

BACKGROUNDER

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The Future of Natural Gas

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Executive Summary

Natural gas is a vitally important domestic resource, supplying 24 percent of our end-use energy demand. Gas is used in a range of functions, from fueling electricity plants to heating homes and powering light-duty and heavy-duty vehicles. Given the significant role natural gas plays in the U.S. economy, having access to secure and substantial natural gas resources is a key part of the nation's energy security. This paper assesses the future of natural gas, the likelihood of energy security problems related to gas imports into the United States and the formation of a world gas cartel, and the implications of cartel formation on natural gas prices, both in the United States and the rest of the world. This report considers a number of important questions, including the following.

- When will the United States need to begin relying heavily on imported liquefied natural gas (LNG)?
- Is the United States at risk economically and politically because of unstable, international sources for natural gas?
- Is there a good chance for gas price volatility and manipulation by market players?
- Main conclusions are as follows.

U.S. Natural Gas Resources and Time Window

The United States is in a stronger position than many other developed countries in Europe and Asia relative to domestic natural gas supplies. Specifically, although domestic production for conventional gas is declining, the United States has large, unconventional gas resources and as yet relatively untapped areas (e.g., Alaska) that could fill the supply gap. Massive infrastructure, though, needs to be developed to get this gas to market, such as the proposed Alaska pipeline which, if developed, could be the biggest-ever private sector project in North America. To date, the United States has been able to rely on pipeline gas from Canada. Using estimates from the reference case of the *Annual Energy Outlook 2009* (AEO, April 2009 version) produced by the U.S. Department of Energy (DOE), if one considers only the current projections, the net total domestic demand for natural gas in 2010 is estimated

to be 21.89 trillion cubic feet (Tcf). This is made up of 19.62 Tcf from domestic supply and 1.96 Tcf of pipeline imports (mostly from Canada), leaving 0.3 Tcf of demand¹ met by the 0.38 Tcf of projected LNG imports. This situation is a bit different in the outer years for which DOE provides complete data for this version of the AEO (2020 and 2030). In 2020, without gas from Alaska but with LNG imports included, the United States is projected to fall short by 0.46 Tcf. With this Alaska gas, the shortfall drops to only 0.10 Tcf, essentially meeting demand. In 2030, this dependency on Alaska gas is more severe because without it, but still including projected LNG imports, the United States would have a deficit of about 2.08 Tcf, but including Alaska gas would bring that amount down to only 0.09 Tcf short. Thus, if no appreciable increase in LNG imports or Alaska gas is anticipated, according to the AEO 2009 projection, substantial increases in domestic production or pipeline gas from Canada will be required to meet anticipated demand. As found in AEO 2010 and in estimates by the Potential Gas Committee (2009), newly available gas shale resources in the lower 48 states should largely meet these demands.²

Foreign Supply

In 2008, LNG from overseas satisfied about 1 percent (0.3 Tcf net LNG imports out of 23.04 Tcf) of total U.S. consumption. This is a much smaller share than the other main foreign supply source, pipeline gas from Canada, which in 2008 accounted for 13 percent of U.S. consumption. DOE's Energy Information Administration, in its AEO 2009, expects the LNG import share to rise to 3 percent of domestic consumption by 2030. Dependence on LNG imports has the potential to be problematic given the competition among parts of the world, including those with little or no natural gas or dwindling supplies, which have typically been willing to pay higher prices (e.g., Asia). Although most LNG trade is in the form of long-term contracts, spot markets, if they become more prominent, will probably increase the price of imported gas and put the United States at risk from foreign sources with the ability to exert market power, especially if a gas cartel forms. Some estimates from the University of Maryland's World Gas Model indicate that a premium of \$4.47 per thousand cubic feet (beyond a reference case with no cartel³) would be added in 2030 by a cartel exerting market power, with a loss of consumer surplus of about \$91 billion. Importantly, this figure was generated using a variety of assumptions from earlier DOE Annual Energy Outlooks that relied much more heavily on LNG imports than the April 2009 version) and

¹ DOE reports that discrepancies of 0.53 Tcf are due to various accounting issues; thus, values less than this figure are deemed relatively negligible in the overall picture.

² The Potential Gas Committee report was initially finished in winter 2009 based on 2008 data that underforecasted today's U.S. domestic supply picture. Although the supply potential for the United States has been greatly enhanced, in part because of estimates of shale gas reserves that are much larger than previous estimates, some skepticism remains about the eventual production profile of shale based on lower decline rates compared to conventional gas (see, for example, Cohen 2009). Also, environmental considerations related to hydraulic fracturing of shale formation and possible contamination of the water table could further decrease the eventual shale gas produced. All this notwithstanding, the estimates provided in this report should be viewed to some extent as a "worst case" relative to the U.S. supply picture in light of the recent, more positive developments.

³ See Section 4 for a discussion of a potential gas cartel.

so should be viewed appropriately. But this figure does point out the potential for large transfers of funds out of the U.S. economy in the event of U.S. reliance on LNG imports when a cartel is present.

Energy Independence and Security

According to a recent National Petroleum Council (NPC) study and echoed by others, it is not realistic to think in terms of “energy independence.” The United States is too dependent on foreign sources of fuel for complete independence. A more sensible strategy would be to moderate demand, expand and diversify domestic energy supplies, and strengthen global energy trade and investment (NPC 2007). Moreover, as the NPC (2007, 6) study points out, “There can be no U.S. energy security without global energy security”. So although the domestic natural gas picture for the United States looks more secure than that of other nations, it would be prudent for the United States to take measures to promote overall global gas security by supporting appropriate political and economic incentives for gas trade.

This background paper is one in a series developed as part of the Resources for the Future and National Energy Policy Institute project entitled “Toward a New National Energy Policy: Assessing the Options.” This project was made possible through the support of the George Kaiser Family Foundation.

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The Future of Natural Gas

Steven A. Gabriel*

1. Introduction

1.1 Purpose and Motivation of This Paper

Natural gas is a vitally important domestic resource, supplying 24 percent of our end-use energy demand. Most (89 percent) of U.S. natural gas comes from domestic sources (compared with only 38 percent of oil consumed [Center for American Progress 2010]), and gas is used in a range of functions, from fueling electricity plants to heating homes and powering light-duty and heavy-duty vehicles. According to the American Petroleum Institute (2006), natural gas is used in 78 percent of restaurants, 73 percent of lodging facilities, 51 percent of hospitals, 59 percent of offices, and 58 percent of retail buildings—in addition to 60 million homes nationwide.

Given the significant role natural gas plays in the U.S. economy, having access to secure and substantial natural gas resources is a key part of the nation’s energy security. This paper assesses the future of natural gas, the likelihood of energy security problems related to gas imports into the United States and the formation of a world gas cartel, and the implications of cartel formation on natural gas prices, both in the United States and the rest of the world.

There are a number of reasons to examine the status and security of U.S. natural gas supplies. First, a risky fuel source can lead to reluctance to build new plants reliant on that fuel. If U.S. dependence on foreign natural gas supply is significant and can cause sharp price fluctuations or significantly higher prices, a rational investor might choose a less risky type of plant—using coal, for example, which the United States has in abundance.

Second, natural gas may figure prominently if the United States adopts a cap-and-trade system or a carbon tax on a national scale. Relative to bituminous coal, natural gas has 43 percent less carbon content (Energy Information Administration [EIA] 2010) and thus could be less costly if a carbon price were put into effect. However, incentives to switch from coal to natural gas assume that ample supplies of natural gas would be available. If 20 percent of the energy (in British thermal units) currently produced using coal—which currently accounts for

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about 50 percent of total U.S. energy production—were replaced by natural gas, an additional 4.36 trillion cubic feet (Tcf) of natural gas would be needed by 2020. If this additional supply is not available, the price advantage of gas might be smaller, especially if harder-to-reach domestic supplies or liquefied natural gas (LNG) imports are needed to fill the gap.

Finally, natural gas plays an important role in the U.S. economy overall. In 2008, the United States consumed 23.04 Tcf of gas, valued at about \$200 billion (AEO, 2009). The industry is important for jobs both in the upstream and downstream sectors. According to estimates from the World Gas Model (WGM; Egging et al. 2009) discussed later in this paper, with the formation of a gas cartel, the United States might have to pay a premium up to \$4.47 per thousand cubic feet (Mcf) in 2030 (in 2005 US\$) beyond a reference case.⁴ Using assumptions from WGM runs, this amounts to a loss of consumer surplus of about \$91 billion. This is a sizeable loss in social welfare, as well as a large transfer out of the U.S. economy to foreign governments, and could have significant economic⁵ and political implications.

Questions considered in this paper include the following.

- When will the United States need to begin relying more heavily on imported LNG?
- Is the United States at risk economically and politically because of unstable international sources for natural gas?
- Is there a good chance for gas price volatility and manipulation by market players?

This paper offers guidance on these and other important questions for the U.S. natural gas market. Following a short background section on the U.S. supply and demand picture for natural gas, this paper presents a brief overview of the global gas market. Other covered topics include the possible formation of a natural gas cartel, questions of market power, and sensitivities in the U.S. natural gas market.

⁴ This loss in consumer surplus should be considered a “worst case” given the more recent, positive U.S. supply outlook.

⁵ This figure was generated using a variety of assumptions from earlier DOE Annual Energy Outlooks that relied much more heavily on LNG imports than the current one (the April 2009 version).

2. Supply and Demand in the U.S. Natural Gas Market

2.1 Overview

Natural gas is consumed principally in four sectors of the economy: residential, commercial, industrial, and electric power generation. (The transportation sector also uses gas, but to a much smaller extent.) As shown in Table 1, natural gas consumption in 2008 was concentrated mostly in the industrial, electric power, and residential sectors, with 31, 30, and 23 percent of the total, respectively. The U.S. Department of Energy (DOE) predicts that these shares will stay roughly the same in 2030 (EIA 2009).

This consumption is satisfied by domestic production, pipeline gas (mostly from Canada), and LNG imports (mostly from Trinidad and Tobago). DOE reports that, in 2008, domestic production accounted for 20.54 Tcf, pipeline gas imports accounted for 2.73 Tcf, and LNG imports accounted for 0.30 Tcf, or 89, 12, and 1 percent, respectively (EIA 2009).⁶

Table 1. Natural Gas Consumption by Sector for 2008 and 2030

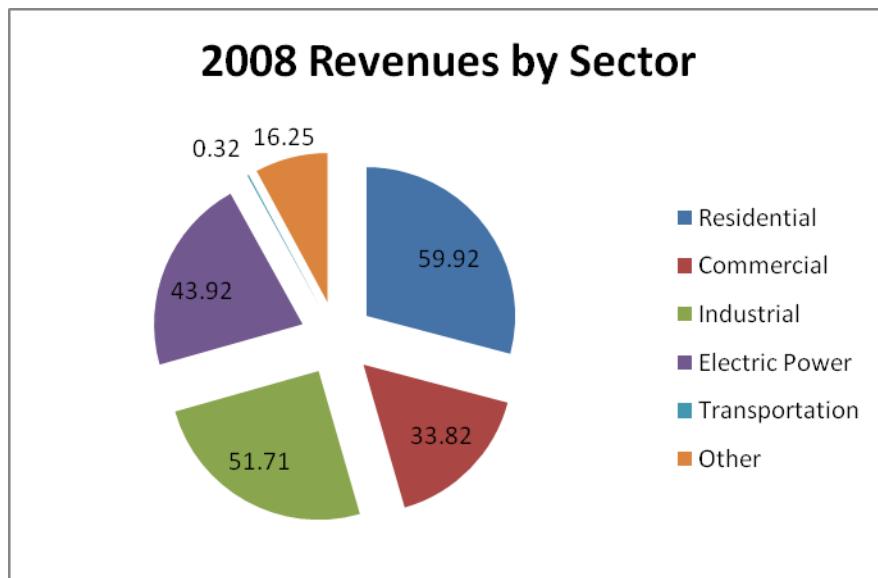
Sector	Natural gas consumption			
	2008 (Tcf)	2008	2030 (Tcf)	2030
Residential	4.92	23%	4.87	23%
Commercial	3.13	15%	3.43	16%
Industrial	6.65	31%	6.34	30%
Electric power	6.40	30%	6.70	31%
Transportation	0.03	0%	0.08	0%
Total	21.13	100%	21.42	100%

Source: EIA (2009).

⁶ These figures include a discrepancy of 0.53 Tcf (2 percent) due to accounting issues; see www.eia.doe.gov for more details.

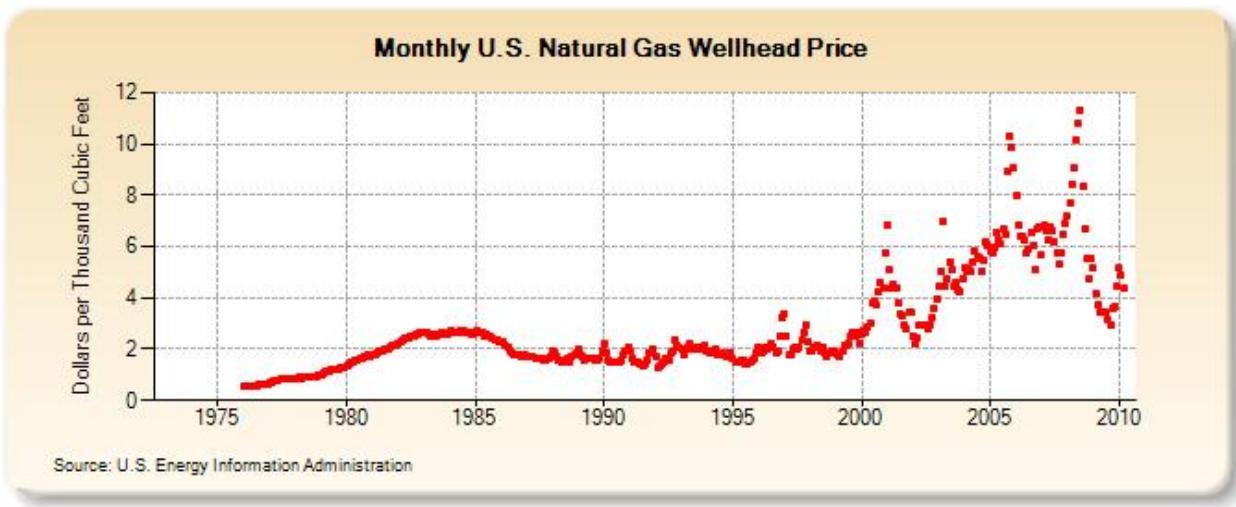
The 2008 price for natural gas varied considerably by sector, from a high of \$13.63 per Mcf in the residential sector to a low of \$9.25 for the industrial sector expressed in 2008 dollars. In terms of 2008 revenues, Figure 1 shows that the residential sector contributed the most (\$59.92 billion), followed by the industrial and electric power generation sectors (\$51.71 and \$43.92 billion, respectively).

Figure 1. 2008 Natural Gas Revenues by Sector (in 2008 Dollars) (EIA n.d.)



Source: <http://www.eia.doe.gov>

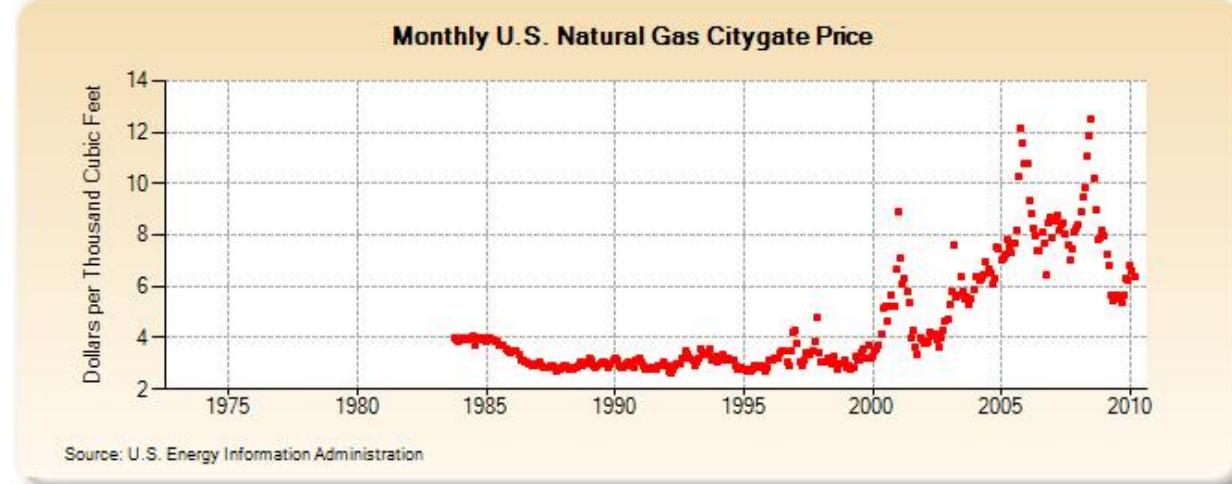
Figure 2. Natural Gas Wellhead Prices



Source: <http://tonto.eia.doe.gov/dnav/ng/hist/n9190us3m.htm>

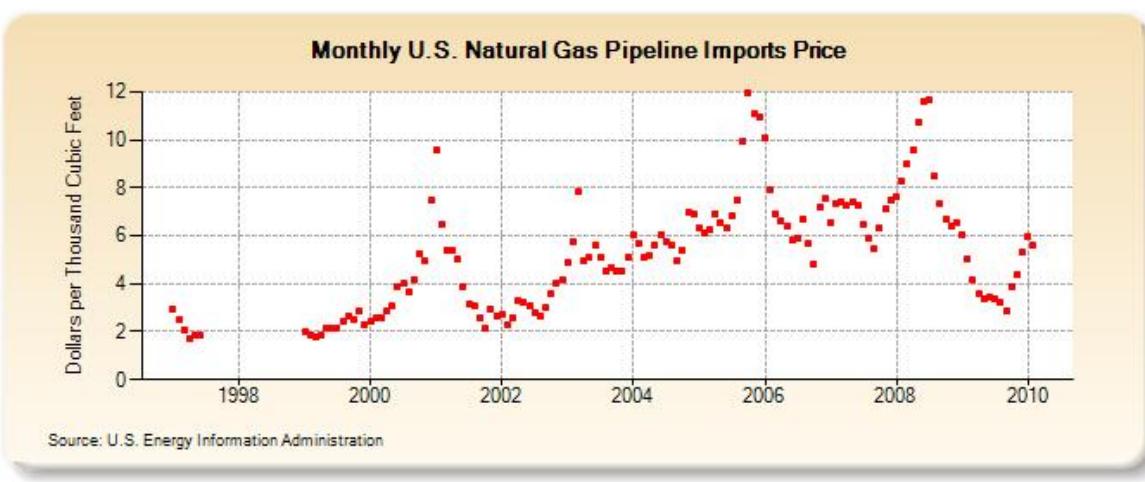
As shown in Figure 2, the wellhead price of gas has become more volatile and has trended upward since 2000. Citygate or wholesale prices—which generally include wellhead prices plus transportation costs—follow a similar pattern (Figure 3). Figure 4 and 5 indicate that both pipeline and LNG import prices have trended upward since 2000, with some fairly high peaks potentially due to seasonality or market imbalances.

Figure3. Natural Gas Citygate Prices

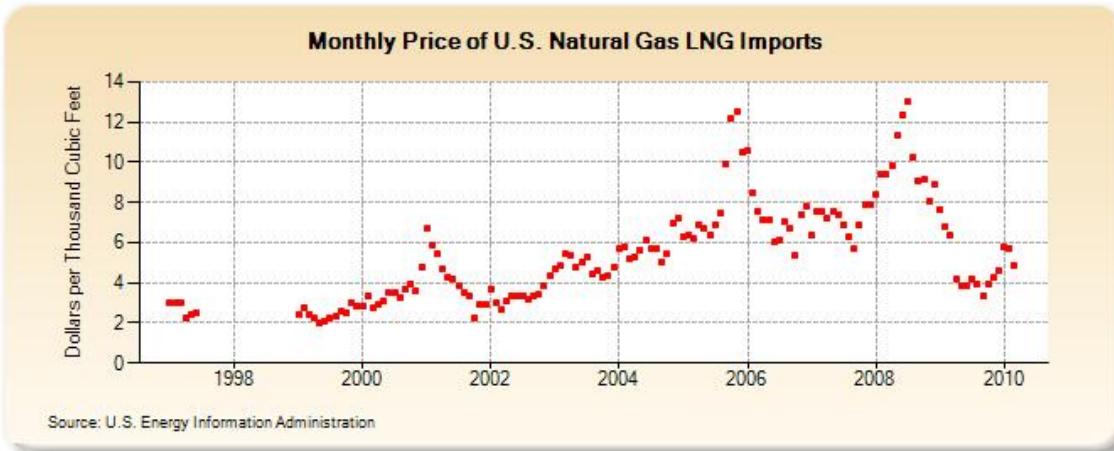


Source: <http://tonto.eia.doe.gov/dnav/ng/hist/n3050us3m.htm>.

Figure 4. Natural Gas Pipeline Import Prices



Source: <http://tonto.eia.doe.gov/dnav/ng/hist/n9102us3m.htm>.

Figure 2. Natural Gas LNG Import Prices

Source: <http://tonto.eia.doe.gov/dnav/ng/hist/n9103us3m.htm>.

2.2 Current Estimates for Supply

The United States has typically not needed to obtain much natural gas from foreign suppliers, apart from Canada. In 2008, the United States imported about 2.71 Tcf of natural gas from Canada, representing 13 percent of total U.S. consumption (EIA 2009).

2.2.1 Conventional Gas Supply

As described in a 2007 National Petroleum Council (NPC) study, U.S. domestic *conventional* gas production will decline over the next 25 years. This decline in conventional production is due to accelerating decline rates (the rates at which production in oil and natural gas wells fall over time), decreasing size of new conventional discoveries, and higher costs of finding and developing gas that is harder to reach (NPC 2003).

Because demand is not expected to decline, but rather to increase slightly, supply to make up for the shortfall could come from three main sources: unconventional gas, Arctic gas reserves (Alaska and the Mackenzie Delta), and/or LNG (NPC 2007). The magnitude and timing of each of these supply sources is key to U.S. energy security, and each carries a very different energy risk profile and associated costs.

2.2.2 Unconventional Gas Supply

Unconventional gas, defined here as gas recovered from tight sands, coalbed methane, and gas shales, includes more low-permeability reservoirs that produce mostly natural gas (without associated hydrocarbon liquids; NPC 2007). Despite the difficulty in extracting gas

from these sources, their huge potential can be more easily reached through recent engineering advances (NPC 2007).

According to EIA (2009), by 2030 unconventional gas is expected to account for 12.34 Tcf per year, or about 54 percent, of dry gas production. Tight gas sands are projected to provide the largest share of the unconventional gas production, which already has risen dramatically in the last 30 years from essentially nothing to almost 30 percent of total U.S. domestic gas supply (NPC 2007).

In 2008, about two-thirds of dry gas production of unconventional gas (6.69 Tcf) came from tight gas. This figure is expected to rise slightly to 6.71 Tcf by 2030, but will constitute a smaller share of unconventional production (54 percent) because of the rise in production from gas shale. Cost-effectively accessing shale gas requires stimulation techniques, such as hydraulic fracturing, as well as advances in horizontal and directional drilling (NPC 2007). EIA (2009) estimates that about 1.61 Tcf of shale gas was produced (16 percent of unconventional) in 2008, but projects that shale gas will constitute almost one-third of all unconventional gas, or 3.66 Tcf, by 2030.

Shale gas is of great importance to the U.S. supply picture. In the first five months of 2008 alone, domestic U.S. gas production increased 8.8 percent compared to 2007, an increase largely due to gas from shale (see Figure 6). According to Michael Stoppard of Cambridge Energy Research Associates, this unconventional gas production will help delay by a decade the United States' need for substantial LNG imports (Stoppard 2008). Indeed, according to Navigant Consulting (2008), there could be as much as 842 Tcf of retrievable gas in shales around the country that would translate to a 40-year supply at today's consumption rate, although thousands of wells still would need to be drilled to access the supplies. Among the most significant plays (i.e., sets of oil or natural gas resources occurring in a small, well-defined geophysical region) are the Barnett Shale Basin in Texas and the Marcellus Shale area in Pennsylvania.

Figure 6. Shale Gas Plays

Source: http://www.eia.doe.gov/oil_gas/rpd/shale_gas.jpg.

A final unconventional gas source is coalbed methane, from which 2.0 Tcf of natural gas was produced in 2008 (EIA 2009). Production has been greatly improved since the 1990s because of engineering advances in dewatering coal seams (NPC 2007). EIA predicts that annual production of gas from this unconventional resource will remain steady at around 1.6–2.0 Tcf per year, or about 16 percent of total production in 2030.

2.2.3 Alaska Gas

According to estimates in a 2003 NPC study, approximately 1,450 Tcf of technically recoverable natural gas remains in the United States. As shown in Table 2, by 2030, NPC estimates that an additional 400–500 Tcf of gas may be recoverable as a result of advances in technology.

Table 1. U.S. Natural Gas Resource Base (in Tcf)

	Current technology	2015 technology	2030 technology
Lower-48 onshore	764	839	1,006
Lower-48 offshore	384	415	486
Alaska	303	331	395
Total United States	1,451	1,585	1,887

Source: NPC (2003).

These figures indicate that Alaska alone accounts for about one-fifth of this total resource base; from a production standpoint, however, Alaska is a much smaller participant in the U.S. market. EIA figures indicate that, from 2002 to 2006, Alaska's share of marketed production in the United States was only about 2 to 2.5 percent per year. According to the AEO 2009 reference case, this share will rise starting in 2022 and will reach about 9 percent in 2030 (EIA 2009).

Obtaining secure domestic natural gas from Alaska holds significant promise but also faces some considerable obstacles. First, a substantial amount of Alaska gas is located in the North Slope region;⁷ reaching this gas has the potential to impinge on the Arctic National Wildlife Refuge, and the harsh environment makes drilling and construction difficult.

In addition, delivering Alaska gas to market would require an extensive gas pipeline. The pipeline could make available an estimated 4.5 billion cubic feet (Bcf) per day (1.64 Tcf per year) or about 8 percent of the present U.S. market (Pritchard and Burke 2008). At present, two competing teams might build this pipeline: TransCanada (working in conjunction with ExxonMobil), or a BP/ConocoPhillips consortium operating under the project name "Denali." TransCanada was awarded \$500 million as seed money by the Alaska legislature to start on plans

⁷ According to DOE, gas producers have proved the existence of 35 Tcf on state lands in the North Slope.

for this pipeline (Houston Chronicle 2008). By contrast, the Denali project is not seeking a state license or a similar amount in state incentive funding.

TransCanada's proposed pipeline (Figure 7) would extend some 1,700 miles from Alaska to connections in Alberta, with TransCanada taking responsibility for the Alaska portion and Foothills Pipe Lines Ltd taking responsibility for the Canadian portion. TransCanada aims to have its pipeline in service by September 2018, with capital costs estimated at more than \$26 billion (Phillips 2008). An additional 1,500 miles of pipeline would also be needed to transport gas from Alberta to U.S. markets.

Figure 3. Proposed TransCanada Portion of Alaska Natural Gas Pipeline



Source: <http://www.transcanada.com>.

The Mackenzie Delta, located in Canada's Northwest Territories, is another potentially large source of Arctic natural gas (Figure 8Figure). In three main natural gas fields (Taglu, Parsons Lake, and Niglintgak), 3, 1.8, and 1 Tcf have already been discovered. A pipeline of 1.2 Bcf per day (0.44 Tcf per year) would take Mackenzie Delta gas (and other gas) to Alberta along a route more than 700 miles long. Although Mackenzie does not hold the same volume of gas as Alaska, a significant amount is nevertheless available. This gas could contribute to the general

North American supply, assuming that appropriate infrastructure passes regulatory hurdles and is eventually constructed.

Figure 8. Mackenzie Delta



Source: <http://www.mackenziegasproject.com/theProject/index.html#>.

2.2.4 Gas Hydrates

Gas hydrates, a solid form of gas with physical properties similar to ice, are another unconventional natural gas source. Gas hydrates are found under permafrost in Arctic regions, near the seafloor on continental slopes, and in deep seas and lakes. This resource is not extensively considered in this paper, however, as drilling is scarce and an economically viable production scheme does not yet exist (NPC 2007).

2.2.5 Moratoria Lands

Considering the 1,450 Tcf of technically recoverable gas in the United States—and the potential growth in this figure based on new technology—requires an examination of how much of this resource is in moratoria lands or other restricted areas. About 162 Tcf of this technically recoverable onshore gas is beneath federal lands in Alaska, the Rockies, the Gulf Coast, and Appalachia, and is restricted or off-limits. In addition, about 92 Tcf of offshore gas is unavailable for development, of which an estimated 86 Tcf is in the federal Outer Continental Shelf (OCS) moratoria regions.⁸

⁸ OCS numbers have a good deal of uncertainty, as the last drilling estimates were in some cases made 25 to 40 years ago (NPC 2007). These estimates of yield could also be higher when more modern drilling and extraction techniques are taken into account.

2.3 Conclusions for a Business-as-Usual Scenario, Best and Worst Cases, and a Time Window for U.S. Natural Gas Security

Based on the above discussion, a key question is, when will the United States need to greatly increase LNG imports, produce gas from Alaska, or tap vast hydrate reserves to meet domestic natural gas demand? Although this computation is difficult to make—as it involves uncertainty in the amount of domestic gas that can be produced, the consumption levels, the LNG import and export capacities, the domestic and North American pipeline capacities, and the prevailing prices for both domestic and imported natural gas—a reasonable place to start is with the current AEO 2009, taking the reference case as a baseline (see Table 3).⁹

Table 2. Summary of Natural Gas Market from AEO 2009 (All Figures in Tcf)

Demand	Year		
	2010	2020	2030
Net total demand	21.89	21.53	23.50
Domestic supply			
Associated-dissolved, lower 48 onshore	1.41	1.32	1.29
Nonassociated-conventional, lower 48 onshore	4.52	3.39	2.14
Nonassociated-unconventional, tight gas, lower 48 onshore	6.35	6.35	6.71
Nonassociated-unconventional, shale gas, lower 48 onshore	2.23	2.71	3.66
Nonassociated-unconventional, coalbed methane, lower 48 onshore	1.73	1.73	1.96
Total offshore, lower 48	3.38	3.72	5.28
Total domestic supply	19.62	19.22	21.04
Net pipeline imports	1.96	0.47	-0.43
Net supply + imports – net demand	-0.30	-1.84	-2.89

Source: <http://www.eia.doe.gov>.

⁹ At the time of this report, no other cases for the AEO 2009 (April 2009 version) were publicly available.

Under business-as-usual settings, including a sizeable share of pipeline gas from Canada, the United States has until 2020 before it needs to turn to supply sources that are more difficult to obtain and/or to imports that are higher priced than domestic gas.

In a realistic best-case scenario, the United States would not need significant volumes of gas from Alaska or LNG imports because of increased unconventional finds—specifically shale. To balance supply and demand, shale gas production would need to increase by 14, 68, and 79 percent in 2010, 2020, and 2030, respectively. These changes are sizeable compared with the levels of production estimated in AEO 2009, especially for 2020 and 2030 (EIA 2009). However, as reported by the Potential Gas Committee (2009), the estimates for natural gas have gone up 35 percent, thanks in part to forecasted increases in shale gas production. This increase, the largest in the 44-year history of reports from this committee, is due in large part to advances in petroleum engineering.

In several realistic worst-case scenarios, a deficit in supply will need to be made up via one of the following methods:

- decreasing gas consumption (and possibly exports);
- producing gas from Alaska and transporting it to the lower 48 states;
- producing gas from moratoria areas, such as the OCS (including hydrates);
- importing more pipeline gas from Canada; or
- importing more LNG from overseas suppliers.

Climate policy aside, decreasing gas consumption implies a shift in behavior patterns by users that seems improbable in the next 10 years. For example, effecting significant decreases in consumption in the residential or commercial sectors would require a switch away from gas used for cooking or home heating—an unlikely prospect in the short-term because of high transition costs for end users in these sectors.

The electric power and industrial sectors might have the incentive to develop dual-fired processes and plants that could shift from gas to another fuel, but only if the price of gas were high enough to make the shift attractive. Should the United States institute carbon allowance pricing, given its lower carbon content, gas might be actually be less expensive than fuels such as coal and oil. It is therefore reasonable to assume that industrial demand for gas will not appreciably drop.

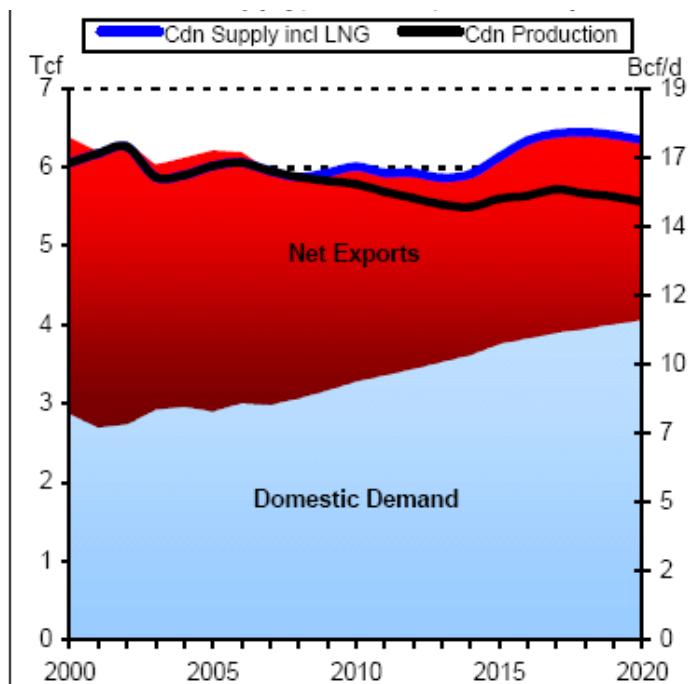
Two viable supply options include trying to boost domestic production or importing more gas. From the perspective of both energy security and domestic employment, increasing domestic production would probably be preferable. EIA (2009) and other sources estimate, however, that the supply of conventional gas will instead decrease over the next 20 years; therefore, recent finds in shale gas make this unconventional source seem the most likely place to increase production. As noted above, however, very large percentage increases would be needed if shale alone were to fill the demand gap.

Turning to imports, the United States would probably prefer to augment its supplies with gas imported from Canada by pipeline, as Canada is a neighbor and a stable trade partner. Determining whether Canada would be able to make up the shortfall in gas starting in 2020 requires an examination of whether:

- Canada has the production capacity and resource base to achieve this increase;
- sufficient pipeline capacity has been, or could be, built; and
- prices are favorable from the U.S. perspective relative to LNG imports.

A 2008 report by Natural Resources Canada (NRCan) indicates that net exports to the United States are, in fact, projected to fall from 3.2 Tcf in 2006 to 2.3 Tcf in 2020, as indicated in Figure 9.¹⁰ These figures reveal two important points: first, in December 2007, the NRCan forecast of 2020 net exports to the United States was higher than that of AEO 2009 (2.3 versus 0.47 Tcf, respectively); and second, the NRCan forecast also indicates a significantly diminishing amount of exports to the United States. Although these numbers can be altered from year to year based on new finds and changing market conditions, one conclusion is that relying solely on Canadian imports might not be prudent for the United States.

¹⁰ The NRCan report was issued in December 2008, and therefore might not capture all of the recent large U.S. shale finds described above. It was assumed that the United States would import up to 5 Tcf per year in LNG; this assumption might be important in determining net exports to the United States.

Figure 9. Canadian Supply, Demand, and Net Exports to the United States

Source: NRCAN (2008).

The options remaining for the United States are to increase supply from Alaska gas or moratoria areas, such as the OCS (including hydrates), and/or increase LNG imports. Each of these options is likely to face considerable obstacles, and also comes with a significant price tag.

Alaska reserves are vast, but transferring product to the lower 48 states means overcoming daunting environmental and transportation issues. TransCanada estimated a completion time for their pipeline of 2018; given that large-infrastructure projects often go over budget or beyond deadlines, however, this date may not be realistic. According to EIA's (2009) AEO 2009 reference case estimates for Alaska gas production (see Table 4), gas is insufficient in 2020 and 2030, on the order of 1 to 1.5 Tcf, to meet overall demand.

Table 4. Time Window with Alaska Gas

	2010	2020	2030
Net supply + imports – net demand	-0.30	-1.84	-2.89
Alaska gas	0.39	0.36	1.99
New net supply + imports – net demand	0.09	-1.48	-0.90

Source: EIA (2009).

It also seems unlikely that moratoria or hard-to-reach areas will be tapped in the near future. The current price of gas does not support the large-scale retrieval of gas hydrates from the ocean floor, as this is still an expensive and complicated procedure. Securing oil from the lower 48 OCS regions is likely to be politically challenging because of the relative proximity of population centers. Finally, although Alaskans (and other Americans) would benefit from extra gas being produced in their state, having both OCS and other supplies drilled at the same time might be ambitious before 2020, given the difficulty of such an undertaking.

The final option for increasing U.S. gas supply is LNG imports. Using the AEO 2009¹¹ figures, Table 5 shows a shortfall of 2 Tcf by 2030 if domestic consumption is met only by anticipated rates of LNG imports.

Table 5. Time Window with LNG Imports

	2010	2020	2030
Net supply + imports – net demand	-0.30	-1.84	-2.89
LNG imports	0.38	1.38	0.81
New net supply + imports – net demand	0.08	-0.46	-2.08

Source: EIA (2009).

¹¹ The 0.46 Tcf shortfall is almost as large as the 0.53 Tcf discrepancy stated earlier.

When both LNG imports (at the AEO 2009 level) and Alaska gas are considered together, the net values for 2010, 2020, and 2030 are 0.47, -0.10, and -0.09 Tcf, respectively. This indicates that pipeline gas from Alaska is needed if no substantial increases in LNG imports or domestic production are considered.

Comparing the LNG imports and Alaska gas options provides some interesting insights. Producing and transporting gas from Alaska carries with it few international risks, given that a pipeline would only cross Canadian territory. Indeed, as noted above, TransCanada has already been awarded a substantial sum to conduct a feasibility study of building an appropriate pipeline. By contrast, importing LNG carries the risk inherent in a dependence on unstable and/or unfriendly regimes in other parts of the world. Although the Gas Exporting Countries Forum (GECF) at present does not seem to pose great risks for downstream countries such as the United States, current or future economic crises may lead the GECF nations to form a cartel, which in turn could lead to higher prices.

Looking at technical risk, the situation is reversed. The Alaska pipeline, which “would be the largest-ever private sector construction project in North America” (Mouawad and Krauss 2009) carries with it a great risk of not being completed within the time and budget allotted. Building LNG import terminals is more standard and, moreover, such terminals would not need to traverse the harsh weather conditions found in Alaska and northwestern Canada.

Another important question is how the United States will be affected in the future by key producers’ market power. According to AEO 2009, of the 23.04 Tcf consumed in the United States in 2008, total net pipeline imports were 2.71 Tcf, and total LNG imports were only about 0.3 Tcf (1 percent of total consumption). Given the stability of the relationship between Canada and the United States, these figures indicate that the United States is currently in a more secure position than Europe, which depends on Russia and other foreign suppliers for much of its natural gas.

If U.S. domestic supplies were limited, we would inevitably be more dependent on the global gas market—and, in particular, on LNG imports. This could lead to more competition with Western Europe for LNG in the Atlantic Basin. In this scenario, the exertion of market power by players in Russia and/or the Middle East could have a dramatic effect on the United States. Likewise, the effects of competing with countries in Asia—for example, Japan and South Korea, which together accounted for 54 percent of global LNG exports in 2007 (Rühl 2008)—could be harmful to the U.S. position.

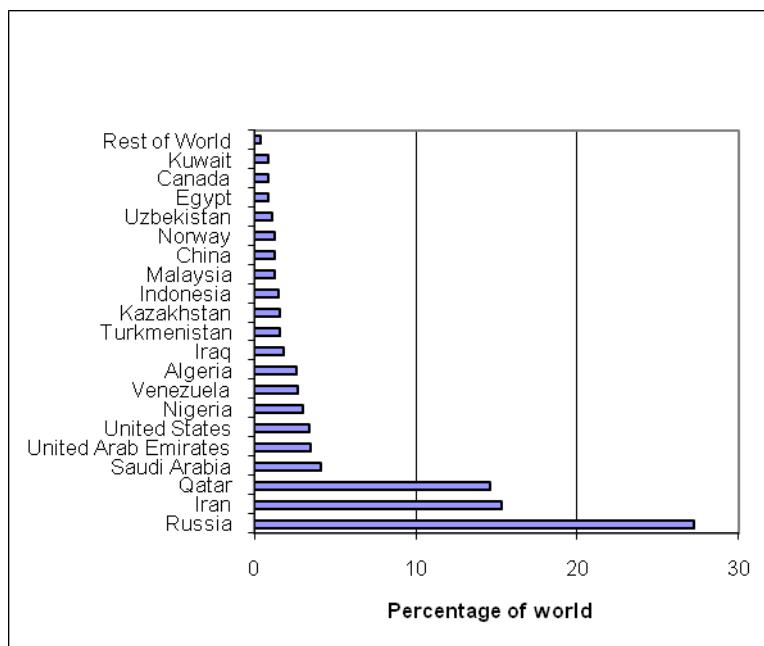
The next section describes the global natural gas market as a way to introduce possible market power effects on the United States via application of the WGM.

3. World Natural Gas Market

3.1 Overview

Natural gas is found in many places in the world, but areas of large reserves and production are more limited. According to the 2008 *BP Statistical Review of World Energy* (Rühl 2008), the most recent figures from the end of 2007 indicate proved reserves of 6,263 Tcf globally. Figure 10 illustrates that more than 55 percent of these proved reserves are concentrated in just three countries: Russian Federation (25.2 percent), Iran (15.7 percent), and Qatar (14.4 percent). Of the 103 Tcf of gas actually produced in 2007, 20.6 percent of the total came from Russia. Iran and Qatar accounted for only 3.8 and 2.0 percent of production, respectively, indicating significant future potential for market dominance. The United States and Canada are also significant producers, with 18.8 percent and 6.2 percent, respectively.

Figure 104. World Natural Gas Reserves (Top 20 Countries), 2008

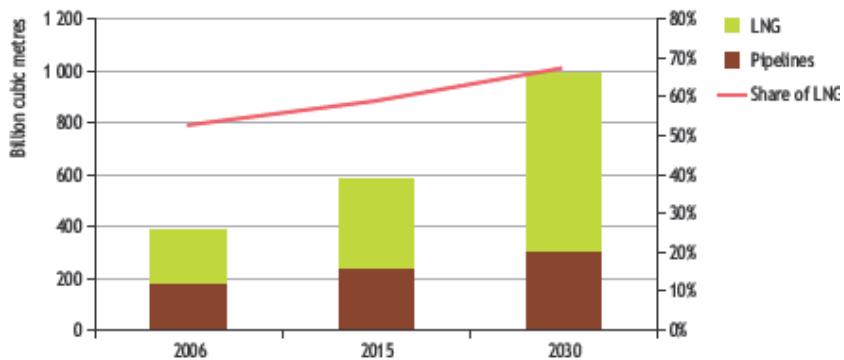


Source: <http://www.eia.doe.gov>.

To reach demand regions (e.g., Europe), gas must be shipped by pipeline or, increasingly, as LNG. As indicated in Figure 11, the role of LNG trade is increasing, with the International

Energy Agency (IEA) forecasting in its 2008 *World Energy Outlook* (WEO) that more than 60 percent of natural gas will be shipped as LNG by 2030 (IEA 2008).

Figure 11. LNG as World Interregional Natural Gas Trade* by Type in the Reference Scenario



*Trade from major WEO regions, not including international trade within each region.

Source: (IEA 2008)

At the same time, IEA also predicts that global LNG liquefaction capacity will plateau by 2013 (IEA 2009), and that the use of LNG liquefaction plants and interregional pipelines may drop significantly over the next few years.

Finally, gas is found only in limited areas, and building transportation infrastructure (pipelines or LNG) is very costly and can take a number of years; thus, there is the potential for market power by the key players. Recent indications of this potential were the temporary shutoffs of gas from Russia to Ukraine over contract disputes, which ultimately affected customers further downstream in Europe in 2006 (Landler 2006; Kramer 2006) and again in 2009 (*The Economist* 2009a,b,c).

3.2 World Gas Market Supply and Demand

As described above, current global gas production is dominated by Russia, the United States, and Canada. Unsurprisingly, the United States is the largest global gas consumer (22.6 percent), and Russia consumes 15 percent. All other countries' consumption, as a percentage of the world total, is much smaller (at most about 3 percent). Europe's dependence on foreign sources—particularly Russia—is illustrated in Table 6.

Table 6. Dependence on Russian Pipeline Gas, 2007

Country	% of own pipeline purchases from Russian Federation (2007)
Austria	74.9
Belgium	2.6
Bulgaria	100.0
Croatia	87.5
Czech Republic	74.5
Finland	100.0
France	22.6
Germany	42.5
Greece	100.0
Hungary	74.9
Italy	32.9
Latvia	100.0
Lithuania	100.0
Netherlands	12.2
Poland	66.7
Romania	52.1
Serbia	100.0
Slovakia	100.0
Slovenia	50.9
Switzerland	11.7
Turkey	75.7

Source: Rühl (2008).

Bulgaria represents a good illustration of the perils of dependence on Russian gas. The country is wholly dependent on Russian gas and, because of recent curtailments, had begun to restart a nuclear reactor at the Kozloduy plant to compensate. However, the country was required to shut down reactors as part of safety standards required for entry into the European Union (Kanter 2009).

Russian–Ukrainian gas disputes have farther-reaching effects throughout Europe, as a quarter of Europe's gas comes from Russia and 80 percent goes through Ukraine as a transit country (Schleifer 2009). The potential for disruptions in supply is spurring interest in, and the development of, alternative pipelines to bypass Ukraine (e.g., the Nabucco pipeline, shown in Figure 12). Russia is also looking for ways to avoid going through Ukraine to get gas to Europe using the Nord Stream Pipeline (Russia to Germany via the Baltic Sea) or the South Stream Pipeline (under the Black Sea through Bulgaria); see Figure 13. Together, these two pipelines

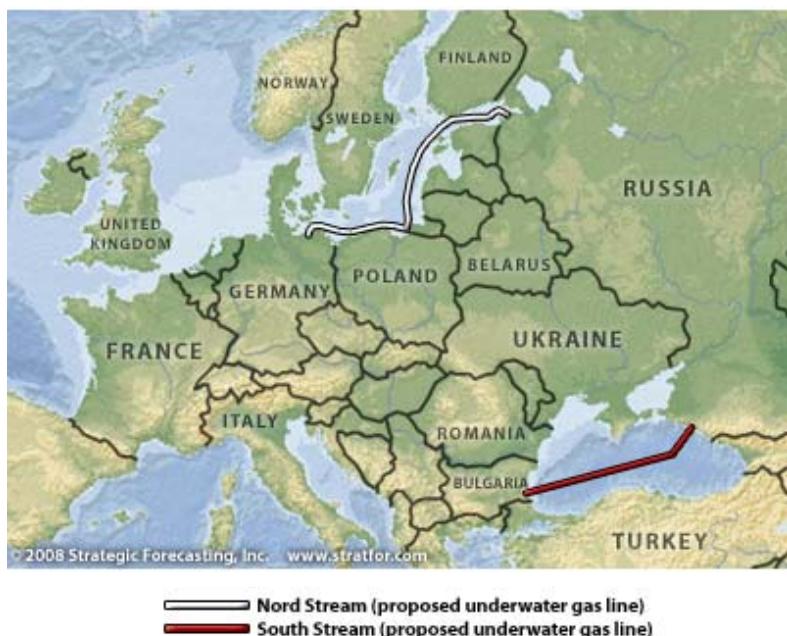
would actually increase European dependency on Russian gas from 25 to 35 percent of its total consumption (Zeihan 2008).

Figure 12. Nabucco Pipeline



Source: Schleifer (2009)

Figure 13. Nord and South Stream Pipelines



Source: Zeihan 2008

These exercises of market power will cause Europe to expand its efforts to find more supply diversity in the form of LNG imports. U.S.–European competition for this LNG could ensue if the United States also comes to rely more on LNG imports to complete its supply.

4. Concerns About the Potential Formation of a Natural Gas Market Cartel

4.1 Background and Arguments Against the Near-Term Formation of a Gas Cartel

The member countries of GECF, an international body that represents the interests of gas-producing nations, include Algeria, Bolivia, Egypt, Equatorial Guinea, Iran, Libya, Nigeria, Qatar, Russia, Trinidad and Tobago, and Venezuela, and, as observers, Kazakhstan and Norway. Together, nonobservers accounted for about 42 percent of global production in 2007 (Rühl 2008) and, perhaps more importantly, held more than 73 percent of the reserves (EIA n.d.).¹² Although these countries have been meeting informally since 2001, they held more formal discussions in December 2008.

Some experts are concerned that these countries will act in unison, somewhat like the Organization of the Petroleum Exporting Countries, to raise natural gas prices by curtailing production. However, although a closer coordination of the natural gas output from these countries is desired by certain members of GECF, evidence shows that this may not be readily accomplished (Energy Business Review 2005; Finon 2007; Finon and Locatelli 2008).

First, most of the world relies on long-term contracts (20–25 years) for natural gas, with North America as the exception. If these long-term contracts persist, as is advocated by Finon (2007), it would be difficult for such a cartel to act in a coordinated fashion, in spite of some flexibility in their contract volumes. Exporters would not find it in their interest to default on these contracts, given the important future revenue streams that would be lost; this is especially true for emerging gas exporters, such as Qatar, Nigeria, Egypt, Angola, and Trinidad and Tobago, which rely on partnerships with international oil and gas companies. Also, because the majority of global gas is not sold in spot markets, a curtailment of production by such a cartel would only affect a small part of the market (Finon 2007).

Another important argument against the formation of a cartel is the heterogeneity of gas markets. North American, European, and Asian markets are somewhat independent of each

¹² The 73 percent is derived from taking the reserves of the top 20 countries that were also part of GECF.

other, given different commercial habits and specific infrastructure (e.g., the mix of pipeline gas or LNG used differently in each region). On one end of the spectrum, North America relies on medium-term contracts, spot markets, and primarily pipeline gas, whereas the European gas trade is in the form of long-term contracts indexed on the price of petroleum products and only partially on LNG. At another extreme is South and East Asia, which relies solely on LNG for supplies via long-term contracts, with prices indexed on the price of oil (Finon 2007).

In addition, GECF members are quite distinct from one another and have differing agendas. Indeed, Qatar has a cooperation agreement with the United States, is developing its liquefaction capacities with the major energy companies, and actually opposes a gas cartel (Finon 2007). Finally, international antitrust laws (Energy Business Review 2005) may come into play should GECF take on a more activist role.

Despite these arguments, the natural gas *troika* composed of Russia, Iran, and Qatar could “produce more natural gas at a much cheaper cost for the U.S. market, effectively shutting down the Barnett Shale and other similar resource plays” (Tronche 2009).

4.2 Arguments for the Medium-Term Foundation of a Gas Cartel

In the medium term, there may be legitimate reasons why GECF or a subset of its members would choose to form a cartel. First, although producers (with the exception of Qatar) generally are not able to supply two of the regional markets, in transatlantic LNG trading exporters can take advantage of higher prices on either side of the ocean to drive up overall prices (Finon 2007). The profitability from the transatlantic trading could make some exporters begin to reevaluate how much of their gas they want to lock in with long-term contracts. Although the LNG volumes are currently small, as mentioned above, IEA (2009) predicts that global LNG trade will continue to grow. This growth in LNG, if realized, could de-regionalize the gas markets, especially in the face of dwindling supplies from countries that normally supply gas by pipeline. The increasing significance of this LNG market could lead to a greater influence of spot markets, as exporters would want the flexibility to sell their gas to the highest bidder. Thus, more gas sold in spot markets, as opposed to long-term contracts, could foster imperfect competition such as cartels. Additionally, a few years in the future, the export facilities will probably be more established in emerging gas-producing nations and, consequently, they may decide to depend less on international oil and gas companies.

Because many of the world’s long-term contracts are indexed on petroleum prices (Finon 2007), a prolonged period of low oil prices—which could help lower gas prices—could lead

exporters to reconsider the wisdom of locking themselves into long-term commitments. This line of reasoning would shift the focus away from long-term markets and toward a system in which spot markets have a greater influence, similar to the North American approach. Such a low oil price might be brought about by a prolonged global economic crisis like the current one.

In this scenario, for economic reasons, a number of exporters would believe that more profit could be obtained by trading in burgeoning spot markets rather than relying on depressed gas prices. These events could set the stage for GECF members to decide that forming a cartel would be in their interests to force higher prices in short-term markets. It is certainly plausible that if LNG accounts for 60 percent of gas trade in 2030, under the right economic conditions of low gas prices, the economic incentives for a cartel could be present.

5. Forecasting Natural Gas Conditions with the WGM

5.1 Overview of the WGM

The WGM is a large-scale market equilibrium system developed by the University of Maryland, in collaboration with Deutsches Institut für Wirtschaftsforschung (German Institute for Economic Research) and Technische Universität-Dresden (Egging et al. 2008a,b, 2009) and based on the earlier works by Gabriel et al. (2005a,b) and Egging and Gabriel (2006). Its purpose is to simulate the global gas market, using principles from game theory, optimization, and engineering, and to gauge the effects of market power discussed above.

The WGM covers 95 percent of (2005) worldwide consumption and includes some 73 production and 75 consumption countries. Eight five-year periods (2005–2040) are used in combination with three seasons to simulate the production, consumption, and intermediate stages of the marketplace. Typical decisions are levels of operations (e.g., production rates in a season and year) as well as endogenously determined investments (e.g., million cubic feet per day of pipeline capacity added in a particular year between an origin and a destination). On the LNG side, both spot markets and a database of contracts are used to add realism.

Unlike most other large-scale economic models for natural gas, the WGM allows some of the players to be strategic (i.e., to withhold supplies to force up prices for larger profits). This feature is important given recent events in today's gas markets, such as recent incidents in which Russia withheld gas destined for Ukraine because of price disputes.

5.2 Summary of Results of Recent Scenarios Using the WGM

The WGM was recently used in two studies to analyze the impacts two scenarios, a possible gas cartel (Cartel case; Egging et al. 2009) and a “post-Bali” backstop technology case (Backstop case; Egging et al. 2008b), in addition to a Base case, as possible future scenarios that would lead to market insights. The WGM was thoroughly calibrated to match observed data (e.g., prices and quantities in 2005). The Cartel case assumes that all production capacities of GECF members are frozen at 2005 levels, whereas the Backstop case assumes that natural gas is not sustainable in the long run as a fuel and includes a backstop producer with constant production costs of \$350 per thousand cubic meters,¹³ increasing 1 percent per year. In addition, other production costs increase 3 percent per year so, over time, the backstop technology becomes more competitive. The output from these runs provides an interesting window into possible futures for global gas markets; summarized below are some of the more salient points as they pertain to North American markets.

In these runs, the United States is modeled as six separate nodes: East, Midwest, Gulf of Mexico (including onshore), Rockies, West, and Alaska. Canada is divided into two separate regions: Canada-East and Canada-West. U.S. Base case production for 2005 reported by the WGM was 15.8 Tcf, 13 percent lower than EIA’s (2008, Table 13) figure of 18.1 Tcf.¹⁴ (Other correspondence with EIA-reported numbers is relatively close.) The rest of the Base case figures for 2005 are shown in Table 7.

Table 7. Base Case Figures for 2005: WGM vs. EIA (in Tcf)

Element	WGM	EIA
Net LNG imports	0.48	0.57
Net pipeline imports	2.91	3.05
Consumption	19.19	22.01

¹³ This value was determined to preclude the backstop producer from producing in the base year.

¹⁴ WGM production values are based on IEA data, net for own use in the energy sector. For the United States, the reported own use is 10 percent. Stock changes and statistical differences account for the rest of the difference.

From Figure 14, we see that the three cases (Cartel, Backstop, and Base case) show roughly the same production pattern: U.S. gas production decreases from 2005 to 2015 and drops even more in 2030. The lowest production occurs under the Backstop case, when the backstop technology substitutes into the energy supply mix.

Prices are generally increasing over time for all three cases, and Figure 15 and Table 8 illustrate that the effects of a cartel on prices are dramatic in later years. This price increase is due to decreased U.S. production that must be compensated for (presumably) by higher-priced imports, in the form of pipeline gas and LNG, on top of an assumed gradual increase in real prices for energy over time.¹⁵ Also, compared to the Base case 2030 price of \$15.26 per Mcf, the Cartel case shows that the price of gas could be as high as \$20.73 (see Figure 16). Again, because its production is decreasing, the United States must import more gas.¹⁶ With an active cartel, however, less LNG is available (Base case for 2030 = 8.7 Tcf, Cartel case for 2030 = 3.6 Tcf) with roughly the same level of pipeline gas for the two cases. As a result, consumption drops because of the higher-priced gas, as shown in Figure 16.

This result is a dramatic demonstration of two effects. First, as a result of diminishing natural gas resources, the United States must rely on considerably more imports by 2030, making it less secure. This fact alone is enough to increase prices across all three cases during all years. Second, the need for more imported natural gas is exacerbated by the cartel's market manipulation, leading to price increases.

Using WGM output but keeping in mind that the LNG output assumptions differ somewhat dramatically from those of AEO 2009, one can estimate the potential loss in consumer surplus under the assumptions of these model runs. From Figure 17, we see that consumer surplus under the Base case is given by the triangle 1-4-5 (i.e., areas A + B + C), whereas for the Cartel case it is the smaller triangle 1-2-3 (area A). Here, p_c^e, p_b^e are the equilibrium Cartel and Base case prices, respectively, and q_c^e, q_b^e are the associated equilibrium quantities. Consequently, the loss in consumer surplus is given by the areas B + C. We see that

¹⁵ This increase is about 3 percent per year, following IEA World Energy Outlook assumptions.

¹⁶ Using a separate node for Alaska, the WGM assumes that the Alaska pipeline comes online partially in 2015 at 1.4 Tcf per year and then moves up to and stays at 2.6 Tcf per year for 2020, 2025, and 2030. Canadian gas from the Mackenzie Delta did not have a separate node in the WGM and, through back-calculation, no gas from this region is assumed.

$B = (p_c^e - p_b^e)q_c^e$ and $C = \frac{1}{2}(p_c^e - p_b^e)(q_b^e - q_c^e)$, so the consumer surplus loss is

$$B + C = \frac{1}{2}(p_c^e - p_b^e)(q_c^e + q_b^e) = \frac{1}{2}\left(\frac{\$4.47}{10^3 \text{ cubic feet}}\right)(18.3 + 22.5)10^{12} \text{ cubic feet} = \$91.2 \text{ billion}$$

Figure 14. U.S. Production, WGM Cases

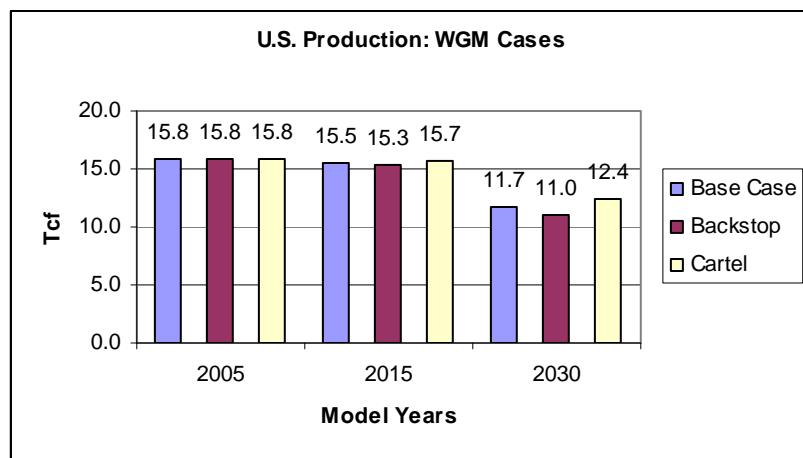


Figure 15. U.S. Volume-Weighted, Wholesale Prices, WGM Cases

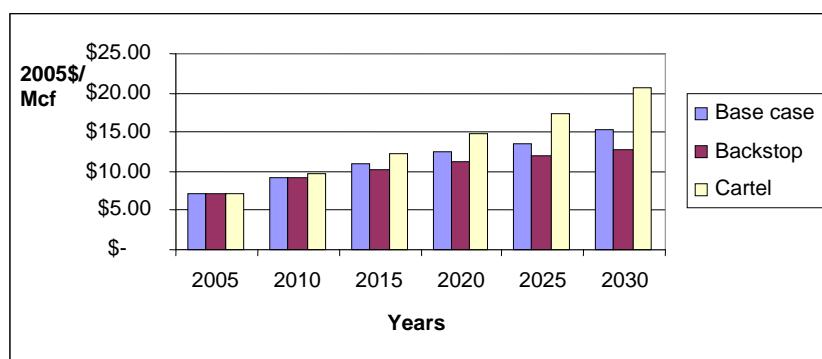


Table 8. U.S. Volume-Weighted, Wholesale Prices, WGM Cases (2005 Values)

	\$/Mcf					
	2005	2010	2015	2020	2025	2030
Base case	\$7.11	\$9.24	\$10.95	\$12.46	\$13.45	\$15.26
Backstop	\$7.11	\$9.23	\$10.09	\$11.19	\$11.92	\$12.70
Cartel	\$7.12	\$9.65	\$12.14	\$14.79	\$17.43	\$20.73

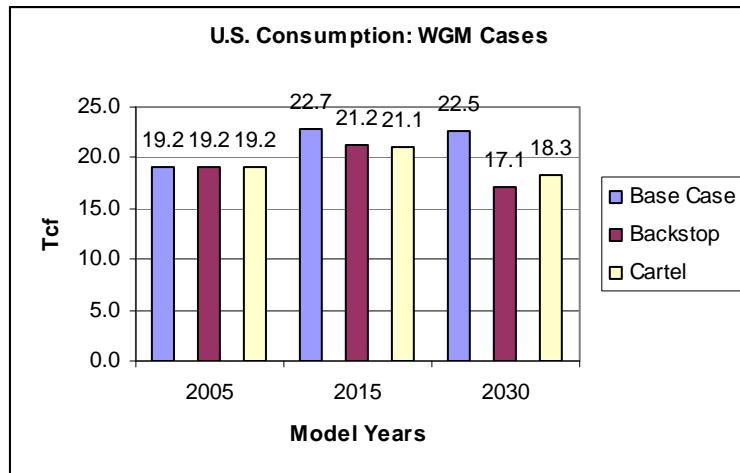
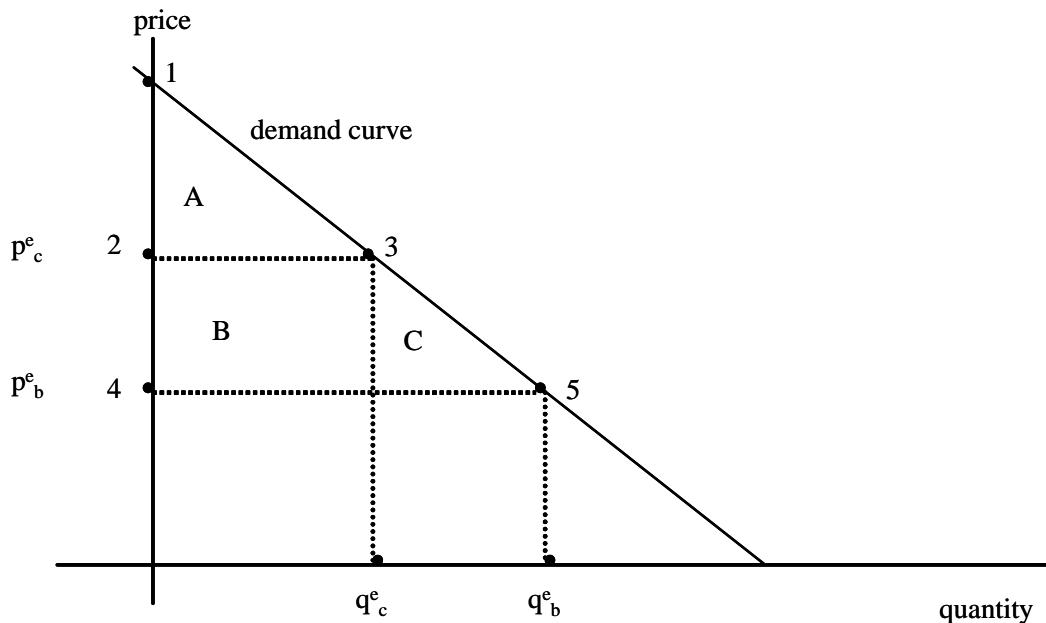
Figure 16. U.S. Consumption, WGM Cases

Figure 17. Consumer Surplus Loss

6. Alternative Future Scenarios and Price Volatility Considerations

This section includes a discussion of additional worst-case scenarios from the perspective of U.S. energy security and explores possible causes and effects of significant price volatility.

6.1 Interactions with the Oil Sector

The relationship between oil and gas prices varies regionally. In the United States and the United Kingdom, due to deregulation, a reference price is based on spot market values for natural gas (Henry Hub in the United States and the National Balancing Point in the United Kingdom.) In Europe, the natural gas price is usually indexed in contracts on fuel oils (heavy oil and home heating oil) because it competes for the most part in the industrial and commercial sectors. In Asia, by contrast, the natural gas price is usually calculated as a function of crude oil prices because that fuel was historically used at most electric power plants in the 1970s (Maisonnier 2006).

Another connection between natural gas and oil involves gas-producing countries such as Libya and Algeria. These countries have been replacing oil-fired power plants with gas-fired ones and selling oil on the world market, as it costs less to ship than LNG (Krauss 2008). However, with oil prices falling from their historic highs, this trend may reverse and more gas may make it onto the world market in the form of LNG exports.

Another potentially important connection between natural gas and oil is in the transportation sector. According to EIA data (2009), in 2008, carbon dioxide emissions from the transportation sector accounted for about 33 percent of total U.S. emissions across sectors. Given the discussion about carbon reduction in both the power and transportation sectors, a move to reduce our dependence on petroleum-based fuel for vehicles is certainly possible. A possible promising solution is to use natural gas to fuel vehicles, which in turn will increase demand for gas (see, for example, Krupnick [2010] on the potential for switching heavy-duty trucks from diesel to LNG).

Consumption levels may also rise in this sector if electric-powered cars become more prominent, in which case, loads on the power grid will rise. Assuming that restrictions on carbon will be in place, this may make natural gas preferred over coal (a “dirtier” energy source in terms of carbon).

7. Conclusions

Given the above discussion, the development of domestic resources—especially promising sources like shale—is vitally important for both cost and security reasons. Such development would carry an overall lower risk than a large-scale endeavor like distributing Alaska gas to the lower 48 states or increasing reliance on LNG imports. Indeed, even if a slight premium in gas price results from procuring this domestic gas, doing so would both provide U.S. jobs in the short- and medium-term and would increase U.S. energy security for the near future.

As shown above, assuming that production forecasts in the Annual Energy Outlook 2009 (EIA 2009) for Alaska gas and LNG imports are accurate, in 2010 we will be able to meet demand if both of these sources are used at their forecasted levels. With additional need for gas (e.g., from carbon reduction programs that disadvantage coal) or a decrease in the above-mentioned sources, the United States is in a more precarious position relative to risk and/or cost. However, with the increase in gas resources shown in AEO 2010 (EIA 2010) and by the Potential Gas Committee (2009), much of this precariousness is alleviated.

Second, the United States should expand to the fullest extent possible the already existing and successful pipeline import relationship with Canada. This country is a stable partner of the United States, and this pipeline gas has recently been less expensive than LNG imports.

Third, the United States already has (or has in the works) more than enough LNG capacity.

Fourth, assuming that Alaska gas can be extracted with minimal environmental damage, it should be produced and transported to the lower 48 states to provide a “cushion” in the face of greater demand from the power sector or other sectors. The lead time is long for such an endeavor, so such a project should be started as soon as it is economically feasible to do so. In some sense, the cost of Alaska gas production and transportation is the value of having a recourse decision if GECF or some other forum imposed market power. At an estimated \$26 billion, the pipeline project is certainly costly; however, from the cartel analysis discussed above, the effects of increased prices based on the WGM results could result in a \$91 billion loss of consumer surplus in 2030. This offers a strong incentive for augmenting our domestic supplies, whether from gas shale, hydrates, Alaska, or other sources.

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