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by

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ABOUT THE STUDY

The past decade has yielded a dramatic change in the natural gas industry. Specifically, there has been rapid development of technology allowing the recovery of natural gas bound up in shale formations. By some estimates, there is as much as 1,000 trillion cubic feet (tcf) of technically recoverable shale gas in North America alone, which is enough to supply the nation's natural gas needs for the next 45 years. This study assesses the impact of U.S. domestic shale gas development on energy security and U.S. national security, with emphasis on the geopolitical consequences of rising supplies of U.S. natural gas from shale and the implications for U.S. foreign policy.

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Medlock's research covers a variety of topics in energy economics, including domestic and international natural gas markets; energy commodity price relationships; transportation; modeling national oil company behavior; economic development and energy demand; and energy use and the environment. Medlock is member of the International Association for Energy Economics (IAEE), the American Economic Association and the Association of Environmental and Resource Economists. In 2001, he won (joint with Ron Soligo) the IAEE's "The Energy Journal" Campbell Watkins Best Paper Award.

Medlock served as an adviser to the U.S. Department of Energy and the California Energy Commission in their respective energy modeling efforts. He also was the lead modeler of the modeling subgroup of the 2003 National Petroleum Council (NPC) study of long-term natural gas markets in North America, and was a contributing author to the California Energy Commission and Western Interstate Energy Board's "Western Natural Gas Assessment" in 2005. He also contributed to the 2007 NPC study "Facing the Hard Truths" and is involved in the ongoing NPC study, "North American Resource Development."

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I. Introduction[1]

The past decade has yielded substantial change in the natural gas industry. Specifically, there has been rapid development of technology allowing the recovery of natural gas from shale formations. Since 2000, rapid growth in the production of natural gas from shale formations in North America has dramatically altered the global natural gas market landscape. Indeed, the emergence of shale gas is perhaps the most intriguing development in global energy markets in recent memory.

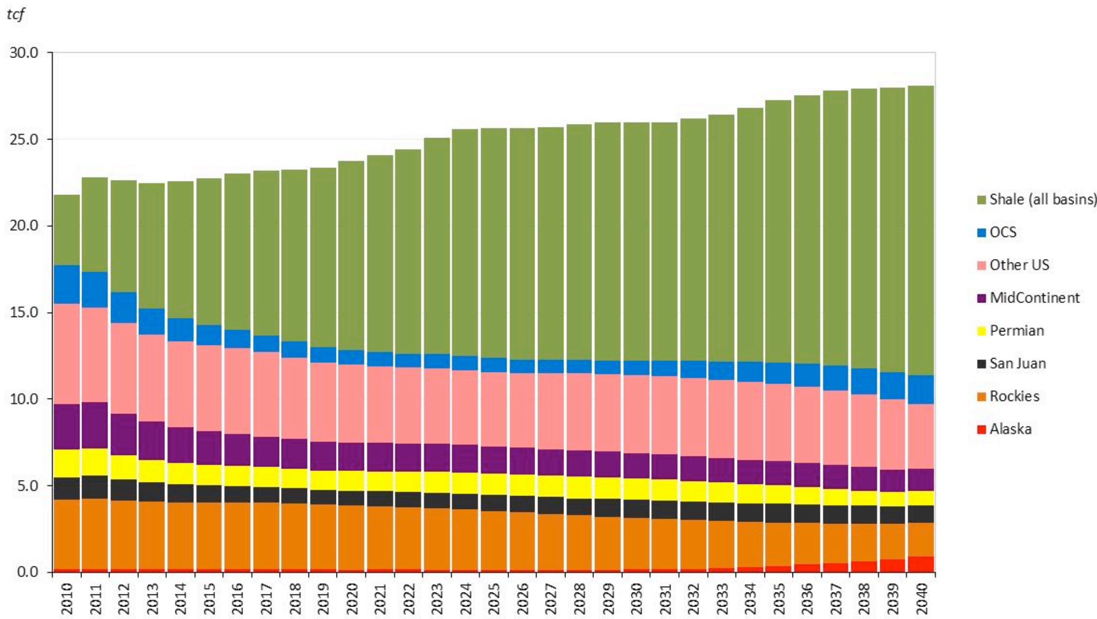
Beginning with the Barnett shale in northeast Texas, the application of innovative new techniques involving the use of horizontal drilling with hydraulic fracturing has resulted in the rapid growth in production of natural gas from shale. Knowledge of the shale gas resource is not new as geologists have long known about the existence of shale formations, and accessing those resources was long held in the geology community to be an issue of technology and cost. In the past decade, innovations have yielded substantial cost reductions, making shale gas production a commercial reality. In fact, shale gas production in the United States has increased from virtually nothing in 2000 to over 10 billion cubic feet per day (bcfd) in 2010, and it is expected to more than quadruple by 2040, reaching over 50 percent of total U.S. natural gas production by the 2030s (see Figure 1).

Natural gas—if not disadvantaged by government policies that protect competing fuels, such as coal—stands to play a very important role in the U.S. energy mix for decades to come. Rising shale gas production has already delivered large beneficial impacts to the United States. Shale gas resources are generally located in close proximity to end-use markets where natural gas is utilized to fuel industry, generate electricity and heat homes. This offers both security of supply and economic benefits.

Rising shale gas supplies have significantly reduced U.S. requirements for imported liquefied natural gas (LNG), which has already had geopolitical implications. For example, it has played a key role in weakening Russia's ability to wield an "energy weapon" over its European customers by increasing alternative supplies to Europe in the form of LNG displaced from the U.S. market.

[1] The authors would like to thank Megan Buckner, Likeleli Seitlheko, Sara El-Hakim, and James Coan for their valuable research assistance.

Figure 1. U.S. Natural Gas Production through 2040



Source: Rice World Gas Trade Model Reference Case, June 2011

Rising shale gas supply has also led to lower domestic natural gas prices, which lowers the costs of initiatives to diversify the American automobile fleet to run on non-oil based fuels such as electricity and compressed natural gas. In both the U.S. and abroad, the promise of growing shale gas production has raised the prospects for greater use of natural gas, an outcome with significant implications for global environmental objectives since lower-cost natural gas can displace fuels associated with higher air pollution and greater carbon intensity, such as coal and oil.

Without doubt, the natural gas supply picture in North America has changed substantially, and it has had a ripple effect around the globe not only through displacement of supplies in global trade but also by fostering a growing interest in shale resource potential in other parts of the world. Thus, North American shale gas developments are having effects far beyond the North American market, and these impacts are likely to expand over time. Prior to the innovations leading to the recent increases in shale gas production, huge declines were expected in domestic production in the United States, Canada, and the North Sea. This meant an increasing reliance on foreign supplies at a time when natural gas was becoming more important as a source of energy.

Shale gas developments stand to exert enormous influence on the structure of the global gas market. Throughout the 1990s, natural gas producers in the Middle East and Africa, anticipating rising demand for LNG from the United States in particular, began investing heavily in expanding LNG export capability, concomitant with investments in regasification being made in the United States. But the rapid growth in shale gas production has since turned such expectations upside down and rendered many of those investments obsolete. Import terminals for LNG are now scarcely utilized, and the prospects that the United States will become highly dependent on LNG imports in the coming years are receding, with some proposals now emerging for *exports* of LNG from North America.

Rising shale gas production in the United States is already impacting markets abroad. In particular, LNG supplies whose development was anchored to the belief that the United States would be a premium market are now being diverted to European and Asian buyers. Not only has this immediately presented consumers in Europe with an alternative to Russian pipeline supplies, it is also exerting pressure on the status quo of indexing gas sales to a premium marker determined by the price of petroleum products. In fact, Russia has already had to accept lower prices for its natural gas and is now allowing a portion of its sales in Europe to be indexed to spot natural gas markets, or regional market hubs, rather than oil prices. This change in pricing terms signals a major paradigm shift.

The recent developments around shale in the United States are also having another, potentially market structure altering, effect. Revelations about the existence of technically—and possibly commercially—viable shale gas resources are also occurring in other regions around the world, with shale gas potential being discussed in Europe, China, India, Australia, and elsewhere. To be sure, the enormity of global shale gas potential will have significant geopolitical ramifications and exert a powerful influence on U.S. energy and foreign policy.

The state of knowledge regarding the amount of shale gas that is economically recoverable has changed rapidly over the last 10 years. A simple chronology is as follows:

- As recently as 2003, the National Petroleum Council[2] estimated that about 38 trillion cubic feet (tcf) of technically recoverable resources were spread across multiple basins in the North America.
- In 2005, the Energy Information Administration (EIA) was using an estimate of 140 tcf in its Annual Energy Outlook as a mean for North American technically recoverable shale gas resources.
- In 2008, Navigant Consulting, Inc.[3] estimated a range of between 380 tcf and 900 tcf of technically recoverable resources, putting the mean at about 640 tcf.
- In 2009, the Potential Gas Committee[4] put its mean estimate at just over 680 tcf.
- In 2011, Advanced Resources International (ARI) reported an estimate of about 1,930 tcf for North America, with over 860 tcf in U.S. gas shales alone.[5]

Note that although each assessment listed above is from an independent source, the estimates are increasing over time as more drilling occurs and technological advances are made, which is an indication of the learning-by-doing that is still occurring in this important play. Moreover, the shift in the generally accepted assessment of recoverable shale resources has left producers, consumers, and governments all grappling with the implications for markets and geopolitics.

Utilizing scenario analysis based on peer-reviewed, scientific assessments of the properties of shales[6] (which the Baker Institute then uses to develop its own technically recoverable estimates and associated finding and development cost curves), this Baker Institute study, sponsored by the U.S. Department of Energy, is able to demonstrate that U.S. shale gas can help abate the enhancement of geopolitical power wielded by key petro-states as global primary energy use

[2] National Petroleum Council, *Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy*, September 2003.
[3] Navigant Consulting, *North American Natural Gas Supply Assessment*, July 4, 2008.
[4] The Potential Gas Committee, *Potential Gas Committee Biennial Assessment*, June 18, 2009.
[5] *World Gas Shale Resources: An Assessment of 14 Regions outside the United States*, a report prepared by Advanced Resources International (ARI) for the United States Energy Information Administration (EIA), April 2011.
[6] Assessments are not taken from nontechnical publications such as investor relations reports. Rather, they rely on published data and articles from the American Association of Petroleum Geologists (AAPG), The Potential Gas Committee, and the U.S. Geological Survey, among others.

shifts increasingly to natural gas. Specifically, shale gas will play a critical role in diminishing the petro-power of major natural gas producers in the Middle East, Russia, and Venezuela and will be a major factor limiting global dependence on natural gas supplies from the same unstable regions that are currently uncertain sources of the global supply of oil. In this way, shale gas can play a critical role in averting a reinforcement of the political risk we currently face in the global oil market.

The geopolitical repercussions of expanding shale gas production include the following:

- Virtually eliminates U.S. requirements for imported LNG for at least two decades
- Reduces competition for LNG supplies from the Middle East, thereby moderating prices and spurring greater use of natural gas, an outcome with significant implications for global environmental objectives
- Combats the long-term potential monopoly power of a "gas OPEC" or a single producer such as Russia to exercise dominance over large natural gas consumers in Europe or elsewhere
- Reduces Russia's market share in non-FSU Europe from 27 percent in 2009 to about 13 percent by 2040, reducing the chances that Moscow can use energy as a tool for political gain
- Reduces the future share of world gas supply from Russia, Iran, and Venezuela; without shale discoveries, these nations would have accounted for about 33 percent of global gas supply in 2040, but with shale, this is reduced to 26 percent
- Reduces the opportunity for Venezuela to become a major LNG exporter and thereby lowers longer-term dependence in the Western Hemisphere and in Europe on Venezuelan LNG
- Reduces U.S. and Chinese dependence on Middle East natural gas supplies, lowering the incentives for geopolitical and commercial competition between the two largest consuming countries and providing both countries with new opportunities to diversify their energy supply
- Reduces Iran's ability to tap energy diplomacy as a means to strengthen its regional power or to buttress its nuclear aspirations

It should be pointed out that the sustained, rapid development of shale gas is not a certainty. A stable regulatory environment that fosters responsible development of domestic resources is critical to achieving the potential benefits presented by shale. There are several factors that could stymie development not only in the United States but also elsewhere in the world. While comprehensive discussion of these factors is beyond the scope of this report, we do note that these variables could greatly impact the pace of shale gas development not only in the United States but also in Europe and other international locations. In particular, environmental concerns regarding the use and potential contamination of water resources have recently dominated the news headlines in the United States and France and therefore are among the kind of major issues that will need to be addressed before governments will allow full realization of shale's growth potential.[7]

A prime, oft underappreciated, factor that has positively benefited growth in shale gas production in the United States is the unique North American market structure. For example, ownership of transportation capacity rights is unbundled from ownership of the pipeline itself. If such a regulatory structure were not in place, it is arguable that shale gas developments would not have occurred at their recent pace. Unbundling of capacity rights from facility ownership makes it possible for a producer to access markets through a competitive bid for pipeline throughput capacity. Absent this, many of the small producers that first ventured into shale might not have been willing to do so, specifically because access to markets could have been limited. This is inherently a problem in most other markets globally, where pipeline capacity is not unbundled from facility ownership and large incumbent monopolies control much of the transportation infrastructure.

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[7] See *Time Magazine*, "The Gas Dilemma," April 11, 2011. More studies are underway regarding groundwater safety and shale gas operations—hydraulic fracturing and produced water disposal in particular. Among the water issues that have been raised are concerns about the availability of water for production; water rights and resource management regulation; flowback options (recycle and/or treatment and disposal) and native infrastructure; concerns about watershed protection during drilling operations (casing failures and fracture migration), etc. In a study released in June 2011, *The Future of Natural Gas*, MIT researchers reported a relatively low frequency of incidents related to well sites, noting 43 widely reported incidents against a backdrop of over 20,000 wells drilled. The MIT study, together with efforts to monitor water quality in Pennsylvania and New York, may be an indication that the problem is not comprehensive in nature and may prove somewhat transitory with better oversight and regulation. Certainly, if severe enough, one major incident can be detrimental to concerns about production everywhere, but the reported issues so far have been largely contained. The likely outcome will be increased transparency in an effort to step up oversight, with some local communities probably banning activity altogether in certain higher risk regions. But, based on the preponderance of evidence, water contamination concerns do not seem likely to lead to a full-scale shutdown of shale gas activities.

More generally, the United States has a well-developed, competitive regulatory framework governing natural gas infrastructure development, transportation services, marketing, and mineral rights ownership and acreage acquisition. This environment has promoted the rapid development of shale resources, and it may not be fully or quickly replicable in other markets around the globe where state involvement in resource development and transportation is more prevalent. For example, investor access to shale resources is likely to be more heavily controlled in China and most European countries, where land ownership is generally distinct from the ownership of mineral rights, than in the United States, where landowners can directly negotiate terms for access to minerals under their acreage.

Another potential impediment to shale development comes in the form of demand-side policies toward energy use. In particular, many European countries have proactive policies that in some cases favor competing resources (renewables, nuclear, etc.). These types of policies could also serve as a brake on shale investment by limiting overall demand for the resource. In addition, beyond Europe's environmental regulations, any new U.S. or Chinese policies that reduce demand for natural gas—possibly including renewable portfolio standards or carbon dioxide (CO_2) cap-and-trade programs that grandfather coal resources—could also hamper future investments in shale gas resources.

One last point related to market structure is also worth mention. In particular, changes in certain tax policies in the U.S. upstream sector—such as proposed changes to expensing rules, investment credits, and/or royalty rates—could also render investments in shale exploration and production unprofitable at current prices. The richness of the U.S. shale gas play owes its roots to small, independent energy companies who took on the risk to pioneer early entry to the technically challenging and initially costly play in the 1990s. Those companies are helped by rules such as the Intangible Drilling Cost (IDC) expensing rule. Generally, IDCs typically represent over 70 percent of well development costs, and are costs that are necessary for drilling and initiating production including but not limited to wages, supplies, contractor services, and other similar expenses for which there is no salvage value. Proposed changes to the IDC expensing rule would greatly constrain smaller risk-taking firms that engage in the kinds of investment programs that brought the shale play to fruition.[8] Smaller independent firms have played a critical role in identifying new resource plays over the decades, a trend evidenced by a Baker Institute analysis that shows that smaller firms were quicker to respond to higher prices by increasing exploration and development spending than the larger, more conservative firms whose drilling budgets stayed unchanged when oil prices increased through the 2000s.[9] Thus, it is important for U.S. energy security to have a thriving and active sector of small, independent energy companies. Without this sector, U.S. shale gas production would likely have taken many more years to grow to its current levels, thereby yielding more market and geopolitical power to a small number of foreign natural gas suppliers.

II. Study Approach

In this study on U.S. energy security, the Baker Institute examines the geopolitical consequences of rising supplies of natural gas from shale and the implications for U.S. security and foreign policy. To investigate this subject quantitatively, we utilize the Rice World Gas Trade Model (RWGTM)[10] to investigate how development of extensive global shale gas resources could alter geopolitical relationships over the coming decades and map out specific implications for U.S. energy security.

The RWGTM is a dynamic spatial general equilibrium model where supply and demand are balanced at each location in each time period such that all spatial and temporal arbitrage opportunities are eliminated. The model, therefore, proves and develops resources, constructs transportation routes and associated infrastructure, and calculates prices to equate demands and supplies while maximizing the present value of producer rents within a competitive framework.

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[8] If IDCs are expensed, they are deducted against the tax liability in the year that they are incurred instead of distributed across future years. Without IDC expensing, the lag between development costs and production revenues could hinder a small firm's available cash for continued investment. In this way, the deduction of IDCs increases the amount of capital available for drilling and production, and has proven to be an important facet of domestic production. Research and investment firm John S. Herold reported that the 50 largest independent producers reinvest 150 percent of their cash flow derived from U.S. operations back into projects based in the United States.

[9] See Amy Myers Jaffe and Ronald Soligo, "The International Oil Companies" (report for the James A. Baker III Institute for Public Policy, Rice University, Houston, Texas, and the Japan Petroleum Energy Center, November 2007), http://www.rice.edu/energy/publications/docs/NOCs/Papers/NOC_IOCs_Jaffe-Soligo.pdf.

[10] See appendix for a more detailed description of the RWGTM. The RWGTM was developed by Kenneth B Medlock III and Peter Hartley at Rice University using the Marketbuilder software provided through a research license with Deloitte Marketpoint, Inc.

Thus, new infrastructure must earn a minimum return to capital for its development to occur.[11] By developing supplies, pipeline transportation routes, and LNG delivery infrastructure, the RWGTM provides a framework for examining the effects of critical economic and political influences on the global natural gas market within a framework grounded in geologic data and economic theory.

The RWGTM allows the examination of potential futures for U.S. and global natural gas in a manner that facilitates quantification of geopolitical influences on resource development and trade flows. The RWGTM predicts regional prices, regional supplies and demands, and interregional flows. Since geopolitical influences can alter market outcomes in many different ways, the non-stochastic nature of the RWGTM facilitates analysis of many different scenarios and allows the model to characterize how events alter previous, current, and future investment decisions. In this way, the intertemporal nature of the RWGTM allows a complete analysis of the impact on investment decision pathways of specific scenarios. This follows from the fact that capacity and reserve expansions are determined by current *and* future prices along with capital costs of expansion, operating and maintenance costs of new and existing capacity, and revenues resulting from future outputs and prices.

The RWGTM is a highly disaggregated representation of existing and potential resources, demand sinks, and distribution networks. The extent of regional detail in the RWGTM varies, and is based primarily on data availability and the potential influence of particular countries on the global natural gas market. For example, large consuming and producing countries, such as China, the United States, India, Russia, and Japan, to name a few, have extensive sub-regional detail in order to understand the effect that existing or developing intra-country capacity constraints could have on current or likely future patterns of natural gas trade. In general, regions are defined at the country and sub-country level, with extensive representation of transportation infrastructure connecting over 290 regions with over 135 supply regions. U.S. demand is characterized at the state and sub-state level for the residential, commercial, industrial, and power generation sectors. Demand in all other countries is less detailed at the end-use level,

[11] Note: The debt-equity ratio is allowed to differ across different categories of investment (proving resources, developing wellhead delivery capability, constructing pipelines, and developing LNG infrastructure).

as it is estimated for the power generation sector and all other sectors—a limitation directly related to data availability.

Supply costs are present for over 135 regions in three primary categories—(1) proved reserves, (2) growth in existing fields, and (3) undiscovered resources—and are present for both conventional and unconventional resources. For this assessment work, we rely on peer-reviewed, scientific assessments of the properties of shales to develop technically recoverable estimates and associated finding and development cost curves. We distinctly avoid non-technical publications such as investor relations reports. Rather, the resource data derives from sources such as the *Oil and Gas Journal* (OGJ), U.S. Geological Survey (USGS), National Petroleum Council (NPC), Australian Bureau of Agriculture and Resource Economics (ABARE), and Baker Institute research on unconventional resources in North America and globally. North America finding and development (F&D) costs for non-shale resources are based on estimates developed by the NPC in its 2003 report "Balancing Natural Gas Policy – Fueling the Demands of a Growing Economy" and have been adjusted using data from the Bureau of Economic Analysis KLEMS to account for changes in the upstream costs since the early 2000s. These costs have been econometrically related to play-level geological characteristics and applied globally to generate costs for all regions of the world. In general, long-run F&D costs increase with depletion, and short-run adjustment costs limit the "rush to drill" phenomenon. Technological change is allowed to reduce F&D costs over the long run.

It should be noted that geologists have been writing about shale resources for decades, and only recently, innovations enhancing the technical feasibility of shale have occurred. The fact that geologists have been writing about the properties of shales since at least the early 1970s is indicative of the fact that, to many of them, shale becoming technically and commercially exploitable was largely an issue of technology, not necessarily geology. Indeed, innovations continue at a pace that is, on average, raising the initial production rate and expected ultimate recovery of wells drilled every year. These two things combined drive down the per-unit cost of development, thereby making more resource economically viable at a given price. The importance of this cannot be understated, from a geopolitical, environmental, and market development perspective. It is the systematic study of these trends that allows us to model projections of how shale production may develop and influence global LNG movements.

In a global natural gas market as develops in the RWGTM, events in one region of the world influence all other regions to the extent trade can occur between regions. Thus, political factors affecting relations between Russia and China, for example, will affect flows and prices throughout the world, not just in Northeast Asia. This follows because transportation links connecting markets transmit price signals as well as volumes of physical commodity. It is in this manner that markets become increasingly connected over time, specifically as profitable spatial arbitrage opportunities are exploited until they are eliminated. The costs of constructing new pipelines and LNG facilities in the RWGTM are estimated using data from previous and potential projects available from the Energy Information Administration, International Energy Agency (IEA), and various industry reports. Within the United States, Federal Energy Regulatory Commission (FERC)-filed tariff rates are used to determine the cost of transporting natural gas via pipeline. For regions outside the United States, a rate-of-return calculation is generally used to construct the tariffs on pipelines, such that the present value of the tariff revenue at 50 percent capacity utilization just recovers the up-front capital cost in 20 years. For LNG, facility throughput tariffs and shipping rates are based on information obtained from various industry reports.

For this study, we use the RWGTM to provide analysis of the recent revelations about shale gas and the role it will play to bolster U.S. energy security in the coming decades. To achieve this purpose, we compare results in an analysis based on three scenarios, which are described below.

- **Scenario One**: The Reference Case for this study posits a scenario in which all known global shale gas resources can be developed, given prevailing commercial technologies and open tendering practices. This scenario will include all global shale resources that have been identified in Europe and Asia and thereby present a full picture of the current expectations for changing geopolitical and market implications of a full-scale development of known shale gas resources.
- **Scenario Two**: Reference Case outcomes are compared to those of a second scenario in which shale gas resources are confined to the state of knowledge that existed prior to 2005. Under this scenario, shale developments in North America are limited to the Barnett, Woodford, and Fayetteville shale plays. Furthermore, under this scenario, no shale gas outside of North America is open for development. This scenario is a counter-

factual aimed to demonstrate what the world would look like if shale gas developments did not progress to the levels currently under way.

In comparing the first and second scenarios, we provide detailed analysis of what the full exploitation of North American and global shale resources will mean for U.S. energy security by demonstrating what the U.S. gas balance and global flows of LNG would have been had shale resources not been developed. This approach allows a clear delineation of the importance of shale resources to U.S. energy security. By comparing the results from these two scenarios, this study is able to highlight dramatic changes that shale gas stands to bring to the geopolitical landscape by demonstrating how it alters the flows of natural gas worldwide.

- **Scenario Three**: Under a third scenario, geopolitical implications of only a partial development of U.S. shale resources are explored. In this scenario, specific U.S. shale plays located north of Virginia are blocked from development by environmental and/or other political, fiscal, or regulatory factors. Commercial investment in all other U.S., Canadian, and other global shale gas is permitted in the scenario. While it is possible that environmental obstacles may, at some point, also impact development of resources in other countries, this scenario focuses solely on the consequences of limiting U.S. Middle Atlantic resource development to highlight the U.S. energy security implications of such policy choices. By comparing this third scenario to the first two scenarios, U.S. policymakers will have the benefit of understanding the costs to U.S. energy security if all American shale gas resources cannot be developed to their fullest extent.

III. Defining the Resource

Beginning with the Barnett shale in northeast Texas in North America, the application of innovative new techniques involving the use of horizontal drilling with hydraulic fracturing has resulted in the rapid growth in production of natural gas from shale. Moreover, the production potential that has been identified since the emergence of the Barnett shale—which until very recently was the largest single producing natural gas play in North America, having just been surpassed by production from the Haynesville shale—has dramatically altered expectations for global LNG trade. Less than 10 years ago, most predictions were for a dramatic increase in LNG imports to North America and Europe, but shale production in North America has turned this thinking upside down. Today, growth opportunities for LNG developers are seen primarily in Asia.

During the first decade of the 2000s, many investments were made to expand LNG potential to North America. At one point, as many as 47 terminals were in the permitting phase. Since 2000, two terminals have been recommissioned and expanded (Cove Point in Maryland and Elba Island in Georgia) and nine others have been constructed. This has increased LNG import capacity from just over 2 bcfd in 2000 to just over 17.4 bcfd currently. Import capacity could reach 20 bcfd by 2012.

Tremendous growth in LNG import capability has also been seen in Europe. In 2000, import capacity was just over 7 bcfd. It is now over 14.5 bcfd and could exceed 17 bcfd by 2012. It is likely that the import capacity developed in Europe will be much more heavily utilized than import capacity in the United States, largely because the shale revolution has not been as strong there. However, shale gas resources have been identified in Europe, so developments around those resources should be carefully watched.

Knowledge of shale gas resources is not new, as geologists have long known about the existence of shale formations. However, the ability to access shale resources in a commercial manner is new. In a study published in 1997, Rogner[12] estimated over 16,000 tcf of shale gas resources in-place globally with just under 4,000 tcf of that total estimated to be in North America. At that time, only a very small fraction (<10 percent) of this was deemed to be technically recoverable—and even less so economically. But recent innovations have rendered this resource accessible both by providing the technological capability and by reducing costs, thereby providing economic feasibility. In fact, the IEA recently estimated about 40 percent of the estimated resource in-place by Rogner (1997) will ultimately be technically recoverable.

A more recent assessment of technically recoverable shale resource done by ARI for the EIA expands greatly upon Rogner's work. In fact, the report notes that it identifies a global shale resource in-place of over 25,300 tcf, even without any assessment of the FSU or Middle East shale potential. This compares to Rogner's findings, which include the FSU and Middle East.

[12] H-H. Rogner (1997), "An Assessment of World Hydrocarbon Resources," *Annual Review of Energy and the Environment*, 22: 217-262.

Taken as an indicator of the rapidly advancing state of knowledge about the shale resource, this highlights the pace at which we are learning about the scale of the shale play.

Despite very large assessments of resources in-place, the commercial viability of shale is determined as a subset of resources in-place. In particular, technically recoverable resources define the boundary of those resources that can be recovered with existing technology, but economically recoverable resources define the boundary of what is commercially accessible. Thus, large resource in-place estimates do not necessarily imply large-scale production is forthcoming because technical innovations and cost reductions are critical to commercial viability.[13]

To be certain, the estimates of resources in-place are very large, and their location is a plus with regard to prevailing market prices and energy security benefit. However, in addition to cost and technology, accessibility is critical, a salient point in Europe and Asia. In particular, as noted above, market structure and government policy are equally important. Arguably, if the current market structure in the United States did not exist, the shale gas boom would not have occurred. This is due to the fact that the small producers who initiated the proof of concept had little to no risk of accessing markets from very small production projects due to the structure of the market governing transportation of gas. A market where capacity rights are not unbundled from facility ownership, such as in Europe and Asia, does not foster entry by small producers, leaving large incumbent transportation monopolies in a prime position to inhibit shale production growth, a point that could discourage innovative behavior.

Perhaps the earliest example of where innovation made shale resources commercially viable was seen in the Barnett shale in northeast Texas. The application of innovative new techniques involving the use of horizontal drilling and hydraulic fracturing propelled the Barnett into the largest single producing natural gas play in North America, a distinction it held until being recently surpassed by production in the Haynesville shale earlier this year. This subsequently altered producers' expectations about the viability of shale resources in other locations, and

[13] In fact, the pace of innovation has been astounding, and is likely a prime factor in the ongoing disagreement about the commercial viability of some shale plays. Analysts such as Arthur Berman have challenged the commercial viability of shales in the current $4/mcf price environment, arguing that higher prices are needed for sustained development. While our own work suggests prices will rise from their current levels, it does not suggest that shale will play any less an important role in the U.S. energy mix going forward.

triggered a virtual rush to shale. Innovations aimed at lowering costs continue, with longer laterals, increased frac stages, and better proppants. For example, Schlumberger recently reported very promising results in test wells from the use of its innovative new "HiWAY" fracking technique, yielding up to double the daily production and greater expected ultimate recovery when compared to standard slickwater fracs. Currently in North America, breakeven prices for some of the more prolific shales are estimated to be as low as $3, with a large majority of the resource accessible at below $6. Ten years ago, costs were significantly higher. As firms continue to make cost-reducing innovations, greater quantities of the shale resource will become both technically and economically viable.

Despite the magnitude of the assessments of shale resources reported in just the past couple of years, modeling done at the James A. Baker III Institute for Public Policy at Rice University indicates an estimate of U.S. technically recoverable shale resource of 637 tcf. A detailed account is provided in Table 1. The "breakeven price" indicated in Table 1 is the average price needed for development of up to 60 percent of the identified technically recoverable resource.[14]

Shale gas resources are not limited to only the United States. Most notably is Canada, which is an integrated piece of the broader North American market. Shale gas developments are already underway in western Canada in the Horn River and Montney basins, and are even being linked to a proposed export project at Kitimat on the west coast of British Columbia. Shales in Mexico—while having been identified in the Burgos and Sabinas basins in northern Mexico and Tampico basin farther south—have not to date been explored, making their viability somewhat questionable. Accordingly, the data represented in the RWGTM may understate the potential of shale gas production in Mexico. Nevertheless, the combined U.S., Canadian and Mexican shale assessments bring the total North American assessment of shale to about 937 tcf, with 165 tcf in Canada and 135 tcf in Mexico (see Table 2).

[14] As previously noted, we rely on peer-reviewed, scientific assessments of the properties of shales to develop technically recoverable estimates and associated finding and development costs, distinctly avoiding non-technical publications such as investor relations reports. Given the pace of knowledge enhancement, we incorporate more recent geologic and economic data as it comes available, which allows us to update our projections. Accordingly, while further drilling and experience is likely to produce better delineation of the size of the US shale gas resource base over time, it should be noted that even at estimates far smaller than say 1,000 tcf, our work has indicated that shale gas can still easily comprise 40 to 50 percent of US total production over the next three decades, radically changing the US import picture and greatly influencing the geopolitical picture in the global gas world.

Table 1. United States Shale Gas Assessments in the RWGTM

	Mean Technically Recoverable Resource (tcf)	Breakeven Price
Antrim	13.2	$ 5.50
Devonian/Ohio	220.4	
Utica	5.4	$ 6.25
Marcellus	185.0	
Marcellus Tier 1	46.3	$ 4.00
Marcellus Tier 2	64.8	$ 5.25
Marcellus Tier 3	74.0	$ 6.50
NW Ohio	2.7	$ 6.75
Devonian Siltstone and Shale	1.3	$ 6.75
Catskill Sandstones	11.7	$ 6.75
Berea Sandstones	6.8	$ 6.75
Big Sandy	6.3	$ 6.00
Nora/Haysi	1.2	$ 6.25
New Albany	3.8	$ 7.00
Floyd/Chatanooga	4.3	$ 6.00
Haynesville	160.0	
Haynesville Tier 1	32.0	$ 4.00
Haynesville Tier 2	56.0	$ 5.00
Haynesville Tier 3	72.0	$ 6.25
Fayetteville	36.0	$ 4.25
Woodford Arkoma	8.0	$ 4.50
Woodford Ardmore	4.2	$ 5.75
Barnett	58.0	
Barnett Tier 1	30.0	$ 4.00
Barnett Tier 2	28.0	$ 5.50
Barnett and Woodford	35.4	$ 6.50
Eagle Ford	42.0	$ -
Eagle Ford Tier 1	22.0	$ 3.75
Eagle Ford Tier 2	20.0	$ 5.25
Palo Duro	4.7	$ 6.25
Lewis	10.2	$ 6.25
Bakken	1.8	$ 4.50
Niobrara	1.3	$ 6.50
Hilliard/Baxter/Mancos	11.8	$ 6.50
Paradox/Uinta	13.5	$ 6.50
Mowry	8.5	$ 6.50
Total US Shale	637.0	

In fact, the dearth of commercial activity in shale plays outside of the United States and Canada renders any assessment in those regions highly uncertain, meaning the data represented in the RWGTM may actually understate the potential. However, in-depth studies are currently underway to fully assess shale resource potential in Europe, Asia, and Australia, and the recent aforementioned ARI/EIA study provides a preliminary look at the technically recoverable resource in many of these areas. In Europe, while some estimates exist, there is active research into assessing shale potential in Austria, Sweden, Poland, Romania, Germany, Croatia, Denmark, France, Hungary, the Netherlands, Ukraine, and the United Kingdom, to name a few locations.

Table 2. Shale Gas Assessments outside the United States in the RWGTM

		Mean Technically Recoverable Resource (tcf)	Breakeven Price
CANADA	Horn River	90.0	
	Horn River Tier 1	50.0	$ 4.50
	Horn River Tier 2	40.0	$ 5.25
	Montney	65.0	
	Montney Tier 1	25.0	$ 4.75
	Montney Tier 2	40.0	$ 5.50
	Utica	10.0	$ 6.50
MEXICO	Burgos Basin	90.0	
	Burgos Tier 1	20.0	$ 5.75
	Burgos Tier 2	30.0	$ 6.75
	Burgos Tier 3	40.0	$ 8.00
	Sabinas Basin	20.0	$ 7.25
	Tampico Basin	25.0	$ 7.00
EUROPE	Austria	40.0	$ 6.25
	Germany	30.0	$ 6.25
	Poland	120.0	
	Silurian Tier 1	45.0	$ 6.00
	Silurian Tier 2	75.0	$ 7.25
	Sweden	30.0	$ 6.50
PACIFIC	China	230.0	
	Sichuan/Jianghan	45.0	$ 6.50
	Ordos	35.0	$ 5.75
	Tarim/Junggar/Tuja	120.0	$ 7.25
	Songliao	30.0	$ 6.00
	Australia	50.0	$ 4.50
	Total non-U.S.	800.0	

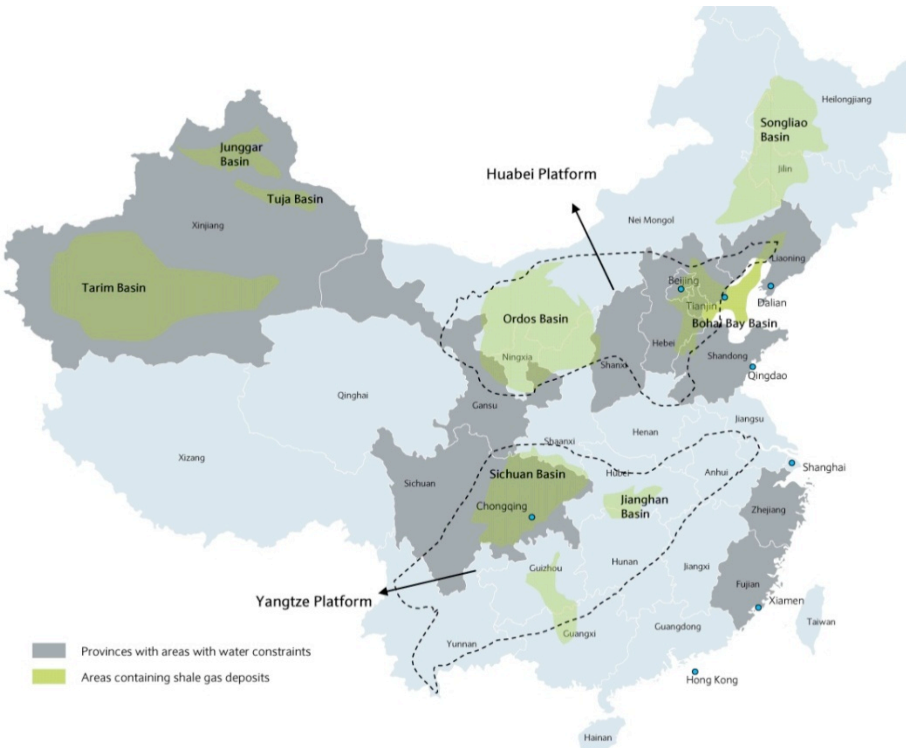
Currently, our work at the Baker Institute indicates a technically recoverable assessment in Europe of roughly 220 tcf split between Sweden, Poland, Austria, and Germany, with the largest proportion (about 55 percent) in Poland, and entry costs in the $6-7.50 per thousand cubic foot (mcf) range. Data for the Asia-Pacific region is generally even more preliminary, but as of the date of the modeling done for this study, potential has been identified in China (230 tcf of recoverable resources) and Australia (50 tcf of recoverable resource), to name two. Table 2 summarizes the shale gas resources outside the United States that are included in the RWGTM.

The estimates for regions outside of the United States and Canada in particular are very preliminary and are thus full of uncertainty, but it is possible that estimates of commercially accessible resources in these regions will grow over time, particularly as technologies are developed to lower costs. It is also important to note that in regions where water resources are deemed scarce, the assessment included in the model is reduced, and in some cases where water constraints are extremely severe, no resources from that region are permitted into production at all. In China, for example, water availability for hydraulic fracturing may considerably diminish the potential for domestic shale development in certain regions. Figure 2 highlights these potential water availability issues in China. For example, in the case of the shale resources in western China, water constraints are likely to make shale development cost prohibitive. Such constraints might also restrict the potential of the gas-prone Sichuan Basin to a lesser extent. China has already awarded acreage to Chinese firms for shale development in Chongqing, Guizhou, and Hunan provinces.[16]

A reduction of the technically recoverable shale gas resource base in areas with potential water constraints is done primarily because the cost of development has been deemed prohibitive due to the necessity of technologies that reduce the water requirements, which may be in development but are not yet proven. It is possible, therefore, that breakthroughs in the use of things such as briny water from deep-source aquifers, top-side water recycling capability, and/or the use of super-critical nitrogen or LPGs to hydraulically fracture the shale will make much of this resource more viable at some point in the future. Indeed, the emphasis on such technologies could carry with it some environmental benefit as well.

[16] "China Holds Shale Gas Bid Round," *International Oil Daily*, July 7, 2011.

Figure 2. China Shale Resource and Water Stress Map[17]



While discussion of environmental issues related to shale gas production are beyond the scope of this study, the U.S. government might gainfully investigate the role it could play in promoting these new fracking technologies, given shale gas's positive contribution to U.S. energy security.

To the point of technical recoverability, a recent assessment performed by ARI for the EIA indicates that there are as much as 6,600 tcf of technically recoverable shale gas resource globally, with over 4,600 of that outside North America. This speaks to the nature of the shale gas resource—it is large—but assessment of commercial feasibility is still filled with uncertainty in many areas, leaving technology with a critical role to play. The full assessment identified in the ARI/EIA report is not included in this study. The properties for those identified shale resources are still under review, but a preliminary assessment indicates that the cost of development is likely much higher in certain regions, thus challenging its economic viability. For

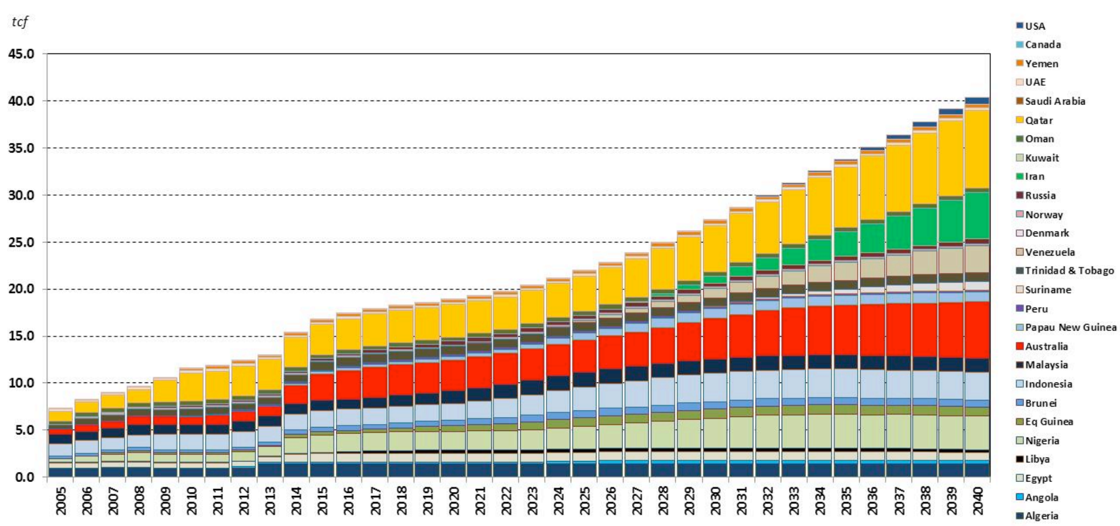
[17] Map replicated from "Natural Gas Weekly Kaleidoscope," Barclay's Capital Commodities Research (November 16, 2010).

example, shale that is clay-rich is generally not prone to yield high production rates, which in turn tends to reduce its attractiveness commercially, even if there is a large assessment of technically recoverable resource.

IV. Geopolitical Trends

Prior to the innovations that led to the recent growth in shale gas production, huge production declines were in the United States, Canada, and the North Sea. That meant an increasing reliance on foreign-sourced supplies, which, in turn, left two countries in particular with an apparent stranglehold over future supplies: Russia and Iran. Before the revelations about shale, these nations were expected to account for more than half of the world's known gas resources. Russia made no secret about its desire to leverage its position and create a cartel of gas producers—a kind of latter-day OPEC. This seemed to set the stage for a matriculation to the gas market of the oil issues that have worried the world over the past 40 years—geopolitical instability, the policing of sea lanes, and hand-wringing about the security of supply.

Figure 3. Reference Case LNG Exports (by country) to 2040



Geopolitically, the repercussions of expanding shale gas production are profound. To begin, under the Reference Case scenario where shale is developed unfettered, LNG exports originate from a wide diversity of sources instead of being concentrated in any one geographical region, and no single supplier gains significant market leverage (see Figure 3). U.S. ally Qatar remains the largest LNG exporter while Australia, notable for its strong support to U.S.-led security coalitions, emerges as a close second. Eventually, Nigeria, Iran, and Venezuela each grow to positions of prominence, collectively accounting for about 26 percent of global LNG exports by 2040. But the rise of Iran's and Venezuela's role in global gas markets occurs 20 years and 15 years, respectively, later than in Scenario Two, in which the revelations about shale are assumed to have never come to pass. The rise in U.S. shale gas supplies thereby leads to significant delays in Iran's ability to tap natural gas resources as a means of energy diplomacy, giving Tehran less leverage to use in the short run to counter U.S. diplomatic efforts at containment.

Thus, shale gas, by displacement, not only has spatial impacts on the global gas market, but also temporal impacts. More specifically, shale gas delays for well over a decade the world's reliance on regions that have historically been volatile and greatly reduces the chance of any individual or group of producers exercising decisive monopoly powers. In the United States, in particular, growth in LNG imports is put off by at least two decades.[18]

Despite the fact that the United States is less reliant on LNG due to domestic shale gas production, global LNG trade will continue to grow, largely due to demand growth in Asia, where imports are projected to be about five times the level seen in the United States by 2040. In fact, the Reference Case reveals a very different reliance on LNG across regions, ranging from very low in North America to very high in Asia (see Figure 4). In sum, the development of shale gas to the fullest extent does not hamper significant growth in global LNG trade. It just reduces American market participation as a major LNG purchaser.

The deepening of the global gas market has distinct benefits. In particular, as shown in Hartley and Medlock,[19] growth in LNG trade implies growth in physical liquidity, which increases arbitrage, allowing for shocks in one region to be transmitted to others. While this may seem undesirable, it actually mitigates the impact of any single shock. For example, a greater ability to import LNG provides European consumers a means of dealing with future disruptions in Russian supplies, or U.S. consumers a means of coping with unexpected hurricane damage. Thus, the impact of the shock on any one region is reduced through arbitrage.

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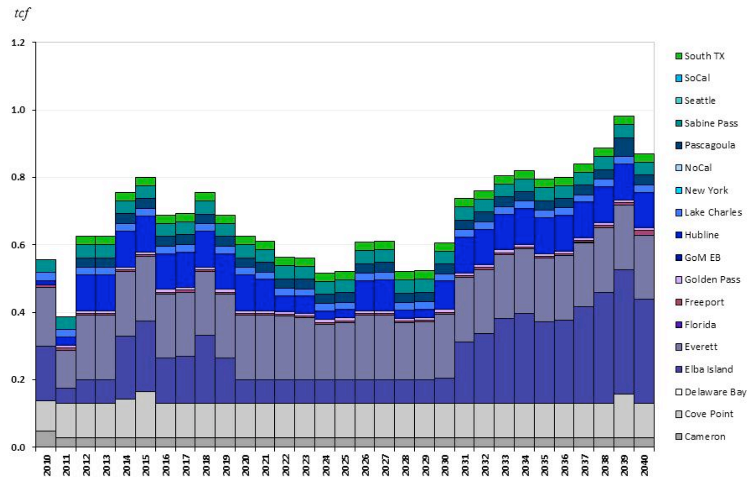
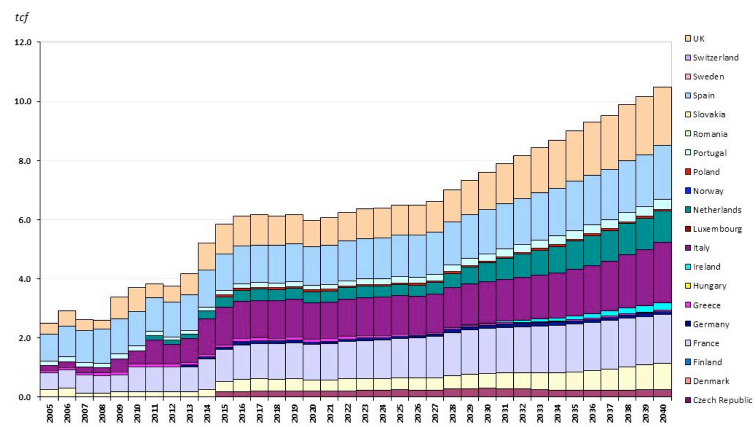
[18] Ultimately, LNG imports rise as declines in conventional resources continue and domestic production growth begins to taper. More information on the model is available upon request.

Figure 4. Reference Case LNG Imports (by country and region), 2010-2040

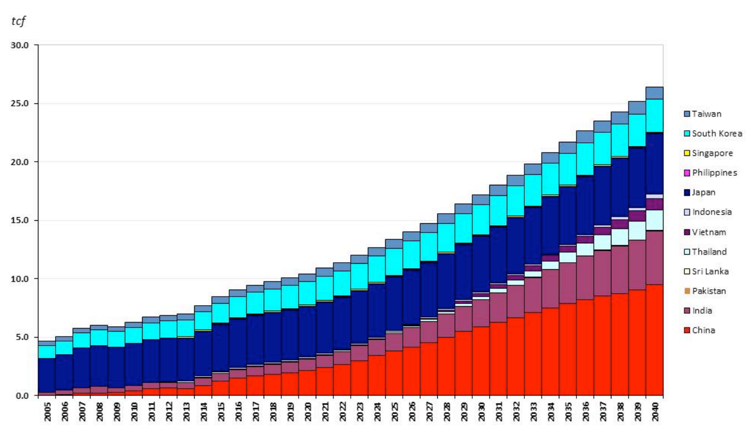
United States



Europe

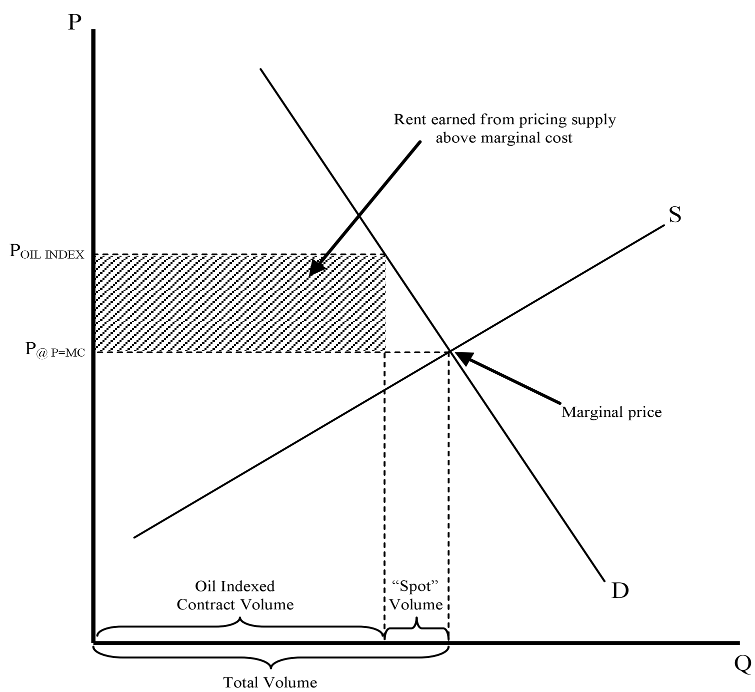


Asia



Brito and Hartley[20] show that growth in physical liquidity also limits the ability of a single supplier to price above marginal cost. The relative abundance of LNG, prompted by the dramatic growth in shale, also puts downward pressure on demand for pipeline gas supplies, meaning Europe and Asia see increased competition. Importantly, this has implications for the pricing terms at which existing and future supplies are negotiated. In fact, as the natural gas supply curve becomes more elastic, as is the case with an increasing abundance of shale gas, it will become increasingly difficult to price natural gas above marginal cost, meaning oil indexation is likely to lose some of its prominence.

Figure 5. Oil Indexation and Price Discrimination



Absent storage and physical liquidity, oil indexation provides an element of price certainty. But, to be sure, oil indexation is a form of price discrimination. Figure 5 provides an illustration of price discrimination. Note that oil indexation does not preclude the existence of spot transactions, but market structures that do not easily allow resale can severely limit them. In

[20] Peter Hartley with Dagobert Brito, "Expectations and the Evolving World Gas Market," *Energy Journal* 28, no. 1 (2007): 1-24.

Figure 5, about 15 percent of the marketed volumes are sold on a spot basis, with the remaining 85 percent contracted above marginal cost.

In general, for a firm to be able to price discriminate, (1) it must be able to distinguish consumers and prevent resale, and (2) its consumers must have different elasticities of demand. Both of these conditions are met in Europe and Asia. However, an increased ability to trade between suppliers and consumers (i.e., increased physical liquidity) leads to a violation of condition (1). This is more likely to happen as the supply curve in Figure 5 becomes more elastic (flatter).[21]

Even now, evidence of a diminished ability to price discriminate is emerging in Europe as there have been multiple announcements of changes in contractual terms, with a propensity to index at least a portion of sales to spot prices. Thus, by displacement, the increase in shale production in North America has begun to have impacts on traditional pricing mechanisms in other markets. If shale resources are proven to be commercially viable in Europe and Asia, this will accelerate, and the "new normal" could very well be characterized by more intense competition. This change will help promote the use of natural gas versus other more carbon-intensive fuels, stimulating environmental benefits.[22]

Had this competition from shale not emerged, Russia and Iran would have been dominant forces in the global market, with potentially negative geopolitical consequences for major consuming countries. The emergence of shale will not only limit the market influence of Russia and Iran but it also limits the near-term possibility of a successful natural gas cartel by increasing the elasticity of supply of natural gas in countries outside the Gas Exporting Countries Forum (GECF), thereby reducing the monopoly power that can be exerted by the GECF countries. Thus, shale gas yields security benefits more broadly than just to the United States.

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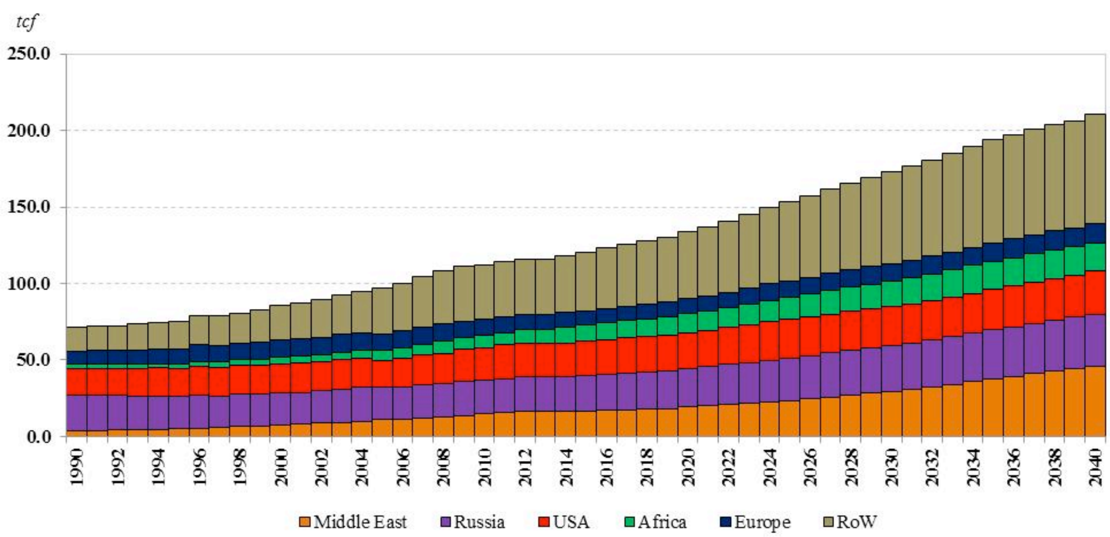
[21] This will also happen in a liberalized market where trading of capacity rights is allowed, insomuch as the arbitrage allows price signals to clearly transmit. This promotes entry and, to the extent that hubs develop, financial liquidity. Once that occurs, the means to use capital markets to underwrite physical transactions increases and liquidity grows, thus making it difficult to price discriminate.

[22] For more detailed discussion of the competition of fuels and greenhouse gas implications, see "Energy Market Consequences of an Emerging U.S. Carbon Management Policy," published by the James A. Baker III Institute for Public Policy at http://bakerinstitute.org/programs/energy-forum/publications/energy-studies/energy-market-consequences-of-an-emerging-u.s.-carbon-management-policy. Baker Institute analysis showed that the United States was likely to make a major shift away from carbon-intensive coal use to a higher proportion of consumption of domestic natural gas, easing the increase in greenhouse gases that would come about from rising U.S. energy use.

In fact, in the Reference Case, as can be seen in Figure 6, world dependence on Middle East natural gas remains below 20 percent until the late 2030s, when rising demand from Asia finally makes its mark. Reliance on Middle East natural gas is significantly lower in a world where U.S. shale gas production can grow unfettered than under Scenario Two where U.S. shale gas output is greatly constrained. In particular, in Scenario Two the Middle East supplies about 27 percent of all natural gas by 2040. By contrast, under the unconstrained shale gas case, Middle East supplies only constitute 20 percent of the market by 2040. The Middle East country that is disadvantaged the most as a result of rising shale gas production is Iran, whose exports are effectively delayed by over a decade relative to Scenario Two.

Figure 6. World Supply by Region, 1990-2040 (Reference Case)



As Figures 7 and 8 indicate, Middle East and Russian supplies play a far greater role in global gas markets under the constrained shale gas case than under the unfettered shale gas case after the mid-2020s. Under Scenario Two, in which no new shale is developed, dependence on Middle East and Russian supplies becomes substantial as production falls in other regions.

Under Scenario Two, increased production from Russia and the Middle East is needed to maintain the supply-demand balance, even though overall world demand for natural gas is also lower and prices are higher than under the Reference Case. Under Scenario Three, where U.S. production in the northern United States is constrained, the reduction in U.S. supply is largely met by increased output from Venezuela (not pictured separately), which exports a large measure of its production as LNG to the United States. Still, shale gas developments in China and Europe, if not similarly hampered by the same political/environmental constraints in the northern U.S., would make up some of the gap created by lost shale production in New York and Pennsylvania. In fact, more shale is produced in these regions in response to the slightly higher global prices induced by increased competition for LNG from the United States.

Figure 7. World Supply by Region, 1990-2040 (Scenario 2 Delta to Reference Case)

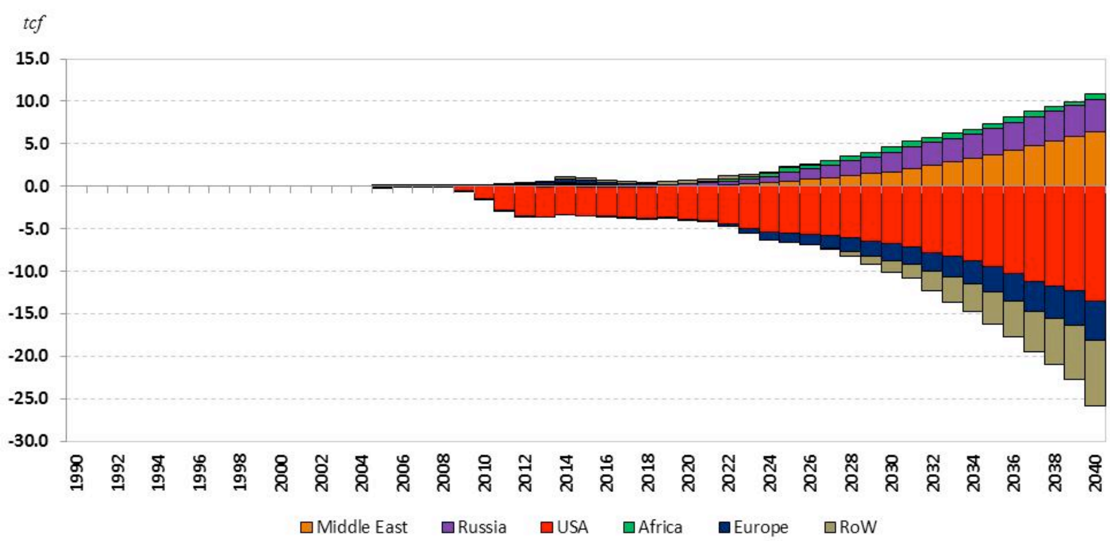
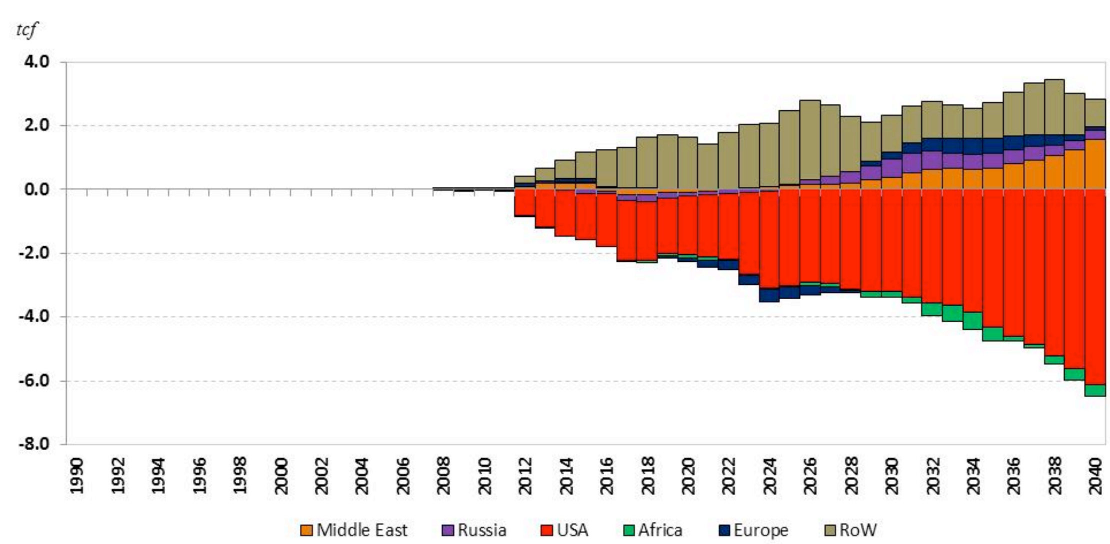


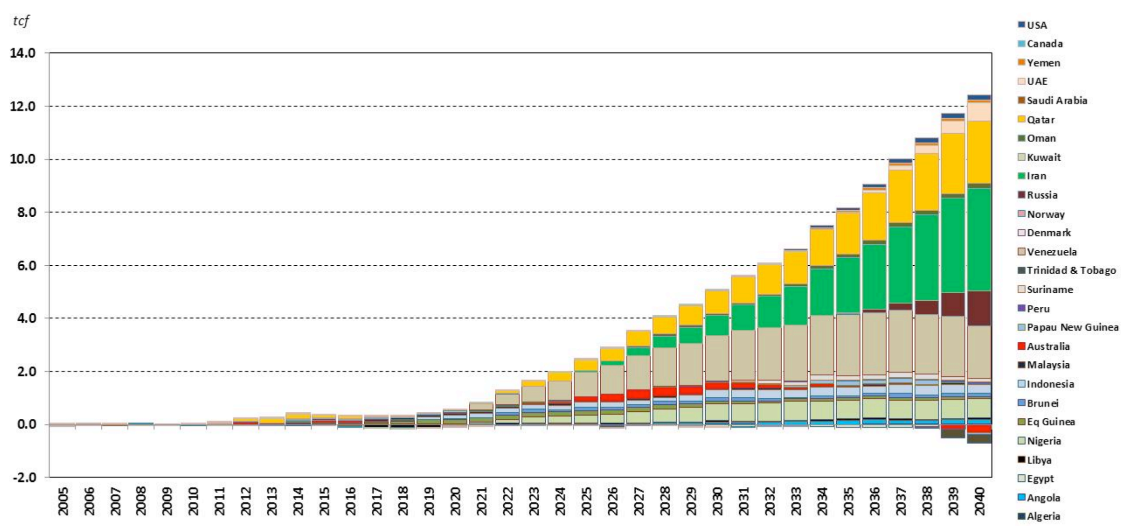
Figure 8. World Supply by Region, 1990-2040 (Scenario 3 Delta to Reference Case)



Regarding LNG, as can be seen in Figure 3 above, Reference Case LNG exports from Iran, Venezuela, Australia, and Qatar account for over 60 percent of all LNG exports by 2040, with the majority of the volumes destined for Asia. Middle East LNG shipments do not begin to grow substantially until after 2030, and LNG from Australia and Nigeria is increasingly important after 2025.

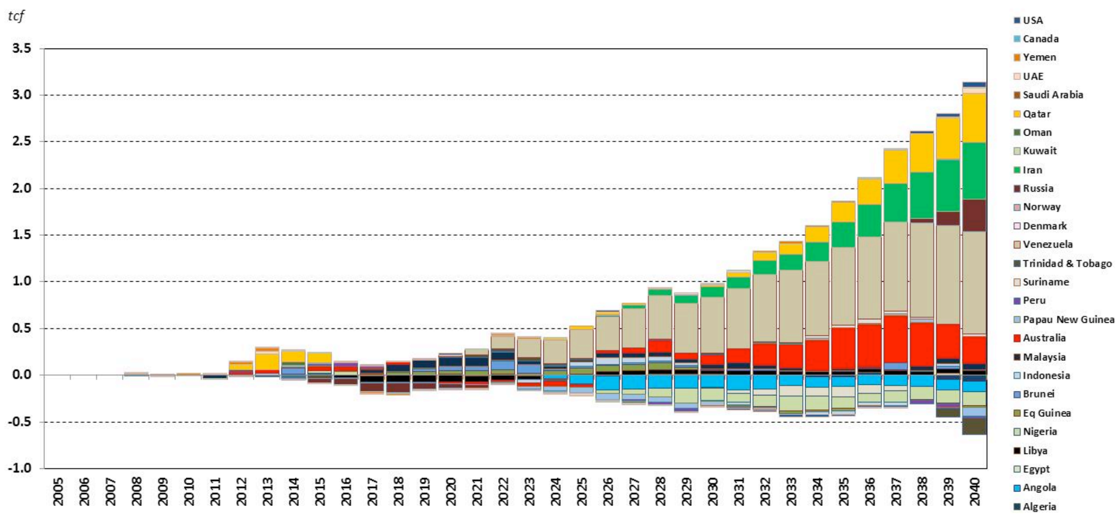
Under Scenario Two, where shale gas supply is constrained, LNG exports, especially from the Middle East, increase substantially relative to the Reference Case (see Figure 9). The largest increases are seen in Iran and Qatar. Thus, the absence of shale reveals a world that is far more dependent on Iranian LNG supplies to meet demand. Since natural gas is expected to become a pivotal fuel in meeting growing energy demands and environmental objectives, Iran becoming a crucial supplier runs counter to U.S. interests against the existing backdrop of U.S.-Iranian relations.

Figure 9. LNG Exports (Scenario 2 Delta to Reference Case)



Interestingly, in Scenario Three, the effects center on a redistribution of supplies rather than absolute increases across the board (see Figure 10). Much of this is due to the increase in pipeline exports from Russia to both Europe and Asia. Since the primary point of increased imports is the Northeastern United States, we see that Venezuela, which enjoys a transportation advantage being in the Atlantic basin, is the largest responder. Overall, Venezuela, Australia, Iran and Qatar are the biggest gainers as a result of a policy motivated reduction in supplies in the Middle Atlantic states in the U.S.

Figure 10. LNG Exports (Scenario 3 Delta to Reference Case)

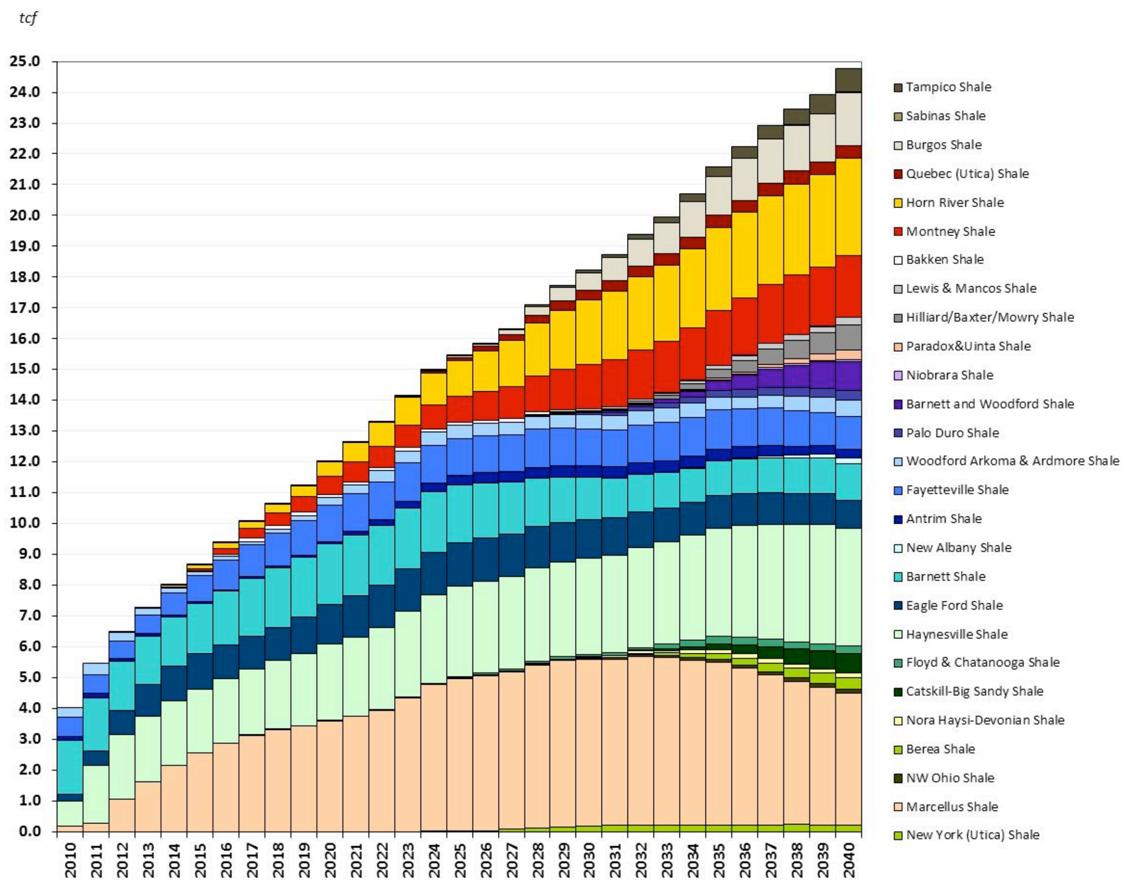


V. Geopolitical Trends: Focus on the U.S. Supply Balance

For the United States, the geopolitical impacts of rising domestic shale gas production are dramatic. Even a casual examination of projected North American shale gas production (see Figure 11) makes obvious the dramatic implications that this resource will have on the domestic supply-demand balance. U.S. natural gas imports from the Middle East are virtually nil from 2011 to 2030 under the Reference Case and then only rise modestly in the 2030s. This is in contrast to markedly higher foreign dependency conditions that might have emerged, had U.S. shale developments not occurred. In fact, under Scenario Two, U.S. LNG imports rise substantially (see Figure 12). This increased competition for global LNG supplies results in higher prices and allows greater entry by suppliers from historically volatile regions.

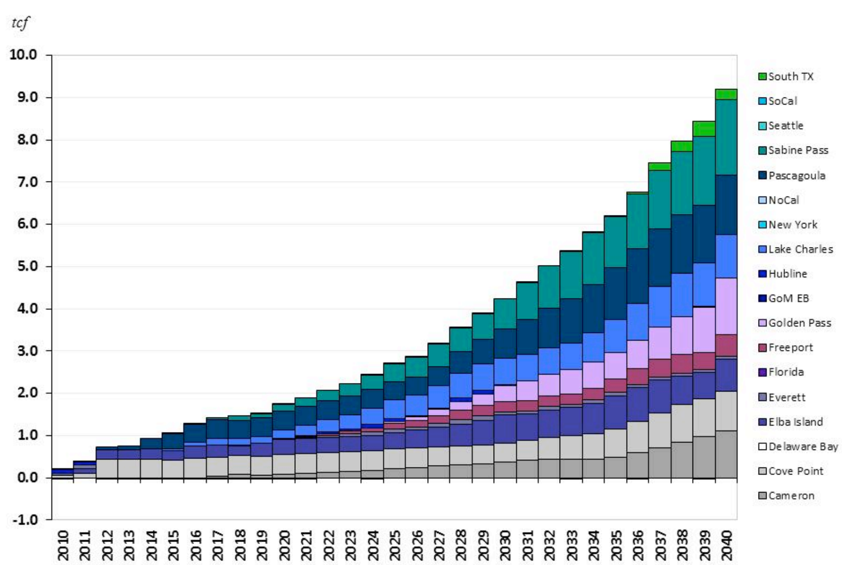
The U.S. economy already faces challenges from the high costs of importing foreign oil. Large trade deficits driven by expensive oil imports contribute to the overall weakening of the dollar, and the threat of oil supply disruptions remains a risk factor to overall economic growth and stability. Increasing U.S. exposure to events in the Middle East or Russia through rising purchases of imported LNG is a less desirable outcome than being able to rely on domestic energy supplies that are not subject to geopolitical risks and where monies paid for energy remain inside the U.S. economy. Thus, to the extent that natural gas supplies can be sourced from North America and not in the form of imported LNG, the United States is—all things considered—better off.

Figure 11. North American Shale Gas Production



The availability of cheaper, ample domestic natural gas supplies could also give the United States greater flexibility to forge policies to diversify its transportation sector away from overwhelming reliance on oil-based fuels. As seen in Figures 12 through 14 below, the price of natural gas is up to one dollar lower, and sourced domestically, when shale developments occur unfettered. The difference in both price and source can be important when trying to encourage fuel-switching, particularly if policy measures are involved. Previous Baker Institute studies have demonstrated that an effective way to reduce U.S. oil demand and foreign imports would be an aggressive campaign to launch electric vehicles into the automotive fleet.[23] Since the United States uses barely any oil to generate electricity, ample natural gas for electricity generation means a shift to electrified vehicles would lessen our dependence on imported oil at a lower cost than might otherwise have been possible. Similar benefits could come from increasing the number of compressed natural gas (CNG) vehicles or LNG vehicles. However, differences in vehicle efficiency mean that an increase in the number of electric cars would have less impact on U.S. energy markets and prices than a high penetration of CNG passenger vehicles.[24]

Figure 12. U.S. LNG Imports (Scenario 2 Delta to Reference Case)



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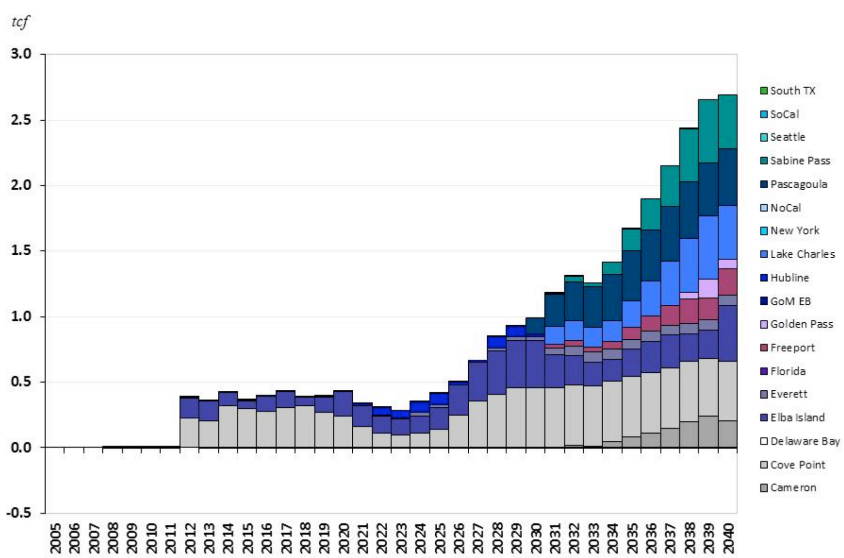
[23]See "Energy Market Consequences of an Emerging U.S. Carbon Management Strategy," available at http://bakerinstitute.org/programs/energy-forum/publications/energy-studies/energy-market-consequences-of-an-emerging-u.s.-carbon-management-policy.

[24] CNG vehicles still rely on internal combustion engine technology, which is less efficient in fuel requirements than electric vehicles, whose engines gain energy from braking and have higher operational efficiency. In fact, a recent analysis of best-in-class vehicle technologies indicates that the well-to-wheel energy efficiency of electric vehicles is roughly three-and-a-half times greater than CNG vehicles. Thus, a shift to a comparable penetration of CNG vehicles would require more energy production than the same penetration of fuel efficient electric vehicles powered by electricity generated in high efficiency natural gas combined-cycle power plants. For more detailed discussion of this point, see "Energy Market Consequences of an Emerging U.S. Carbon Management Strategy," available at http://bakerinstitute.org/programs/energy-forum/publications/energy-studies/energy-market-consequences-of-an-emerging-u.s.-carbon-management-policy.

Under the Reference Case of unconstrained shale production, low capacity utilization remains a feature of U.S. regasification capacity through the 2020s (see Figure 4 above). By contrast, LNG imports to the United States would be substantially higher under the constrained case, Scenario Two (see Figure 12). In fact, by the 2020s imported LNG represents a major component of the U.S. natural gas outlook under the constrained shale case, with resultant higher prices and greater chances of externally driven supply disruptions.

Under Scenario Three where shale gas is not developed in New York and Pennsylvania, LNG imports to the United States are also higher, although the terminals that receive the majority of the incremental volume are on the East Coast. As in Scenario Two, the increased competition for LNG results in higher prices overall, with global implications, albeit the impacts are smaller.

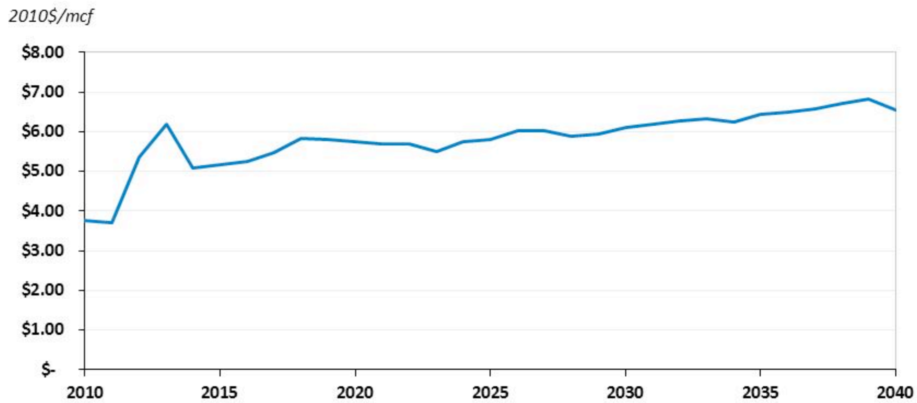
Figure 13. U.S. LNG Imports (Scenario 3 Delta to Reference Case)



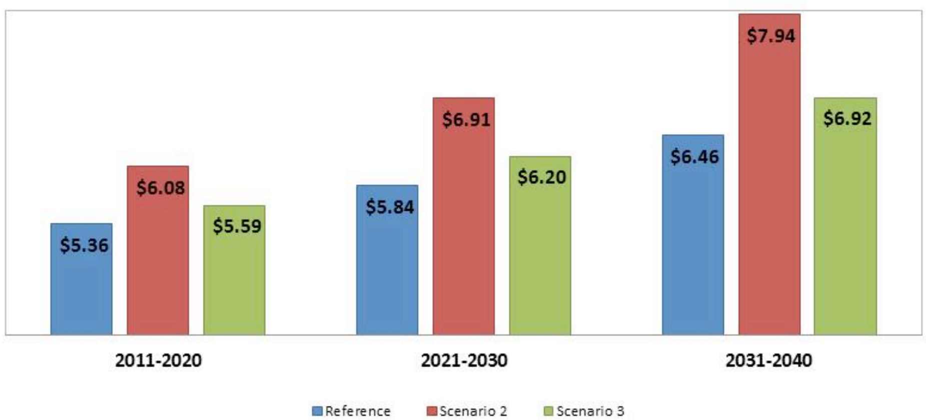
In the Reference Case, shale gas represents 60 percent of U.S. domestic production by 2040, with additional non-shale sourced supplies coming from the Rocky Mountain area (see Figure 1 above). U.S. shale production in the Reference Case is driven by strong growth in the Marcellus and Haynesville shales in particular, but growth occurs across multiple regions. The scale and distribution of natural gas production across scenarios has implications for prices throughout North America, as is evidenced by the changes in basis differentials across the scenarios examined herein (see Figure 15).

Figure 14. Henry Hub, 2010-2040

Reference Case



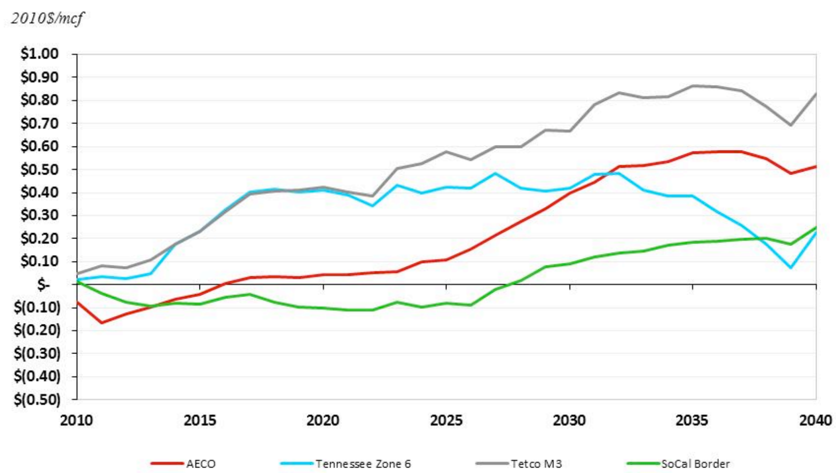
Decadal Averages across Scenarios



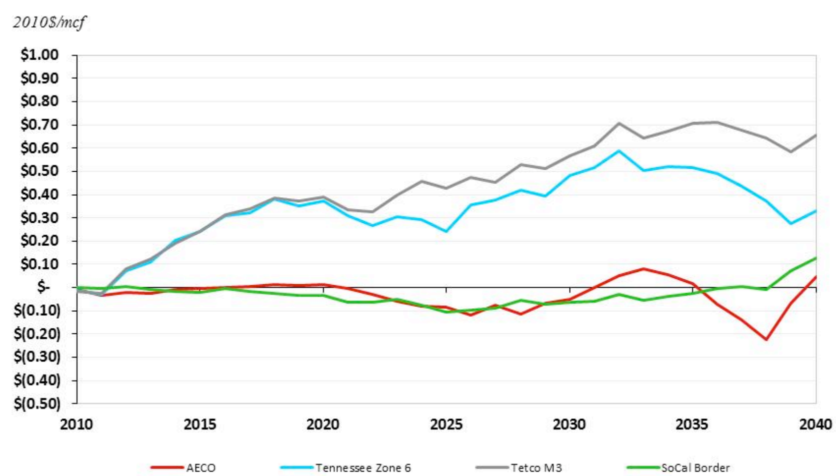
The price at Henry Hub is significantly higher in Scenario Two than in the Reference Case, approaching an average of $1.50/mcf by the 2030s. The lack of domestic production raises prices, reduces demand, and forces an increased reliance on LNG imports. In Scenario Three, while LNG import dependence rises due to lower domestic production, the price at Henry Hub is increased by an average of just under $0.50/mcf by the 2030s. Most of the price impact in Scenario Three is regional because shale developments in Texas, Louisiana, Arkansas, and Oklahoma are assumed to continue. As a result, the price impact in those states is smaller as production responds positively (not pictured) and long haul pipeline capacity to the Middle Atlantic and Northeast states is utilized more heavily.

Figure 15. Select Regional Impacts on Basis to Henry Hub

Scenario 2



Scenario 3



In the case with no new shale production (Scenario Two), there is considerable strengthening of price in most locations (see Figure 15). In contrast, Scenario Three reveals strong price impacts in the regions closest to where shale production is not allowed, meaning there is a more substantial price impact in the Middle Atlantic and Northeast, which can be seen by the changes in basis in those regions (see Figure 15). This has implications for the competitiveness of natural gas when it comes to meeting stated environmental objectives. In particular, the likelihood of gas displacing older coal-fired power plants in the dispatch order is diminished when shale developments are inhibited in the region.[25]

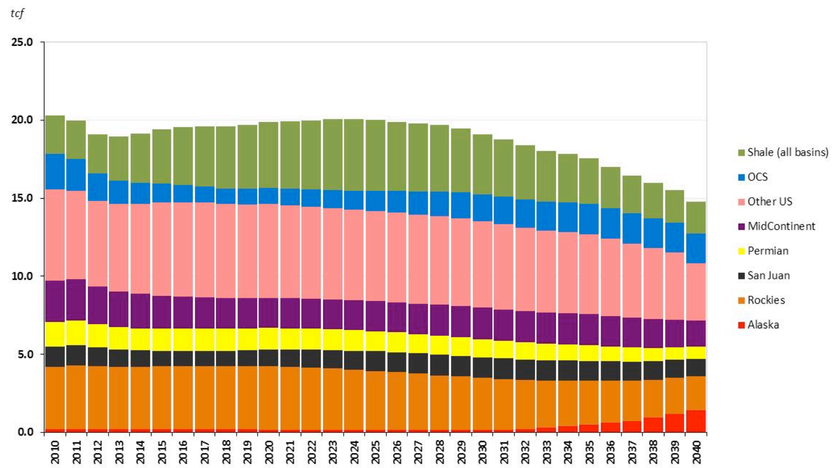
The shift in the no-shale "counterfactual" case to higher prices and greater LNG imports is, as the description of Scenario Two suggests, the result of a dramatically different domestic production outlook. Figure 16 summarizes the U.S. production outlook for both Scenarios Two and Three. Recall, shale production in some regions, particularly those with activity already underway in 2005 (i.e., Barnett and Fayetteville), is present in Scenario Two, while new developments are allowed to occur in Scenario Three except in New York, Pennsylvania, and Ohio. In Scenario Two, the fact that no new shale developments are allowed to occur results in the continued steady declines seen in Figure 16, which contrast greatly with the Reference Case result indicated in Figure 1 above. The trend in Scenario Three is flat, which is facilitated by strong production in the Barnett, Fayetteville, Haynesville, and Eagle Ford shales in particular.

We see that Scenario Two reveals the kind of world that many were expecting to eventuate just a decade ago. In fact, the inexorable domestic production declines that many expected in the early 2000s would likely have occurred if shale gas development had been restricted to the Barnett and Fayetteville shales, leaving Americans to pay higher prices for natural gas supplies and rendering America far more dependent on LNG imports. These results mean that were shale to be barred from the market, there would be negative implications for U.S. energy security. In both Scenarios Two and Three, two countries with a historically adversarial stance toward U.S. interests—Iran and Venezuela—play a larger role in meeting rising global LNG demand. In addition, the resultant high natural gas prices create negative environmental repercussions since natural gas' potential role in meeting any CO_2–related environmental objectives would be greatly reduced.

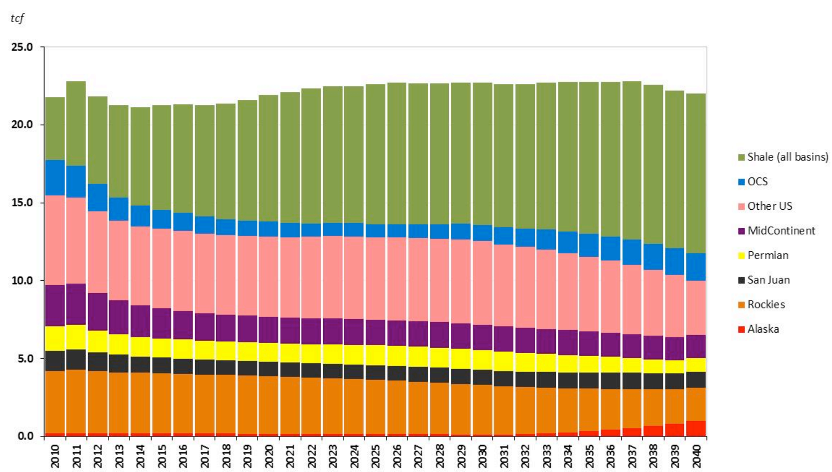
[25] See the Baker Institute study, "Energy Market Consequences of Emerging Renewable Energy and Carbon Dioxide Abatement Policies in the United States," available at http://www.bakerinstitute.org/publications/CarbonHartleyMedlock-Final%20with%20cover%20092410%20secured%20.pdf.

Figure 16. U.S. Natural Gas Production to 2040 (Scenarios 2 and 3)

Scenario 2



Scenario 3



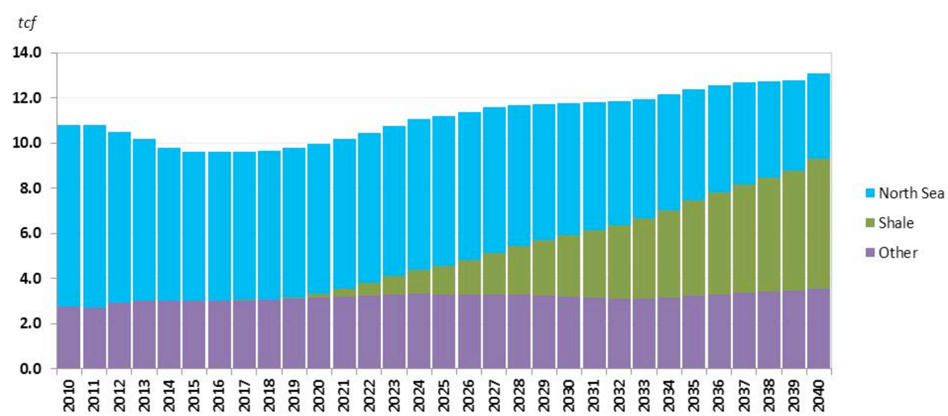
VI. Geopolitical Trends: The Outlook for Russian Exports

Given the impacts across scenarios already highlighted, it is quite obvious that shale development has already had, and will continue to have, significant impacts on regional production, demand, and pricing. Shale gas development has already had a major impact on Russia's status as a global gas exporter and will bring about a more dramatic weakening of Russia's position in Europe over time. If the shale potential now being examined in Europe and Asia reveals any resemblance to what has come to fruition in North America, the impact will be potentially far reaching. In particular, it will carry implications for U.S. allies in Europe, who face a litany of energy security dilemmas surrounding the delivery of natural gas from Russia, North Africa, and the Middle East.

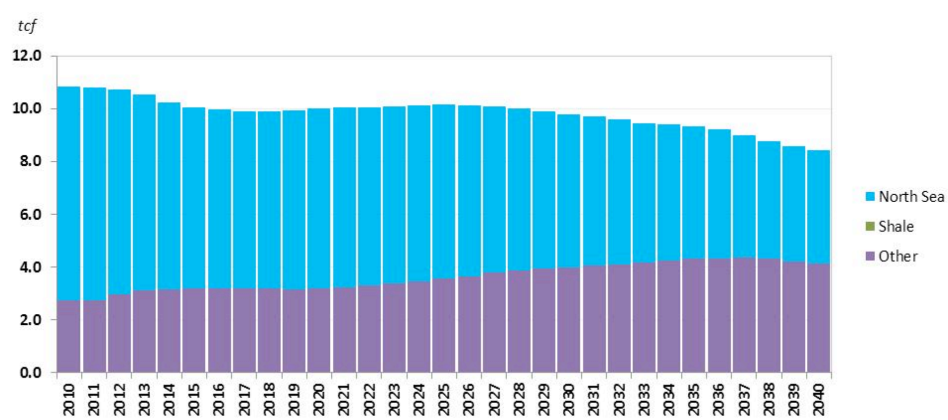
In fact, had the shale play not emerged as a major new source of supply for North America, Europe's dependence on Russia would have remained a major feature of global gas markets and natural gas geopolitics. Local shale gas eventually becomes a major feature of European supply under the Reference Case, following the North America example, but this would not have occurred had shale gas been limited to the Barnett shale play (see Figure 17).

Figure 17. Europe Natural Gas Production to 2040 (Reference Case and Scenario 2)

Reference Case



Scenario 2



Under the Reference Case, Russian exports continue to grow, but the main destination for export growth is the Far East. The prime means of exports from Russia to the Far East is via the development of pipeline transport routes in both West and East Siberia. In particular, the case sees development of the Altai project from West Siberia to western China as well as pipeline development from Sakhalin and Kovykta beginning in 2014. While under this case Russian volumes to Europe decline only slightly, Russia's market share in non-FSU Europe continues to erode, declining to less than 13 percent by 2040 (see Figure 18). None of the proposed Russian pipelines aimed at feeding the European market, except Nord Stream, are developed. Russian LNG exports from Murmansk, tied to the development of fields in the Barents Sea, and development of resources and LNG export capability from the Kara Sea and Yamal peninsula, do not occur well after 2030. These are clear signals of the lack of demand for Russian Arctic gas resources in particular.

The dramatic lessening of Europe's dependence on Russian gas will likely have considerable geopolitical implications in thwarting Russia's ability to exercise an "energy" weapon or to unduly influence political outcomes on the Continent. European buyers will have ample alternatives to Russian supplies, thereby reducing Moscow's political leverage. This outcome would also contribute positively to the balance of power between Russia and the EU, putting Europe in a stronger position to influence Russian foreign policy near Europe's borders. To wit, Europe's high dependence on Russian pipeline natural gas supplies made it difficult for certain European leaders to engage in diplomacy objecting to Russia's invasion of Georgia in 2008[26] and weakened their support of the shaky election of pro-Western Ukrainian president Viktor Yushchenko, who was negatively targeted by Moscow for his anti-Russian stances.

A more diverse energy supply for Europe enhances U.S. interests by buttressing Europe's abilities to resist Russian interference in European affairs and help border states in the Balkans and Eastern Europe assert greater foreign policy independence from Moscow. U.S. coalitions with European nations are an important element to U.S. national security, including efforts to combat international terrorism and prevent humanitarian crises. An energy-independent Europe will be better positioned to join with the United States in global peacekeeping and other international initiatives that might not have the full support of Russia.

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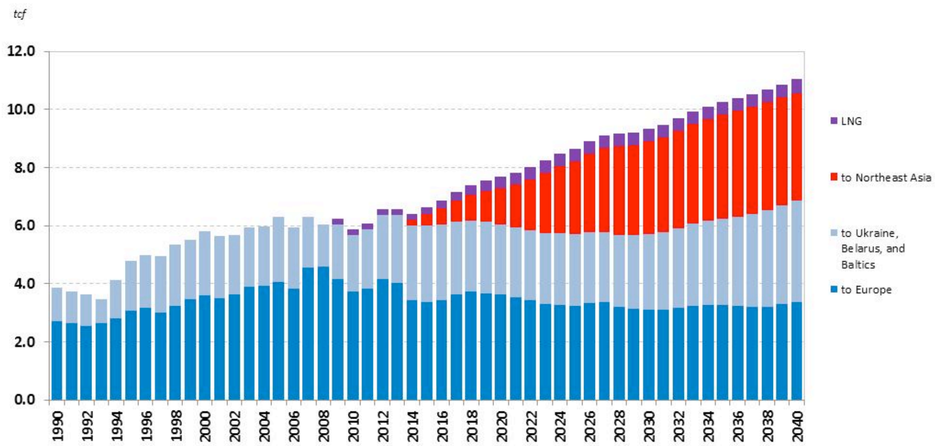
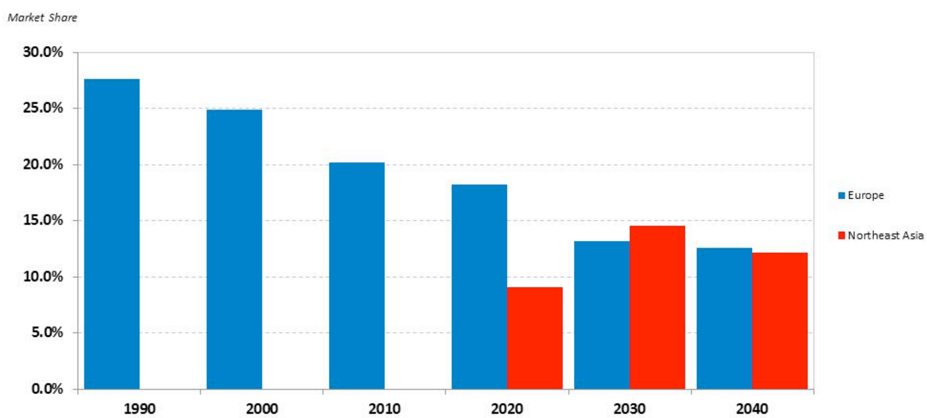
[26] Germany opposed sanctions against Russia in the aftermath of its invasion of Georgia, and German Chancellor Angela Merkel traveled for meetings in St. Petersburg, Russia in December 2008 and made it clear in a joint press conference that Germany opposed placing the Ukraine and Georgia on the path to NATO membership, despite American pressure in the opposite direction. http://www.stratfor.com/weekly/20081006_german_question. Other European nations, including Italy, also failed to condemn the Russian military action.

Figure 18. Russian Exports, 1990-2040 (Reference Case)

Exports



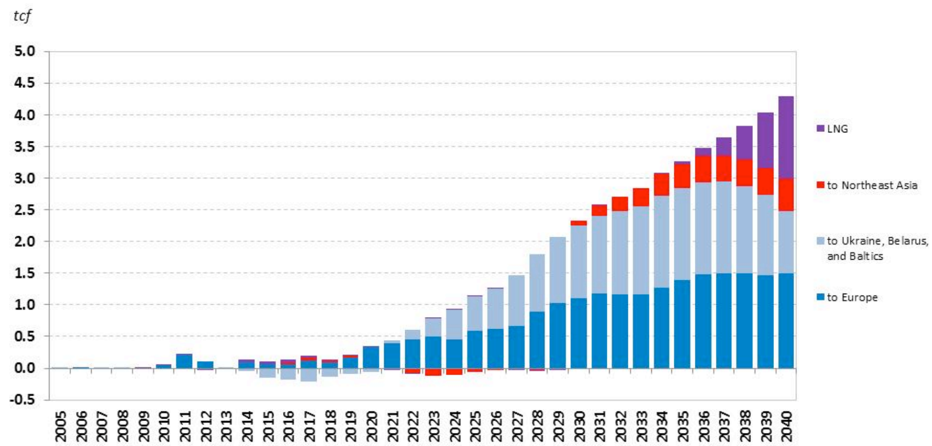
Regional Market Share



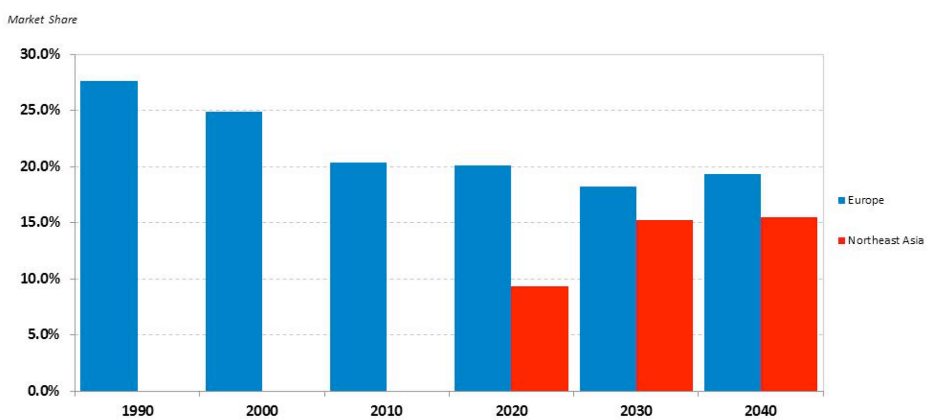
Russia's footprint in Northeast Asia (defined here as China, Korea, Japan, and Taiwan) grows as pipeline export opportunities increase, even as shale gas developments begin in Asia. However, Russia's market share in Northeast Asia only increases to 13 percent by 2040, again giving it less geopolitical sway than if exports are higher. Importantly, the assessments for shale gas resources in China are highly preliminary. In fact, if shale gas resources prove to be as robust in China as they are in North America, the outlook for Russian gas to Northeast Asia would dim significantly. Although not analyzed explicitly herein, research is underway at the Baker Institute to assess the implications of these and other potential Asia-centric developments on global gas markets.

Figure 19. Russian Exports, 1990-2040 (Scenario 2)

Scenario 2 delta to Reference Case



Market Share



In stark contrast to the Reference Case, if no new shale is developed (Scenario Two), Russia is by the far the biggest winner both in geopolitical terms and in terms of improvements in market share (see Figure 19). With less competition from emerging shale resources, Russia's market share in non-FSU Europe remains at more than 20 percent into the 2020s and stabilizes at around 19 percent longer term. Moreover, Moscow benefits from higher European prices. In Northeast Asia, Russia's market share increases to about 16 percent as it takes advantage of greater competition for LNG from the United States and develops greater pipeline capacity to meet growing demands in China, in particular.

VII. Implications for Caspian Infrastructure and Resources

The Nabucco pipeline project has been discussed for over a decade as a further solution to diversifying the EU's access to diverse natural gas supplies from Central Asia and Iraq. An intergovernmental agreement for the project was signed by Turkey, Romania, Bulgaria, Hungary and Austria in July 2009, and was intended to both reduce Europe's dependence on Russian gas as well as create new transportation outlets for Caspian resources, thereby strengthening the political links between the Caspian nations and the EU. The 2,050 mile-long pipeline was aimed to carry 1.1 tcf of gas a year from the Middle East and the Caspian to Europe. However, the high expense of the project and doubts about the viability and timing of gas supplies have presented the project with substantial obstacles.[27]

But given possible scenarios for the rise of alternative supplies to Europe as shale gas production accelerates, it becomes further unclear whether the Nabucco project will make either geopolitical or commercial sense. Ultimately, the availability of shale gas under the Reference Case scenario means that Caspian flows will not make economic sense as competing supply to Europe. Rather, under the Reference Case, the Nabucco pipeline project is not constructed until after 2020, at which time lower-cost Iraqi gas would be able to flow into the line. It should be noted that for the purposes of this modeling exercise, it is assumed that political and other obstacles will prevent Iraqi natural gas to be available in large quantities until 2020.

In July 2011, Iraq initialed a $17 billion Shell-led joint venture that would capture flared natural gas from Iraq's southern fields for use in domestic markets and eventual export, but political delays continue to plague natural gas development. The deal, which still needs government approvals, will continue to fall under intense scrutiny because of its intent to facilitate the export of Iraqi gas. Major social protests in Iraq have focused squarely on the country's severe shortages of electricity, leading many politicians to back off any suggestions for programs that would favor natural gas exports over provision of domestic electricity services. This is calling into question whether it will be politically feasible to mount a major gas export initiative in Iraq any time soon. There are legal and economic aspects of the deal that must be sorted out as well, particularly since the country's new oil and gas law has been stalled for two years and because

[27] Judy Dempsey, "European Pipeline Project Faces Formidable Obstacles," *New York Times*, March 7, 2011.

under the old oil and gas law passed in Saddam Hussein's regime, only SOMO is allowed to export natural gas or crude oil.[28] Baghdad has tentatively delayed its fourth bid round tender for exploration for natural gas until early 2012. The gas-rich Anbar region is also pursuing its own provincial-level oil and gas exploration deals, which could also complicate future natural gas resource development and export plans.

While we see the fate of Nabucco squarely focused on the availability of Iraqi gas in the Reference Case, this result is little changed in Scenarios Two and Three, with Iraqi gas exports rising only slightly (less than 10 percent) from the Reference Case to the constrained shale cases. This is indicative of the large commercially attractive volumes of conventional gas available in Northern and Western Iraq and the fact that those resources are relatively high in the merit order (low cost) for emerging gas consumers in southeast Europe.

This Iraqi result is in stark contrast to outcomes for gas sourced from both Turkmenistan and Azerbaijan where shale is a definitive factor influencing the development of outlets for Caspian natural gas exports. Gas supplies from Turkmenistan are about 15 percent greater in Scenario Two where no new shale development is permitted, a result driven by a greater need for gas supplies from both Asia and Europe. In fact, the constrained shale case sees the majority of incremental Turkmen exports flow to China, largely because the increased competition for LNG from the U.S. puts China in a position of securing more of its supply from pipeline sources.

Natural gas exports from Azerbaijan are also disadvantaged by shale gas developments, dropping by just over 10 percent when shale is developed unfettered. Thus, Azerbaijan is the exporter most hurt by the advent of shale gas because it closes its opportunity to export its supply via a Nabucco-type project. All together, shale gas development impacts gas suppliers from FSU countries in the Caspian region similar to the manner in which it impacts Russia—lower production and reduced market share in end-of-pipe markets in Asia and Europe.

The implications for U.S. foreign policy of the negative impact on the Nabucco project from shale gas availability are complex. First and foremost, the United States needs to better articulate what its goals are for backing of the Nabucco project. If the primary purpose of the Nabucco line

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[28] "Shell Iraq Natgas Venture Delayed by Legal Issues," *LNG Intelligence*, Energy Intelligence Group, February 16, 2011.

is to diversify European supply away from heavy dependence on Russian gas exports, chances are shale gas availability will remove the primary impetus toward this aim, making Nabucco a relatively unimportant geopolitical priority and arguing for the United States to abandon its proactive support for the pipeline. Instead, the United States may want to focus more on Nabucco's potential as a conduit for economic development of Western Iraq and solidifying Iraqi relations with the West. In this case, the commercial realities will be under less duress from the changing economics brought to Europe by the wider availability of shale gas, and it is more feasible that the line might make sense at some later date once Iraqi gas is ready to flow amply and securely.

However, shale gas plays will mean that the EU and the United States will have greater difficulty developing energy corridors to link the Caspian region countries more closely to the West, and therefore other economic and political avenues will need to be developed to achieve this geopolitical goal, as natural gas exports are unlikely to play a major role in strengthening ties between the two regions.

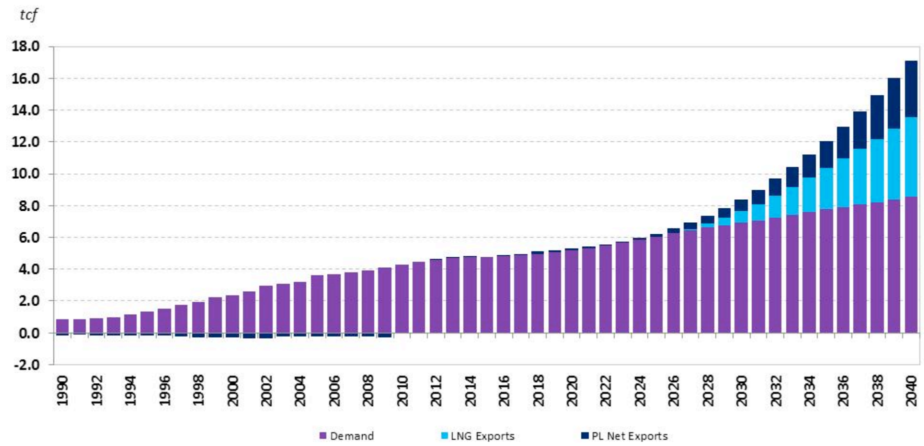
VIII. Geopolitical Trends: Implications for Iran

At the present time, economic sanctions against Tehran have been inhibiting natural gas export project development in Iran. This includes both its previously planned South Pars LNG export projects and a proposed pipeline to Pakistan and India. With no signs of conflict resolution between Iran and the West in sight, it is assumed that the development of Iranian export projects could not begin until 2020 at the earliest.

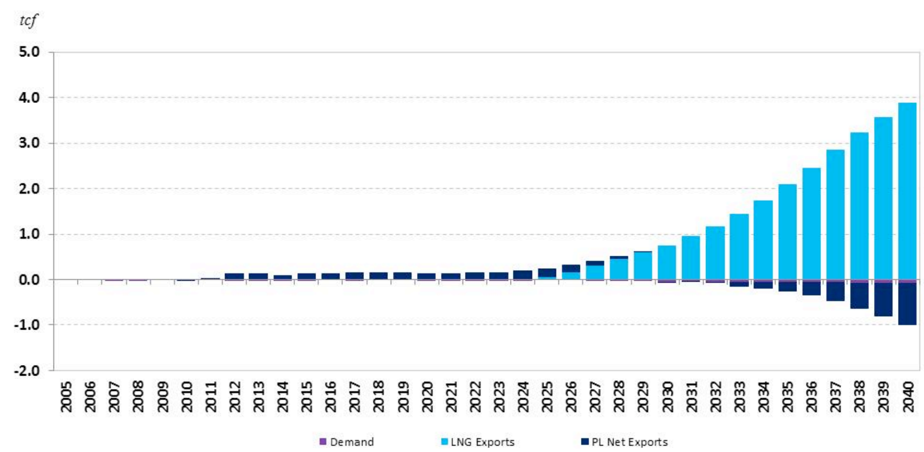
Greater shale gas production in the United States, and eventually Europe, will also make it more difficult for Iran to profit from exporting natural gas. Since Iran is currently hampered by Western sanctions against investment in its energy sector, by the time it can get its natural gas ready for export, the marketing window to Europe will likely be closed by the availability of shale gas. This reality may give the United States and its allies more leverage over Iran for a longer period of time, helping to shape outcomes in the Middle East more positive for U.S. and allied interests.

Figure 20. Iranian Supply Disposition

Reference Case



Scenario 2 delta to Reference Case



Iran is more likely to become a much larger exporter in the case in which no new shale is developed (Scenario Two), primarily because of greater LNG demand from the United States. In the Reference Case, Iran only emerges as an LNG exporter in the late 2020s and its market position is more limited. However, in the constrained shale case (Scenario Two), Iranian LNG exports grow more quickly and, by 2040, they are about 75 percent higher than in the Reference Case. Thus, shale gas plays an instrumental role in delaying the opening for Iran to sell its natural gas, thwarting its ability in the near term to use natural gas exports as a means to develop bilateral relations with major gas consuming countries and limiting its opportunity to use energy diplomacy to strengthen its regional position[29] or buttress its pursuit of nuclear weapons.

Although there are many complex factors that influence Iran's political leverage globally, the circumstance of lower requirements for Iranian natural gas could make it easier for the United States to achieve buy-in for continued economic sanctions against Iran. Lower interest in Iranian gas reduces the chances that Iran can use its energy resources to drive a wedge in the international coalition against it. By delaying the need for Iranian gas by over a decade, the United States buys time to find a better solution to the Iranian nuclear problem and leaves open the possibility that political change will take place in Iran before its influence as a major global natural gas supplier grows. In addition, the long delay in the commerciality of Iranian gas means that Tehran will have trouble getting Asian pipelines to India or Pakistan off the ground with mutually acceptable terms, thereby reducing—for at least the time being—a potential source of tension between the United States and India.[30]

VIII. Geopolitical Trends: Implications for Chinese Energy Security

Under all scenarios, China becomes a major importer of natural gas both via pipeline and LNG. In fact, China is the largest driver of growth in LNG trade going forward under all scenarios. This makes the question of Chinese demand growth a pivotal one when analyzing the geopolitics of natural gas. Although not addressed herein, the Baker Institute is engaged in a separate study that considers the impact of Chinese demand growth, domestic supplies, and import supply options on global gas market developments. Like the United States, China benefits from growing shale gas production, which reduces its overall reliance on potentially volatile Middle East suppliers such as Iran.

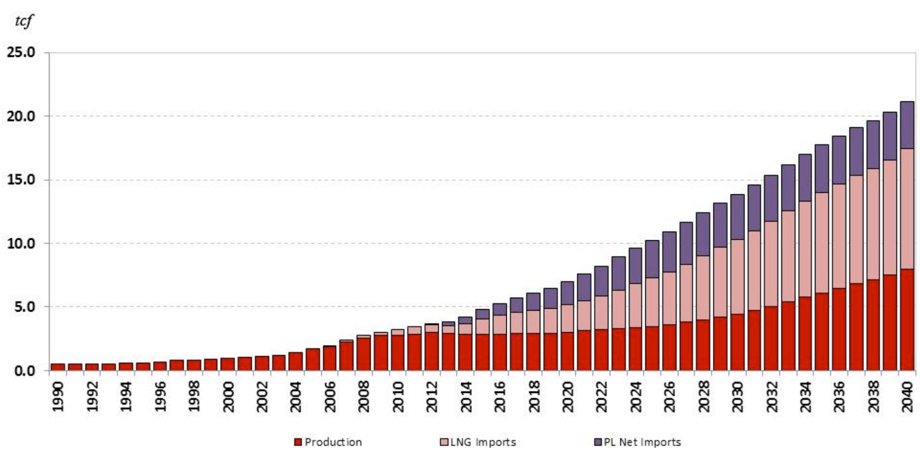
[29] Iran has cultivated bilateral relations with important countries such as China and Turkey by offering upstream investment deals in its natural gas industry. China's state CNPC is involved both in Phase 11 at Iran's giant South Pars gas field and also in the South Azadegan project.

[30] India reshuffled its cabinet in 2006, removing then-petroleum minister Mani Shankar Aiyar, who was known for his support of the India-Pakistan-Iranian (IPI) pipeline. His removal paved the way for improved U.S.-India relations, according to Indian press reports. In recent years, India has stopped negotiations regarding the pipeline project due to tension with Pakistan.

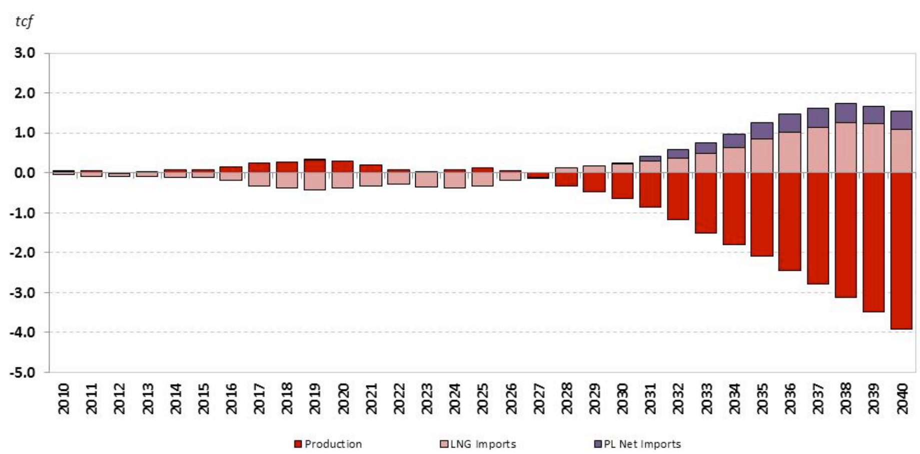
The case in which no new shale is developed (Scenario Two) drives an increase in Chinese imports from both pipeline and LNG, and a decline in domestic production due the removal of shale gas. Higher prices also result in this scenario, which slows Chinese demand growth somewhat. Nevertheless, the scale of the changes in resulting in Scenario Two is dwarfed by the scale of demand and import growth indicated in the Reference Case.

Figure 21. Chinese Supply Disposition through 2040

Reference Case



Scenario 2 delta to Reference Case



However, in all cases examined herein, strong Chinese demand for natural gas leads to the strengthening of energy ties between Russia and China. Although this is not necessarily directly against U.S. interests, it could nonetheless make it more difficult for the United States to promote U.S.-China energy cooperation. China may be less interested in strong bilateral or multilateral consumer energy relations involving the United States if it has strong pipeline-oriented dependencies. One can also imagine that a deeper relationship between China and Russia in general might influence the balance of power in Northeast Asia in a manner that is detrimental to U.S. allies in the region.

IX. Shale Gas and Geopolitics: Concluding Thoughts

This Baker Institute study on U.S. energy security has examined some of the geopolitical consequences of rising supplies of natural gas from shale and the implications for U.S. security and foreign policy.

The study finds that full development of commercial shale gas resources in the United States will have multiple beneficial effects for U.S. energy security and national interests. The full and timely development of U.S. shale gas resources will limit the need for expensive imports of LNG, reducing the energy-related swelling of the U.S. trade deficit and thereby helping to strengthen the U.S. economy. Shale gas will also lower the cost to average Americans of reducing greenhouse gases as the country switches to cleaner fuels. Moreover, as greater shale gas production creates greater competition among suppliers in global markets, U.S. and international prices for natural gas are kept from rising substantially. Increased competition among world natural gas suppliers due to shale gas developments also reduces the threat that a Gas-OPEC can be formed, and it will trim the petro-power of energy producing countries such as Russia, Iran, and Venezuela to assert themselves using an “energy” weapon or “energy diplomacy” to counter U.S. interests abroad. In particular, shale gas’ role in global markets will greatly reduce Russia’s leverage over Europe, eventually limiting Moscow’s share of the non-FSU European market to less than 13 percent, down from its recent peak of 26 percent in 2007.

The dramatic lessening of Europe’s dependence on Russian gas will likely reduce Russia’s ability to unduly influence political outcomes. European buyers will have ample alternatives to Russian supplies, thereby reducing Moscow’s leverage in the balance of power between Russia and the EU. Europe’s high dependence on Russian pipeline natural gas supplies has in recent years made it difficult for certain European leaders to engage in diplomacy to forcefully object to Russian interference on the European continent, including Russia’s invasion of Georgia in 2008. A more diverse energy supply for Europe enhances U.S. interests by buttressing Europe’s abilities to resist Russian interference in European affairs and help border states in the Balkans and Eastern Europe assert greater foreign policy independence from Moscow. In general, a more energy independent Europe will be better positioned to join with the United States in global matters that might not have the full support of Russia.

Rising U.S. shale gas supplies will also assist the United States in its policies toward Iran. Given global market economics under a full development of shale scenario, the commercial window for Iran to export large amounts of natural gas is likely to be closed for an additional 20 years, making it easier for the United States to achieve buy-in for continued economic sanctions against Iran. Shale gas development lowers the chances that Iran can use its energy resources to drive a wedge in the international coalition against it. By delaying the need for Iranian gas, the United States buys time to find a better solution to the Iranian nuclear problem and leaves open the possibility that political change will take place in Iran before its influence as a major global natural gas supplier grows. In addition, the long delay in the commerciality of Iranian gas means that Tehran will have trouble moving forward with the development of pipelines to India or Pakistan until at least the mid-2020s, thus reducing a potential source of tension between the United States and India.

Finally, the rise of shale gas will lower the global requirements for natural gas from volatile Middle East and North Africa over the next few years, giving the region time to sort out its current political and social turmoil before its importance as an energy supplier grows from already high current levels.

Natural gas stands to play a positive role in the global energy mix, making it easier to shift away from more polluting, higher carbon-intensity fuels and increasing the near-term options to improve energy security and handle the challenge of climate change. The ample geologic endowment of shale gas in North America and potentially elsewhere around the globe means that natural gas prices will likely remain affordable and that the high level of supply insecurity currently facing world oil supplies could be eased by a shift to greater use of natural gas without fear of increasing the power of large natural gas resource holders such as Russia, Iran, and Venezuela.

To tap this benefit, it will be essential for the United States to promote a stable investment climate with regulatory certainty. In particular, the United States will need adopt policies that ensure shale gas exploitation can proceed steadily and predictably with sound environmental oversight. The United States should focus squarely on setting the policies needed to ensure that shale gas can play a significant role in the U.S. and global energy mix, thereby contributing to greater diversification of global energy supplies and to the long-term national interests of the United States.

Appendices

Reference Case Demand (*units: tcf*)

	2010	2015	2020	2025	2030	2035	2040
WORLD	**109.7586**	**117.7645**	**130.6200**	**150.1043**	**169.5490**	**189.8743**	**206.6328**
AFRICA Total	**3.6968**	**4.1719**	**4.9538**	**6.1668**	**7.6399**	**9.1707**	**10.4383**
Algeria	1.0490	1.1111	1.2185	1.3611	1.5445	1.8408	2.1875
Angola	0.0331	0.0257	0.0256	0.0323	0.0428	0.0579	0.0763
Egypt	1.3595	1.5695	1.8748	2.3878	3.1275	3.7149	4.1889
Libya	0.2664	0.2589	0.2795	0.3228	0.4037	0.4513	0.4850
Morocco	0.0020	0.0046	0.0084	0.0136	0.0192	0.0256	0.0310
Nigeria	0.4370	0.5583	0.7140	0.9415	1.1610	1.4236	1.6165
Other Africa	0.3885	0.4446	0.5873	0.8170	1.0143	1.2990	1.4721
Tunisia	0.1613	0.1993	0.2457	0.2906	0.3269	0.3576	0.3810
ASIA Total	**8.4015**	**10.8465**	**14.1177**	**19.0366**	**24.6538**	**30.7462**	**36.2930**
Afghanistan	0.0015	0.0026	0.0041	0.0066	0.0102	0.0155	0.0215
Bangladesh	0.6043	0.6870	0.7640	0.8475	0.9417	1.0307	1.1326
China	3.2180	4.7961	6.9990	10.2173	13.8373	17.7154	21.1646
India	1.6628	2.1780	2.8434	3.9498	5.3045	6.7605	7.8936
Myanmar	0.1434	0.1460	0.1655	0.1953	0.2359	0.2904	0.3390
Nepal	0.0009	0.0011	0.0016	0.0023	0.0028	0.0033	0.0039
Pakistan	1.1606	1.3450	1.5649	1.8714	2.1505	2.4705	2.9738
Sri Lanka	0.0000	0.0000	0.0042	0.0064	0.0091	0.0124	0.0161
Thailand	1.3437	1.4036	1.4497	1.5620	1.6755	1.8233	1.9784
Vietnam	0.2664	0.2872	0.3214	0.3780	0.4864	0.6242	0.7695
PACIFIC Total	**9.7289**	**11.1584**	**12.5197**	**14.3451**	**15.8386**	**17.1992**	**18.2537**
Australia	1.0988	1.3366	1.4064	1.6949	1.9503	2.2209	2.4996
Brunei	0.1242	0.1216	0.1224	0.1271	0.1370	0.1501	0.1624
Indonesia	1.3025	1.4882	1.7227	2.2344	2.6822	3.0554	3.2846
Japan	3.7235	4.0140	4.2997	4.5641	4.7292	4.8884	5.0602
Malaysia	1.0456	1.2390	1.4558	1.6902	1.8950	2.0593	2.2055
New Zealand	0.1527	0.1731	0.2146	0.2160	0.2196	0.2372	0.2628
Papau New Guinea	0.0050	0.0103	0.0119	0.0154	0.0186	0.0233	0.0281
Philippines	0.1285	0.1784	0.2118	0.2551	0.2969	0.3320	0.3580
Singapore	0.3343	0.3933	0.4360	0.4901	0.5318	0.5560	0.5632
South Korea	1.3600	1.6547	1.9815	2.2757	2.4897	2.6913	2.7614
Taiwan	0.4528	0.5480	0.6555	0.7802	0.8861	0.9823	1.0644
SOUTH AMERICA Total	**5.0473**	**5.1062**	**5.5012**	**6.3849**	**7.3287**	**8.3202**	**9.1170**
Argentina	1.6763	1.6248	1.6249	1.7548	1.9027	2.0893	2.2648
Bolivia	0.1027	0.1092	0.1206	0.1394	0.1567	0.1794	0.2081
Brazil	0.8569	0.7904	0.9060	1.2042	1.5477	1.9659	2.2881
Chile	0.2091	0.2641	0.3499	0.4311	0.4992	0.5688	0.6248
Colombia	0.2917	0.2896	0.2941	0.3314	0.3905	0.4211	0.4258
Cuba	0.0396	0.0480	0.0529	0.0643	0.0753	0.0927	0.1078
Ecuador	0.0184	0.0157	0.0169	0.0234	0.0322	0.0361	0.0440
Other Latin America	0.0451	0.0622	0.0887	0.1273	0.1713	0.2242	0.2552
Paraguay	0.0029	0.0022	0.0019	0.0025	0.0037	0.0045	0.0057
Peru	0.1093	0.1080	0.1389	0.1931	0.2396	0.2681	0.2955
Trinidad & Tobago	0.7222	0.8126	0.8753	0.9257	0.9681	0.9977	1.0123
Uruguay	0.0044	0.0027	0.0023	0.0029	0.0036	0.0045	0.0053
Venezuela	0.9688	0.9768	1.0288	1.1848	1.3380	1.4680	1.5797

	2010	2015	2020	2025	2030	2035	2040
EUROPE Total	**18.5791**	**18.9364**	**19.9827**	**21.7659**	**23.4237**	**25.3074**	**26.6736**
Austria	0.3129	0.3262	0.3452	0.3801	0.4176	0.4598	0.4922
Balkans	0.1822	0.2051	0.2412	0.2761	0.3105	0.3512	0.3842
Belgium	0.6124	0.6212	0.6609	0.7289	0.7883	0.8598	0.9137
Bulgaria	0.1625	0.1569	0.1719	0.2000	0.2231	0.2423	0.2489
Czech Republic	0.2991	0.2946	0.3140	0.3540	0.3955	0.4390	0.4702
Denmark	0.2107	0.1941	0.1918	0.2047	0.2195	0.2402	0.2566
Finland	0.1778	0.1830	0.1897	0.2118	0.2379	0.2678	0.2878
France	1.8089	1.9345	2.0826	2.2866	2.4843	2.7152	2.8792
Germany	3.3167	3.4243	3.4922	3.6796	3.8547	4.0759	4.2193
Greece	0.1263	0.1401	0.1602	0.2018	0.2343	0.2650	0.2774
Hungary	0.4376	0.4151	0.4294	0.4588	0.4887	0.5209	0.5431
Ireland	0.1877	0.2071	0.2376	0.2722	0.2973	0.3260	0.3524
Italy	2.6495	2.6815	2.7943	2.9250	3.0377	3.1607	3.2480
Luxembourg	0.0487	0.0497	0.0525	0.0580	0.0636	0.0699	0.0745
Netherlands	1.4335	1.4990	1.6053	1.7520	1.8805	2.0274	2.1368
Norway	0.1905	0.2461	0.2960	0.3494	0.3910	0.4384	0.4739
Poland	0.5505	0.6697	0.8000	0.9561	1.1079	1.2513	1.3514
Portugal	0.1841	0.2186	0.2474	0.2754	0.2927	0.3185	0.3345
Romania	0.5560	0.4931	0.5076	0.6005	0.6964	0.7750	0.8289
Slovakia	0.2187	0.2130	0.2239	0.2467	0.2699	0.2928	0.3088
Spain	1.3475	1.5109	1.7051	1.8824	2.0127	2.1576	2.2764
Sweden	0.0566	0.0614	0.0681	0.0857	0.1145	0.1488	0.1680
Switzerland	0.1119	0.1215	0.1346	0.1519	0.1689	0.1870	0.1995
UK	3.3970	3.0698	3.0310	3.2280	3.4362	3.7169	3.9479
FSU Total	**23.1064**	**24.3974**	**26.5994**	**29.6309**	**32.4265**	**34.8767**	**36.6286**
Azerbaijan	0.3718	0.3849	0.3906	0.4086	0.4331	0.4625	0.4924
Belarus	0.7021	0.6924	0.7104	0.7498	0.7874	0.8232	0.8446
Kazakhstan	0.4595	0.4739	0.5558	0.6910	0.8305	0.9650	1.0712
Other FSU	0.4928	0.4984	0.5361	0.6036	0.6755	0.7459	0.8006
Russia	15.8268	16.4077	17.5041	19.0121	20.4113	21.6540	22.4764
Turkmenistan	0.6947	0.8254	0.9727	1.1966	1.4154	1.6147	1.7825
Ukraine	2.8561	3.1135	3.5267	4.1265	4.6307	5.0121	5.2552
Uzbekistan	1.7026	2.0012	2.4029	2.8427	3.2426	3.5993	3.9057
MIDDLE EAST Total	**12.7080**	**14.3534**	**16.3445**	**19.2446**	**22.3820**	**25.8278**	**28.5740**
Bahrain	0.4188	0.4322	0.4829	0.5515	0.6318	0.7121	0.7842
Iran	4.2829	4.7969	5.1867	6.0571	6.9264	7.7536	8.5575
Iraq	0.0760	0.0731	0.1883	0.1527	0.2051	0.3127	0.3981
Kuwait	0.4748	0.4898	0.6137	0.7111	0.8467	1.0183	1.1198
Oman	0.4452	0.4980	0.5368	0.6043	0.6703	0.7531	0.8379
Other Middle East	0.4553	0.5515	0.6833	0.7761	0.9633	1.1583	1.2929
Qatar	0.7002	0.6940	0.6631	0.6972	0.7477	0.8069	0.8807
Saudi Arabia	2.8790	3.2523	3.9238	4.8472	5.8377	7.0280	7.7681
Turkey	1.1522	1.4757	1.7422	2.1892	2.5488	2.8727	3.0940
UAE	1.8236	2.0900	2.3237	2.6583	3.0042	3.4120	3.8407
NORTH AMERICA Total	**28.4905**	**28.7943**	**30.6011**	**33.5296**	**35.8559**	**38.4262**	**40.6547**
Canada	3.7595	3.5855	3.7212	4.2114	4.7249	5.2193	5.5777
Mexico	2.2189	2.2979	2.5658	3.0136	3.3352	3.8155	4.1620
USA	22.5120	22.9110	24.3141	26.3046	27.7958	29.3914	30.9150

Reference Case Production (*units: tcf*)

	2010	2015	2020	2025	2030	2035	2040
WORLD	**112.4141**	**120.6245**	**133.6684**	**153.1451**	**172.9786**	**193.6831**	**210.5337**
AFRICA Total	**7.9677**	**10.6881**	**12.3976**	**14.4042**	**16.6395**	**18.3049**	**18.4446**
Algeria	3.3148	3.9151	4.3152	4.4809	4.4777	4.5032	4.3823
Angola	0.0331	0.2477	0.3070	0.5437	0.7596	0.8697	1.0296
Egypt	1.9084	2.1239	2.3612	2.6155	3.3103	3.8176	1.2972
Libya	0.7166	1.0162	1.4572	1.7223	1.8887	1.9407	1.3817
Morocco	0.0027	0.0019	0.0011	0.0006	0.0004	0.0002	0.0001
Nigeria	1.1986	2.2920	2.6209	3.3621	4.4249	5.0614	4.1897
Other Africa	0.6333	0.9565	1.2192	1.5465	1.6106	1.9189	5.9870
Tunisia	0.1603	0.1348	0.1159	0.1325	0.1673	0.1932	0.1770
ASIA Total	**7.5413**	**8.2690**	**9.4929**	**10.8063**	**11.9913**	**12.8713**	**13.1210**
Afghanistan	0.0011	0.0025	0.0138	0.0303	0.0495	0.1326	0.2692
Bangladesh	0.6043	0.7077	0.8783	1.0031	1.0943	1.1386	1.0854
China	2.8539	2.8492	3.0262	3.4717	4.4308	6.1155	7.9409
India	1.2800	1.5232	1.8527	2.2987	2.5440	2.3150	1.6399
Myanmar	0.3157	0.5326	0.8700	0.9868	1.1542	1.0553	0.6913
Nepal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pakistan	1.1622	1.3469	1.5652	1.7624	1.7864	1.5856	1.2346
Sri Lanka	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Thailand	1.0578	0.9372	0.8828	0.8575	0.6967	0.4130	0.2039
Vietnam	0.2664	0.3697	0.4041	0.3960	0.2355	0.1158	0.0558
PACIFIC Total	**8.3701**	**11.6199**	**13.1747**	**15.9912**	**18.6629**	**20.3090**	**20.8526**
Australia	1.9755	4.1605	4.6982	5.1647	6.2646	7.5207	8.4818
Brunei	0.4039	0.6230	0.6945	0.8795	0.9107	0.9229	0.9157
Indonesia	3.1940	3.3991	3.6776	5.0963	6.1155	6.6489	6.9809
Japan	0.1858	0.0979	0.0622	0.0540	0.0476	0.0368	0.0175
Malaysia	2.2858	2.7266	3.2796	3.5871	3.7769	3.6849	3.0344
New Zealand	0.1527	0.1707	0.2146	0.2160	0.1652	0.0873	0.0464
Papau New Guinea	0.0050	0.2622	0.3439	0.7204	1.0638	1.0684	1.0691
Philippines	0.1286	0.1543	0.1879	0.2296	0.2633	0.2959	0.2832
Singapore	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
South Korea	0.0265	0.0184	0.0105	0.0061	0.0035	0.0020	0.0011
Taiwan	0.0124	0.0072	0.0057	0.0375	0.0519	0.0413	0.0224
SOUTH AMERICA Total	**5.5567**	**5.5471**	**5.9793**	**7.0162**	**8.5948**	**10.7527**	**12.7010**
Argentina	1.5779	1.4104	1.2464	1.1690	1.1659	1.2100	1.1266
Bolivia	0.4511	0.4228	0.6030	0.7935	0.8807	0.9222	0.9639
Brazil	0.4772	0.3357	0.4174	0.7192	1.0671	1.5552	1.9527
Chile	0.0652	0.0907	0.1713	0.2321	0.2430	0.2028	0.1579
Colombia	0.3563	0.3385	0.2936	0.2844	0.3432	0.3742	0.3167
Cuba	0.0396	0.0392	0.0510	0.0613	0.0657	0.0833	0.1030
Ecuador	0.0419	0.0335	0.0288	0.0326	0.0377	0.0361	0.1248
Other Latin America	0.0051	0.0046	0.0051	0.0054	0.0731	0.4857	0.9740
Paraguay	0.0029	0.0051	0.0189	0.0838	0.0910	0.0795	0.0690
Peru	0.1549	0.2445	0.3213	0.3843	0.4378	0.4644	0.4569
Trinidad & Tobago	1.4139	1.6707	1.7864	1.8239	1.8672	1.9136	1.9301
Uruguay	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Venezuela	0.9707	0.9513	1.0359	1.4266	2.3224	3.4257	4.5254

	2010	2015	2020	2025	2030	2035	2040
EUROPE Total	**10.5805**	**9.4248**	**9.7543**	**10.9523**	**11.4993**	**12.1234**	**12.7753**
Austria	0.0588	0.0548	0.0587	0.4140	0.8869	1.2333	1.4818
Balkans	0.0715	0.1176	0.1122	0.0949	0.0626	0.0397	0.0262
Belgium	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bulgaria	0.0004	0.0118	0.0120	0.0097	0.0066	0.0048	0.0033
Czech Republic	0.0062	0.0474	0.0374	0.0236	0.0154	0.0097	0.0059
Denmark	0.2974	0.2076	0.1999	0.3713	0.6501	1.1932	1.8075
Finland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
France	0.0487	0.0313	0.0228	0.0431	0.0954	0.1551	0.1780
Germany	0.5116	0.4463	0.5524	0.9576	1.2818	1.3921	1.2880
Greece	0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000
Hungary	0.0928	0.2336	0.2031	0.1411	0.0896	0.0568	0.0371
Ireland	0.0138	0.0072	0.0069	0.0079	0.0080	0.0049	0.0023
Italy	0.2829	0.3317	0.4257	0.5219	0.5566	0.4728	0.3710
Luxembourg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Netherlands	2.8448	2.2154	2.0337	1.7296	1.2976	0.8783	0.5856
Norway	3.5357	3.0495	3.1321	3.4303	3.3204	3.0983	2.5238
Poland	0.2069	0.2536	0.3373	0.5369	0.8353	1.3269	2.0958
Portugal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Romania	0.3833	0.5846	0.6153	0.5217	0.3806	0.2490	0.1605
Slovakia	0.0036	0.0147	0.0143	0.0094	0.0060	0.0040	0.0026
Spain	0.0005	0.0002	0.0001	0.0003	0.0024	0.0938	0.2857
Sweden	0.0000	0.0000	0.0000	0.0670	0.2072	0.5328	0.9828
Switzerland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
UK	2.2214	1.8173	1.9903	2.0720	1.7968	1.3780	0.9374
FSU Total	**28.4439**	**29.8167**	**33.1188**	**37.0646**	**40.4490**	**43.5099**	**45.4891**
Azerbaijan	0.5862	0.5407	0.6523	0.7796	0.7984	0.9579	1.2529
Belarus	0.0053	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047
Kazakhstan	0.9102	1.7536	2.3124	2.4067	2.3845	2.3502	1.9800
Other FSU	0.0044	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
Russia	21.7063	23.0469	25.1879	27.6666	29.7362	31.9004	33.5129
Turkmenistan	2.3437	2.4086	2.9395	3.8167	4.9369	5.8062	6.4604
Ukraine	0.7208	0.6063	0.7678	1.0436	1.1570	1.1535	1.1682
Uzbekistan	2.1670	1.4517	1.2500	1.3424	1.4272	1.3328	1.1059
MIDDLE EAST Total	**15.2349**	**16.7679**	**19.3379**	**23.6630**	**29.6872**	**37.6975**	**46.1971**
Bahrain	0.4188	0.3775	0.4251	0.4084	0.4953	0.3363	0.2995
Iran	4.2096	4.7627	5.3008	6.2333	8.3999	12.0634	17.1004
Iraq	0.2680	0.2981	1.0817	2.6073	3.7371	4.5337	4.7921
Kuwait	0.4054	0.4055	0.4184	0.4965	0.5953	0.7194	0.7608
Oman	0.9387	1.2133	1.3396	1.4201	1.3754	1.2589	1.1178
Other Middle East	0.5878	0.6945	0.7824	0.8278	0.7549	0.6821	0.6623
Qatar	3.7753	4.5294	5.1686	5.5500	6.7954	8.3394	9.7797
Saudi Arabia	2.8909	3.2852	3.9961	5.3573	6.8066	8.8666	10.3873
Turkey	0.0252	0.0478	0.0372	0.0231	0.0144	0.0091	0.0062
UAE	1.7150	1.1539	0.7879	0.7391	0.7129	0.8887	1.2910
NORTH AMERICA Total	**28.7189**	**28.4911**	**30.4128**	**33.2473**	**35.4545**	**38.1143**	**40.9530**
Canada	5.5912	4.6340	5.3800	6.2912	7.9224	8.8112	9.2316
Mexico	1.8050	1.5754	1.7480	1.7794	2.0423	2.6975	3.4049
USA	21.3228	22.2817	23.2849	25.1767	25.4897	26.6057	28.3165

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