2020 if the national consumption targets are met but shale production targets are not met.[36]

Without shale production, China could be 50 percent dependent on imported gas by 2020.[37] Import dependency could decline to 20–30 percent if shale "succeeds."[38] Gas costs drive the focus on shale,[39] and imported gas cost pressures have been becoming increasingly onerous.[40] Ultimately, domestic shale should be far cheaper than LNG.[41]

China has considerable shale resources on paper. The EIA estimates China holds the world's largest shale gas reserves at 31.6 tcm (1,275 tcf) of technically recoverable reserves. Although China's Ministry of Land and Resources declares a more conservative estimate of 25 tcm, both assessments are higher than the 24.4 tcm (862 tcf) of shale gas reserves estimated for the US (the second largest). The Sichuan and Tarim basins are deemed to be the most prospective at this point, with deposits also in the Ordos, Junggar, Tuha and Bohai basins.

Global natural gas consumption in 2011 was about 110 tcf. Global reserve estimates have increased in the last 30 years from about 3,000 tcf to 8,000 tcf of natural gas, mostly located in Russia, Iran, Qatar, and Turkmenistan. In 2011 China produced 3.6 tcf and consumed 4.6 tcf of natural gas, which is a relatively small (about 5 percent) share of its total energy use. China's natural gas production volumes are still quite far off those of the bigger producers like the US (23 tcf of dry natural gas production per year) or Russia (21.4 tcf per year in 2011).[42] Before shale gas received such significant attention, China had planned for a substantial increase in natural gas imports both via LNG and pipelines from Turkmenistan and Russia.[43]

The dramatic change in the energy fortunes of the US is also beginning to reshape those of China. It has generated enormous interest in China as to whether the US shale revolution can be replicated.[44] China is still at the beginning of the learning curve – and at an early stage in terms of technology – and must find a commercial pathway to shale production under different geological challenges to those North America faces. The question is whether China can "crack the shale code" and, if so, how quickly it can ramp up production. China has set ambitious production targets for the end of the decade: 6.5 bcm by 2015, 60–100 bcm by 2020. The current 12th five-year plan is primarily dedicated to China accelerating through the exploration and appraisal phase for domestic shale gas production, with the hope that this preparation translates into an aggressive production ramp-up in the 2016–2020 plan period.[45]

> The US recorded a very pedestrian rate of shale production growth during 2000–2005, but it accelerated in both percentage and absolute production growth terms in and after 2006, going from 15 bcm in 2005 to 31 bcm in 2006 (+107 percent year-on-year), then adding 40–50 percent annually thereafter.[46]

According to Credit Suisse,

> … if we make a series of well production assumptions and assume China "inflects" in 2016 and follows the US production growth trajectory (2006 forward), it would hit 56 bcm in 2020 and 110 bcm by 2022.[47]

TABLE 4.2 HERE

However, 2023 is a more realistic target for reaching 60 bcm. If we take 2018 as the inflection point, China would hit 60 bcm in 2023 and 100 bcm in 2025.[48] At the current pace, the 6.5 bcm target for 2015 looks challenging. Many industry insiders say that this will be hard to achieve. "As we are facing enormous cost pressures and other problems, the speed of exploration has been slower than anticipated," Zhang Dawei, director of the Mineral Resources and Reserves Evaluation Center of the Ministry of Land Resources (MLR) said at a symposium in June 2013.[49]

China has taken a two-pronged approach so far: "trial" blocks and open bidding. China has segregated the blocks targeting shale production, with the Chinese supermajors working blocks in conjunction with foreign majors on a "trial" basis.[50] There have been multiple "trial" initiatives between Chinese and foreign entities.[51]

The MLR offered four shale gas blocks in 2011 to six qualified bidders, of which two were eventually taken up—one by Sinopec (Nanchuan block) and the other by Henan Provincial Coal Gas Development & Utilisation Co. (Henan CBM, the Xuishan block); both blocks are in Chongqing.[52] On September 10, 2012, the MLR set the date for China's second shale gas block auction on October 25, 2012. Participants would bid for 20 blocks in eight provinces and municipalities, with a total area of 20,002 km.[53] "On October 25, the MLR announced that it received 152 bids from 83 pre-qualified companies for 20 blocks, and that 19 of the 20 blocks received at least the minimum of three bids required for the award to go forward."[54]

In the first half of 2013 "… 56 shale gas wells were in the exploratory phase in the country, but only 24 were producing gas."[55] However,

> Only six wells … had a daily output capacity of 10,000 cubic meters or more, and all the shale gas blocks sold in the most

> recent round of auctioning were in the early phases of prospecting—meaning they had not produced a drop.[56]

Several different factors have combined to support the recent US shale boom, namely:

> … favorable geological conditions, (access to) infrastructure, substantial public support (amongst others spurred by attractive mineral rights legislation), available service industry, broad political support, a large market, and a favorable fiscal climate.[57]

Small and mid-sized companies – not traditional oil and gas powers – account for over 80 percent of US shale gas production.[58] From the very beginning in the United States, it was small companies that had a handle on the technology because their investment-recouping models were different. In 2005, 23 companies were developing shale gas projects in the United States. Two years later this number jumped to 64. In the face of high cost pressures, small and medium-sized companies are quick to upgrade technology.[59]

Several factors stand in the way of shale development. Most of China's shale deposits lie in the earthquake-prone and mountainous southwest or the remote arid deserts of the far west.[60] The gas deposits are also deep—often 4 kilometers (or 13,000 feet) below the surface, compared with 2–4 kilometers in the United States.[61] According to the EIA, the first horizontal shale well drilled by PetroChina, the Chinese oil and gas firm that has been exploring shale most aggressively, took 11 months to drill compared with the usual two weeks in North America.[62] The most likely region to see early shale gas success is the Sichuan basin in southwest China. Flow rates on test wells in the Changning block being explored by PetroChina reached 150,000 cubic meters (or 5.3 million cubic feet) per day in June, 2013. Unlike the deserts where much of China's shale deposits are located, the Sichuan basin has ample supplies of the water required by the hydraulic fracturing process.[63]

There are also several above-ground challenges to the rapid development of China's shale resources, the most formidable of which is the structure of China's oil industry.

> The shale revolution in the United States was launched by a large number of small independent operators driven by a desire to strike it rich. In contrast, China's onshore oil industry is dominated by two state-owned behemoths, CNPC and Sinopec, which are motivated by factors other than greed.[64] In addition, CNPC, which has exposure to some of the country's most promising shale gas resources, has other priorities in the short-term. The company is more interested in producing its

> large domestic conventional natural gas reserves and marketing expensive pipeline and LNG imports.[65]

According to Credit Suisse's estimates, China needs to drill 6,800 wells by 2020 to get to the bottom end of the NDRC production target.[66] To reach the NDRC's 6.5 bcm target by 2015, it is estimated that 410 wells will need to be drilled. China needs 10,000 wells by 2020 to achieve the 100 bcm production target.[67] A horizontal well in the US can cost in the range of US $5–10 million.[68] The first few horizontal wells drilled in China cost two to three times those in the US. Currently, a single horizontal well can cost around $15 million in China. Current drilling costs in China are also high, but are expected to come down with higher economies of scale.[69]

> China is "rig rich" but will still need considerable additional rigs to reach its shale production target.[70] China has around 1,500 land rigs on the ground. However, hardly any of them are tailored for shale gas drilling.[71] Honghua last year sold three land rigs to Shell's JV in China with shale drilling specifications.[72]

China needs 280 additional rigs in Credit Suisse's base-case scenario for producing 60 bcm by 2020.

Europe

Europe is highly import-dependent for natural gas. The EU currently brings in well over half of the energy it consumes. While the continent itself is only in the earliest stages of exploration for shale gas, the focus on unconventional gas has been intense. According to the IEA, Europe has over 620 tcf of recoverable shale gas reserves, with France and Poland possessing over 60 percent of those reserves.

The US has effectively utilized its unique combination of resources, private property rights, pre-existing network of pipelines, abundant financial tools, and entrepreneurialism to spike shale production. The comparison of these key factors in Europe highlights a number of challenges for a European shale revolution. Europe is not going to "see a revolution, but more of a bumpy evolution."[73] Part of the opposition has been driven by Europe's belief that the real solution to the region's energy needs should come from renewable energy. The European Union aims to derive 20 percent of its energy from renewables by 2020 and governments have been spending billions of dollars on supporting wind and solar power. The biggest downside to the abundance of shale gas is the impact on renewable energy.

The most significant factor behind US success is the fact that it has a fully liberalized market for natural gas. The failure of market reforms in the natural gas sector and the cost of moving gas long distances combine to explain why a US-style shale revolution cannot be replicated outside the US. In the 1990s the US deregulated its natural gas by dismantling long-term contracts and separating the trading of gas from the more monopolistic business of transportation. [74] Major infrastructure investments were made, intended to bring natural gas to market. A case in point is the rapid growth in gas-fired power plants during the 1990s. A liberalized and competitive market formed an important regulatory backdrop to the unconventional gas revolution in the US. Reforms to the EU's internal gas market and electric market have been slow. Some strong laws requiring market competition passed, but recent developments indicate that EU market liberalization and a single energy market is far from complete. In the US case, what prompted the technological advancements was the expectation that US domestic supplies would run short, which led inexorably to all new projects.

Unlike in the US, shale gas in Europe is very unlikely to become an important source of energy due to differences in legal frameworks.[75] A key to the regulatory framework is how to manage multiple landowners and their claims. U.S. residents earn royalties from the shale gas extracted from beneath their homes. US landowners own both surface and mineral rights. In Europe, because any underground mineral rights belong to the government, landowners have no incentive to support shale gas development.

In Europe, the geology is also less favorable, notably with the shale containing a higher clay content making it more difficult to use hydraulic fracturing. Unlike in North America, shale gas in Europe is located in densely populated areas where active drilling and hydraulic fracturing would not be practical;[76]

> The only correspondence with the U.S. is that there is a large market. Test drilling operations in Sweden and Poland have shown that the geological conditions in those parts of Europe are not as favorable as those in parts of the U.S.[77]

In Europe, the public debate is almost exclusively about the environmental concerns.

> In Germany, the Netherlands and the Czech Republic, the public has demanded that their administrations conduct further studies, while in France, Bulgaria and Spain, there have been calls for a ban on the currently preferred technology. In the United Kingdom, Lithuania and Romania, governments have cautiously moved ahead.[78]

In the UK, Prime Minister David Cameron made a spirited call for shale development, but public opposition appeared robust, with a well reported anti-fracking protest in the south of England. Poland will become a large producer of shale gas as production has full governmental support. Poland is heavily dependent on Russia (Gazprom supplies 11 bcm out of 15 bcm of Polish consumption) and is therefore keen to diversify supply.[79] By 2017–18 Poland should be in a position to significantly reduce offtake from Gazprom, but will not be able to reach self-sufficiency until after the end of this decade.[80] There are obviously infrastructure challenges, expanding existing pipelines to production areas.[81] Ukraine also has some of the richest deposits of shale gas in Europe but is currently at earlier stages of unconventional gas development. Given full governmental support, Ukraine could produce up to 10 bcm of gas from shale and coal-bed methane by 2017.[82]

The alternative of large-scale exploration for shale will probably receive renewed impetus due to the Ukrainian crisis, and we can expect it to resume in Ukraine as soon as conditions permit. But Germany has forsaken nuclear energy, thereby adding to its dependence on imported (i.e. Russian) gas, and France has renounced shale. There are reportedly large shale deposits in Eastern Europe but considerable political pressure –funded at least in part by Moscow – to prevent governments from exploring them.[83] The new crisis over Crimea may rekindle European interest in shale gas and oil and weaken that opposition. Nevertheless, such explorations involve huge capital outlays and take time to deliver large amounts of gas. Thus the political will to drive these projects to completion is critical, even though Europe is overpaying for Russian gas. Taken together, all these factors suggest that in the absence of exports from outside Europe (e.g., Qatar and the US) it will take considerable time and expense for Europe to reduce substantially its dependence on Russian gas.

> In 2013, Gazprom's share of the European gas market jumped to 30 percent, a significant increase over its 25.6 percent share in 2012. And the company expects to maintain its dominance of the European market for years to come. At the London meeting, Gazprom's head of strategy, Dmitry Lyugai, declared, "there will be no shale miracle in Europe. Any effort to dramatically increase gas drilling and production in Europe will take a decade or more. Even if European countries wanted to emulate America's success in extracting oil and gas from shale deposits, Europe doesn't have enough drilling rigs, nor does it have enough trained personnel and service-related infrastructure."[84]

The Shale Revolution: Impact and Expectations

Although there are still divergent views about the role of natural gas, the universal support for it is significant. The natural gas market's evolution and stability will shape global economics and geopolitics. Natural gas has the potential to capture 30 percent of the world's total primary energy supply by 2025, rising further to 35 percent by 2035. Today's share of fossil fuels in the global energy mix is 82 percent. The strong rise of renewables will only reduce this to around 75 percent by 2035. Conventional gas currently dominates worldwide natural gas production, accounting for 85 percent of total marketed output today. The share of unconventional gas will be 30 percent by 2035. There has been ample evidence that LNG is changing the characteristics of global gas markets. LNG will represent 14 percent of global gas consumption by 2020, up from 9 percent in 2010. Global LNG capacity will increase by 61 percent by 2020. Thanks to the shale revolution, North America will be a net gas exporter by 2015 and could become a net oil exporter by 2035. In terms of the impact of shale gas on LNG markets, over the long run, increased production of global shale gas will strengthen global LNG markets as it will lead to a further shift of demand toward natural gas. The sizable increase in shale gas production in the US alone has already impacted the global LNG market. Two-thirds of the world's gas is still consumed in the country where it is produced. Increased shale gas production around the world could further increase LNG trading as more suppliers and buyers enter the market and the LNG market becomes more liquid. According to the *Economist*,

> Given the vast global shale gas resource base, the shale-gas boom in America, and the potential for similar bonanzas around the world, is turning a seller's market into a buyer's paradise, promising deep and liquid markets with a growing diversity of supplies that improves security for buyers.[85]

Changes in the Global LNG Market

In terms of the structural changes in the global gas market in the last few years, the rapidly evolving LNG supply landscape is noteworthy. Supply has significantly increased with new sources and technologies:

> Supply is also increasing from newer geographies. Russian gas is gradually becoming available to Asia with as many as 13 deals signed in the last 3 years that are expected to deliver over 13 mtpa by 2020. Africa's liquefaction capacity will nearly triple to 127 mtpa by 2020. Meanwhile, over 108 mtpa [of] onshore Australian LNG is expected to come on stream by 2020, but at high breakeven costs.[86]

Significant upcoming projects and seaborne supplies will be mostly driven by Australia, which will add 50 percent of incremental LNG supply by 2020. There has been a slowdown in final investment decisions for non-US LNG projects, with only Yamal LNG having taken FID (the final investment decision) in the last year. According to Credit Suisse:

> Global liquefaction capacity will rise from 278mpta in 2011 to 449mtpa by 2020. Of the incremental 173mtpa of liquefaction

capacity, 75mpta are already under construction and 97mtpa are "possible" unsanctioned projects.[87]

The development of LNG export projects has been complicated due to host country issues, the types of resources, banks' requirements for financing, and high development and construction costs. The biggest hindrances to the development of new LNG projects have been pricing methods, price levels, certainty of future demand, and the inability of the developers to reach a positive FID. The global LNG market will become tighter until around 2016 as liquefaction additions (only 5.5mtpa of annual LNG additions in 2012–14) are outpaced by demand growth.[88] India and China continue to drive demand growth while new demand centers are emerging in Asia and the Middle East. After 2016, there seem to be enough LNG projects to meet 2017–20 demand.[89]

Significant shale gas production has the potential to lower natural gas prices. For decades, gas was mostly bought and sold in both Europe and Asia under contracts of between 20 and 25 years. The lack of a competitive natural gas market hinders the development of a price reflecting appropriate supply and demand criteria.[90] Prices were fixed, based on the cost of oil, but increasing competition among suppliers and rising demand have led to more gas being traded on a short-term basis, at flexible prices. Emerging gas supply sources (North American LNG, East African LNG, Russian and Central Asian pipeline gas) are seen as offering lower-priced alternatives to new buyers.

The prospect for potential US LNG exports augurs well for a spot market with sufficient liquidity to sustain itself in Asia. The global gas market was regionally segmented to a significant degree, and intra-regional flows of gas were important, with gas flows from Canada to US (92.4 bcm), from Southeast Asia and Australia (SEA) to Northeast Asia (93.9 bcm) and from Central Asia to Russia (31.9 bcm). The largest flow of gas was from Russia and the Central Asian FSU countries to Europe (185.7 bcm), though Europe also received significant gas imports from Africa (84.3 bcm) and the Middle East (45.0 bcm). In addition to gas imports from SEA, Northeast Asia received imports from the Middle East (46.8 bcm) and, increasingly, from the Former Soviet Union as well (16.0 bcm).[91]

North and South America were effectively 'gas islands' isolated from the rest of the world, with few significant transpacific or transatlantic gas flows. The scale of transpacific natural gas trade was particularly small in relation to global gas trade (0.3 percent), as opposed to 1.2 percent for oil and 4.6 percent for coal. Existing gas flows from North America to Asia were largely from the Kenai LNG export terminal in Alaska, which shut down later 2012.[92]

An increasing number of Henry Hub-linked supply contracts (13 deals worth 38 mtpa over the last 3 years) is contributing to the softening of price expectations in Asia. Furthermore, buyers are expecting to renegotiate favorable terms for the substantial 51 mtpa of contracts that will come up for renewal between 2015 and 2020. Of these, 33 mtpa will be renewed between 2018 and 2020, coinciding with the expected supply overhang. Meanwhile, Japan is actively looking to reduce its LNG import costs. Asian players are also investing in assets across the value chain to provide secure and hedged access to gas.[93]

In Europe and Asia, oil-indexation is the dominant price mechanism. Europe continues to shift towards more gas-to-gas based pricing. The Asian premium is the price for security of supply that consumers have to pay to attract LNG volumes from all over the world. Despite enormous efforts by European reformists to change the pricing mechanism, oil-indexation remains the dominant pricing mode. In 2013, 75 percent of gas imported into Europe was oil-indexed.

Some of the first impacts of the gas boom in the US emerged in Europe in 2008. The US did not begin to import the quantities of LNG from countries like Qatar and Trinidad and Tobago; those quantities have instead been redirected to other markets, including Europe. The LNG glut after 2008 that led to Europe's row over oil indexation between the big energy firms and Gazprom shows how events in other parts of the world can put pressure on regional price mechanisms. While Gazprom has attempted to maintain oil-linked prices that are higher than prices generally reflected on traded gas hub indices, gas customers in Europe are looking for cheaper alternatives during difficult economic times and have forced price reductions for those pipeline supplies.[94]

Asian markets have limited connectivity, low market liquidity and high dependence on LNG for gas imports.[95] Cross-border pipelines are being developed across the region. This supply will compete with LNG. Even pipelines that are still on the drawing board will increase bargaining power for importers of LNG. The depth of Asia's spot and short-term market in LNG has also been steadily growing and now accounts for a quarter of all imports.[96] This provides buyers with greater flexibility and opportunities to create value through trading. The volume of gas sold in Asia in 2011 under short- or medium-term contracts rose 110 percent to 37.3 million tons, out of 61.2 million tons sold world-wide under such deals. The spot and short-term market reached 73.5 mtpa in 2012, or 31 percent of global trade.[97]

The March 2011 earthquake substantially increased the LNG import requirement, and was a key factor in LNG price inflation; average import costs rose from $12/mBtu in February 2011 to $17/mBtu recently. As of May 2012, the premium of Japan's average LNG import price over the

Henry Hub spot price was at an historic high of $14.7/mBtu, while the premium of China's average import price over the US spot was just $8.3/mBtu due to historical, low cost contracts.[98]

Lowering LNG import costs is an urgent task for the governments of Asia. Bloomberg quoted Mitsunori Torihara, Chairman of the Japan Gas Association, on June 7, 2012, as saying:

> Japan should contain LNG purchase costs by: Breaking the current LNG / crude oil price links and pegging imports to other price benchmarks, such as the US Henry Hub and the UK National Balancing Point (NBP), and Looking beyond the Asia-Pacific region for LNG sources."[99]

Most US LNG projects are focusing on Japan and Asia as their main market. Currently approved projects add up to 65 mtpa, which is equivalent to 40 percent of Asia's current LNG demand. US LNG is scheduled to be exported to Japan and other Asian markets starting from 2015. Supply potentially exceeds demand. Only those projects that provide LNG at competitive prices will be able to actually materialize.

Increased LNG market participation by new suppliers and buyers is likely to encourage greater liquidity and destination flexibility in LNG contracts. We anticipate continuing evolution of LNG markets in Asia towards a larger proportion of short-term contracts and spot cargoes. Switching to gas-on-gas competition price from oil-indexed pricing has become a critical concern for governments in Asia. A gas market-indexed pricing is formed by gas supply and demand fundamentals. As the rationale behind oil-indexed gas prices have weakened, it is time to discuss whether there is a sufficient rationale to switch to a regional gas market-indexed pricing system.

Shifting Geopolitics

Increased shale oil and gas production in the US will affect global geopolitics and national security considerations. An influx of Qatari LNG into Europe and Asia, which is diverted from the US, erodes the tremendous market share held by the Russian gas company Gazprom and significantly reduces its pricing power. The 2011 study by Medlock, Jaffe and Hartley predicted that Russia's market share in Europe would decline from 27 percent in 2009 to just 13 percent in 2040.[100] Furthermore, Europe will start importing gas from Central Asia and the Middle East (Azerbaijan, Turkmenistan, Iraq) via new pipelines from 2016–2017 onwards. These countries are expected to supply at least 30 bcm per year.[101]

As part of the impact of the US shale revolution, Russian energy control over Europe will be greatly reduced; hence, Russia's power over the region will also be reduced. Russia has earned between $42 and $60 billion per year from selling gas to Europe. Fewer exports and lower prices will cut those revenues. Given the importance of oil and gas companies to Russia's economics, it is urgent for Moscow to restrict Central Asian production and infrastructure to mainly or even exclusively Russian channels, lest Russian oil and gas become less competitive due to its own high cost, wasteful monopolistic structure and dilapidated infrastructure. According to one analysis, if Turkmenistan could produce LNG it could ship it to Europe through Azerbaijan and greatly reduce Russia's capability to block or interdict such shipments. Liquefaction would thus reduce Russia's and Iran's ability to threaten a trans-Caspian gas pipeline – as they have in the past – and further integrate Turkmenistan and Azerbaijan with Europe. Not only could these states contribute more gas to Europe and gain security and income, Europe would gain an alternative and reliable gas source; given Ukraine's interests in LNG and the relentless Russian pressure upon it, this LNG option could allow Ukraine to utilize its LNG terminal at Odessa to take this gas, reduce Ukraine's and Romania's vulnerability to Russia, and strengthen Georgian security as well.[102] The US assessment is that Europe has greater energy security today than it did just ten years ago, and that Russian foreign policy behavior would be less hostile and seek more trade than simple gas exports with other countries than under high gas prices.

Scholars have found a direct correlation between high energy prices and Russian aggression. The American Enterprise Institute (AEI) compiled an "aggression index" based on 86 events in Russian policy from 2000 to 2007 and found that:

> We found that as the price of oil rose, the aggressiveness index increased: that is, the more valuable oil became, the more hostile Russian foreign policy became. The reverse was also true: when oil prices dropped in 2001 and 2002, so did Russia's aggression. The relationship proved strongest at the annual level: a $1.48 increase in oil prices yearly correlated with an additional "point" increase in Russian aggression.[103]

David Victor, Professor at the School of International Relations and Pacific Studies, the University of California at San Diego, notes:

> 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 but has yet to happen. The Russian state might insulate itself from the loss of gas export revenues because it earns much more selling oil abroad than selling gas.[104]

Although Russia says it is pivoting to Asia, there is still no gas deal with China despite constant announcements that one was forthcoming. There is no doubt that in the Asian market – an area where Russia also has high hopes – Russia is vulnerable should the US decide to export LNG or should China opt for shale based on its own immense holdings.

Indeed, Russian energy prospects in Asia are quite problematic, making opportunities for US exports particularly attractive beyond the price differential with Europe. Russia has discussed large-scale oil and gas sales with East Asian countries for over twenty years, but the results to date are not much to brag about.[105] Despite innumerable stories and claims from Moscow or elsewhere that this time a Russo-Chinese or Japanese gas pipeline agreement is about to be announced, we are still waiting and as of mid-January 2014, despite more such claims, no agreement has been announced.[106] Now Gazprom claims to be drafting a supply contract with CNPC, with a vow to agree on one by the end of 2014.[107] Alternatively, Russian sources report that Gazprom hopes to finalize a deal with China when President Vladimir Putin visits in May 2014, but concedes that there is still no accord on prices for this gas.[108] However, the proliferation of such vague, contradictory but positive reports is a classic Russian tactic to hide the fact that things are not going well. Neither is there much to report regarding oil or gas from Russia to Japan or Korea.

The only relatively positive area of energy sales to Asia is oil sales to China. While the East Siberia–Pacific Ocean pipeline (ESPO) has been up and running since 2011, it was enmeshed in litigation in 2012 and in effect China is buying Russian oil at prices below Henry hub or global market levels when one figures in payments on the $25 billion loan it made to Russia to build that pipeline. Nevertheless China is receiving oil from Russia in 2014 and China has also advanced Rosneft $12 billion as part of the deals it concluded with the company in 2013.[109] In those deals, Rosneft agreed to supply CNPC with 365 million tons of oil for 25 years, an agreement worth $270 Billion. In return, CNPC has apparently made a pre-payment to Rosneft of $60–70 billion. This amounts to 15 million metric tons of crude oil annually for 25 years at just over $10 billion annually, and this oil will probably go through the existing ESPO pipeline to Daqing, China.[110]

In subsequent deals during 2013, at the recent Sino-Russian summit Rosneft gained a contract to triple the size of current oil deliveries to China to 900,000 bpd, putting it on a par with Saudi deliveries to China.[111] However, it won those contracts only at the price of agreeing to further huge Chinese loans of $25–30 billion as infusions of cash to Rosneft and agreeing to facilitate Sinopec's acquisition of oil and gas assets in Russia. Specifically, Rosneft would consider Sinopec's participation in its large-scale project in the Russian Far East (RFE) refinery jointly established in 2007 by Rosneft and Sinopec's rival CNPC.[112] While China will loan Rosneft $2 billion backed by 25 years of oil supply Rosneft will boost oil exports to China by 800,000 metric tons this year and annual exports may reach 31 million tons annually or 620,000 barrels a day, more than doubling present exports. Igor Sechin, Rosneft's Chairman, even hinted at reaching 50 million tons per annum. The deal with CNPC to drill in the Pechora and Barents Seas in the Arctic also highlights CNPC's growing clout in global markets. Finally, Gazprom also announced its intention to conclude the long-awaited gas deal with China in 2013 and that deal too might involve advance payments from China to an increasingly vulnerable Gazprom.[113]

While China may become Russia's biggest customer, it has an enormous cushion of alternative suppliers for both oil and gas, and very likely leverage over oil and gas pipelines that go exclusively to China.[114] Meanwhile Moscow and Rosneft will depend excessively on exports to China and Asia through these leveraged pipelines because Moscow has no other Asian consumer for this oil. This, as energy experts everywhere know, is not a winning strategy for Russia.

Still, it appears that the Russia–Korea gas pipeline, the critical part of Russia's eastward-looking policy, has gone nowhere, and the failure of this proposal to advance has apparently dashed Moscow's hopes – for now at least – in regard to the pipeline and the goals envisioned in Moscow's Korean dream. By supplying both Koreas with energy Moscow could, at a single stroke, establish itself as a major player in Korea. Then these projects would also establish Russia as a major participant in the six-party talks rather than a marginal figure or even a "nuisance" as one diplomat previously described it.[115] The benefits that would accrue to Russia from a direct pipeline to one or both Korean states have also been cited by other analysts (cf. Keun-Wook Paik).[116]

In lieu of the trans-Korean pipeline Russia can either build a new underwater pipeline from its east coast to South Korea or find a way to increase production of liquefied natural gas (LNG) from Sakhalin II to supply to the ROK as well as Japan. It is also building an LNG plant in Vladivostok that Gazprom believes will have a secure resource base and can bring LNG to Asia from Sakhalin II, as well as the forthcoming Sakhalin III and Kirinskoye pipelines, in line with the overall gasification of the RFE.[117] Thus, the LNG plant that Rosneft plans to build on Sakhalin could, it claims, be expanded to 10 million tons of gas, while Novatek, an independent gas company, claimed in October 2013 that its preliminary estimate of the cost of an underwater pipeline from Russia to South Korea would soon be ready, although no word of it has been reported as of this writing.[118] Typically, it appears that such claims are vastly overblown and that, in fact, the gasification project for the RFE is considerably behind schedule.[119]

US shale oil production is playing an even bigger geopolitical role than natural gas and LNG. Estimated US crude oil production averaged 8 mbpd in November 2013, the highest monthly level since November 1988. Officials expect domestic crude output will average 7.5 mbpd in 2013 and 8.5 mbpd in 2014.[120] Unplanned supply disruptions worldwide averaged 2.6 mbpd in 2013, a nearly 37 percent increase (0.7 mbpd) above 2012. OPEC producers accounted for more than 69 percent (1.8 mbpd) of the disrupted volume.[121] Total US liquid production, including NGLs and biofuels, could reach slightly less than 16 mbpd by 2017.[122] Without US shale oil contributions, global oil market prices might have been higher than the current level.

In recent years, there is perhaps no other region that has undergone quite as much geopolitical transformation as the Middle East as a result of the US shale revolution. The ongoing debate about the geopolitical implications of US energy independence within the next decade by and large tends to focus on the question of how it would affect the US military presence in the Middle East. Should we expect a geopolitical US 'retreat' from the Middle East? Daniel Yergin, head of Cambridge Energy Research Associates (CERA), states:

> First, bear in mind that currently less than 10 percent of the … [Arabian] Gulf's energy production is exported to the US. In volume terms, the US is not highly dependent on the Gulf. In spite of that, we have not seen the US disengage from the region. Because what matters to America is that oil should serve the global economy, its growth and the strategic importance of the Middle East.[123]

The genesis of these discussions are projections like those contained in the International Energy Agency's *World Energy Outlook 2012*, which show that in 2035, the US will be importing just 100,000 bpd of oil from the Middle East while China will be importing 6.7 million bpd. [124]

One of the most specific geopolitical consequences of the tight oil boom is the additional leverage it provides the US and EU against Iran in the short-term; "A halt of Iran's exports to the Organization for Economic Cooperation and Development (OECD) economies would likely trigger an initial oil price increase of about 20 to 30 percent."[125] Without the power conferred by oil exports, the United States' commitment to security in the Middle East is "not a function solely of dependence on foreign oil."[126] In reality, Canada is the biggest supplier of oil imports to the US, accounting for 28 percent of the total.[127] However, there may be calls to scale back US engagement in the Middle East, which could also provoke fears among oil partners like Saudi Arabia that the US is poised to abandon the region.[128]

African states have relied heavily on exports to the US; tight oil coming from American shale formations is rapidly replacing imports from Africa. Tight oil is light and sweet (low sulfur) and similar to oil from Africa in quality and type. The US imported 395,000 bpd from Nigeria in May 2013, less than half the total from only two years ago.[129] This deals a blow to the economic viability of these states.

Conclusion

It has long been thought that global unconventional gas resources may be highly significant—roughly equal to conventional resources. The shale revolution is still an American affair. Although it is too soon to predict the ultimate outcome of global shale gas development, the production of US shale gas alone has already impacted global gas markets and geopolitics. China faces geological hurdles while Europe faces internal political opposition. US shale gas production has important implications for global gas trade flows and international security. In the wake of Russia's invasion, occupation, and annexation of Crimea, many in the US and Europe have called for the imposition of strong economic and energy-related sanctions upon Russia. These calls for urgent action are based on the transformation in energy markets prompted by the massive exploration of shale oil and gas in the US and the belief that American shale oil and gas and LNG exports to Europe and/or Asia would seriously injure the Russian economy.

Putin has just advocated synchronizing private and state investments in LNG and Russia has expanded the number of companies that may export LNG from fields in Russia and off-shore. Gazprom likewise expects to raise the amount of LNG it exports from Sakhalin-II to Japan and South Korea from 11 million tons to 30–35 million tons annually by 2018–20. It also is promising to sell LNG to Vietnam. Thus, ironically, Russia's own behavior betrays its apprehensions as to the potential effects of US exports of shale oil and gas and LNG and its vulnerability to such pressure. Thus if US exports went to Asia rather than Europe it would probably free up a great amount of Middle Eastern energy that is now going to Asia and that could go to Europe instead; this move would undoubtedly facilitate the globalization of gas markets discussed above. To the extent that major Asian countries like Japan can build terminals and refineries in the US to store refine, and then ship shale or LNG, they would also facilitate that trend and exert strong downward pressure on gas prices that would certainly injure Russian plans for the Far East and its revenue stream from both Europe and Asia. In addition, the expansion of available gas and oil due to American – and likely Canadian – exports would reduce the incentive to seek energy in the Arctic, the costs of which are enormously high and where cooperation between US firms and Russia will undoubtedly encounter mounting political opposition. Striking at the economic foundations of Russia's Arctic position would also seriously harm Russia given its plans in the area.

Although there are still divergent views about the role of natural gas, the universal support for natural gas is significant, and gas markets are becoming more globalized. As we look to the future, two remaining questions remain: first, in light of the growing environmental challenges and potential additional regulations facing the global shale gas industry, will the United States continue working to ensure that the US legal scheme as a model can be provided to those countries with less developed laws and regulations? Second, the future evolution of LNG markets requires further study; most experts expect LNG markets to continue to evolve from the traditional market structure to a more flexible one. Whether Asia will continue to follow its oil-linked pricing structure is a subject of intense discussion. The general consensus seems to be that the Asian LNG market is going to develop more flexible characteristics. Nonetheless, in the foreseeable future, an oil-linked gas pricing mechanism is likely to remain dominant. With limited options, security of supply will continue to be of paramount concern for buyers such as Japan and Korea.

Acknowledgement

This chapter is partially supported by the National Research Foundation of Korean government (NRF 2012S1A3A2033350).

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required, either to facilitate domestic consumption of natural gas or exports. Both are long-term projects, and although the Polish TSO has stepped up its activities, arguably much work remains to be done, such as the construction of distribution grids or improving the interconnectors with neighboring countries. It is worth noting that the lack of successful initial drilling results and the departure of several private companies from Poland do not help to justify these investments." See Tim Boersma, "Four Questions on Shale Gas Developments in Europe and the U.S.," November 18, 2013.

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