Crossing the Natural Gas Bridge

Matthew Frank, Jenna Goodward, Sarah Ladislaw, and Kate Zyla[1]

May 2009

Executive Summary

While natural gas can play a critical role during the transition to a secure, low-carbon economy, there are both climate and energy security risks associated with a dramatic shift to natural gas. This paper explores the current role of natural gas in the United States' energy mix, reasons that climate change and energy security policies might increase demand for natural gas, and the implications of such a shift. It concludes with several recommendations for policymakers looking to craft a rational role for natural gas in the U.S. energy sector:

- Send a clear, long-term carbon price signal
- Promote natural gas end-use efficiency standards and demand reduction
- Pursue an efficient and environmentally sensitive natural gas development strategy
- Support the development of a flexible and adequately supplied global market
- Address costs and barriers of low-carbon electricity technologies to ensure a diverse and clean power generation mix

Introduction

Addressing climate change will require extensive changes in the ways that we produce, transport and use energy. Given the scope, scale and complexity of the current energy system, the transition to a low carbon energy future will take time, significant investment and carefully crafted polices. During the transition, it is important for policymakers and the private sector to balance the need for aggressive action to reduce emissions with the need for reliable and affordable energy supplies. Natural gas can play a critical role in "building a bridge" to a secure, low-carbon energy system. It is the least carbon intensive fossil fuel (burning gas emits less carbon dioxide than burning coal or oil), and there are readily available supplies, both within and outside of the United States. New natural gas power generation facilities can be brought online quickly compared to other low-carbon sources such as nuclear power. They also enable more renewable energy by providing baseload power generation to complement the intermittent nature of renewables like wind and solar power. There is already a great deal of existing infrastructure –

[1] This paper was written by the authors while working for the Center for Strategic & International Studies (Frank and Ladislaw) and the World Resources Institute (Goodward and Zyla).

from electric power plants and home furnaces to pipelines and ports – that is able to store, transport, and use natural gas.

Natural gas, however, cannot solve our climate problems by itself – and an abrupt and massive "dash to gas" in the short term could raise serious security, economic, social welfare, and power reliability issues.[2] To avoid these problems, the United States needs climate and energy policies that promote a wide range of low-carbon energy technologies, from renewables like wind to nuclear power. At the same time, these policies should recognize that gas eventually must either be replaced by zero-carbon fuels or burned in ways that don't add carbon to the atmosphere.

In this paper, the authors evaluate the security and climate implications of greater natural gas use, explore the outlook for gas supply and demand, and propose policies to guide the future use of this resource. It is the product of a year-long effort to find common ground between the sometimes contradictory goals of energy security and climate change. The focus of the work is to find ways to achieve a secure, reliable, and affordable supply of energy for the United States – while at the same time reducing emissions of dangerous greenhouse gases into the atmosphere.

Background: The Role of Natural Gas

Natural gas plays an important and unique role in the U.S. energy mix. As the third largest contributor to the nation's fuel mix (behind oil and coal), it is used to meet 23 percent of total U.S. energy demand[3] and to generate 22 percent of U.S. electricity.[4] When burned, gas produces fewer pollutants, such as soot, than coal or oil. Although gas also produces relatively few greenhouse gas (GHG) emissions compared to coal and oil, it is nonetheless a significant contributor to U.S. emissions. In 2006, natural gas produced 20 percent of U.S. energy-related GHG emissions, and 15 percent of electricity sector emissions.[5]

Natural gas has a variety of uses. It provides raw materials for industry, powers industrial processes, provides electricity and heat in homes and businesses, and to a much lesser extent, fuels transportation (see Figure 1):

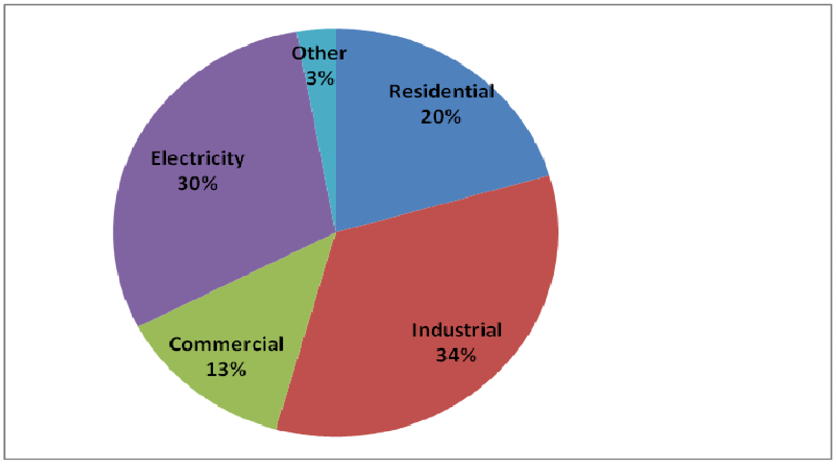
- **Industrial processes** – Natural gas serves as a major "feedstock," or raw material, for petrochemicals, fertilizers, and many other products and is also used to heat and power industrial facilities. For some industries, including fertilizer and plastics, there is no ready substitute.[6]

---

[2] North American Electric Reliability Corporation. Reliability Impacts of Climate Change Initiatives. November 2008 <http://www.nerc.com/files/2008-Climate-Initiatives-Report.pdf>.
[3] Energy Information Administration. "Table 1.3 Primary Energy Consumption by Source, 1949-2007" Annual Energy Review 2007 . June 2008 <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec1_9.pdf>.
[4] Energy Information Administration. "Table ES1 Summary Statistics for the United States, 1996 through 2007" Electric Power Annual 2007. January 2009 <http://www.eia.doe.gov/cneaf/electricity/epa/epates.html>.
[5] Energy Information Administration. Greenhouse Gases, Climate Change, and Energy Brochure. May 2008 <http://www.eia.doe.gov/bookshelf/brochures/greenhouse/Chapter1.htm>.
[6] Energy and Environmental Analysis, Inc. Natural Gas Issues for the U.S. Industrial and Power Generation Sectors May 2004 <http://www.icfi.com/markets/energy/doc_files/eea-gas-issues-summary.pdf>.

- **Residential and commercial fuel –** In homes and businesses, natural gas is used primarily for heating, cooling and cooking, with 52 percent of U.S. households relying on natural gas for home heating.[7] These households can't easily switch to another fuel, since both the delivery infrastructure (pipes, etc.) and the heating systems (furnaces and boilers) are specifically built for natural gas

Figure 1. U.S. natural gas consumption by end use[8]



- **Electricity –** Natural gas is also used to generate electricity for homes and businesses. The fuel is valued for its flexibility, reliability, and low emissions of both GHGs and traditional pollutants.

  Natural gas plays a unique role in the electricity sector. It can be easily transported and stored in large volumes with minimal energy loss.[9] Unlike many other fuels, natural gas-fired power plants can be quickly brought online to generate electricity during periods of peak demand, or to back up intermittent renewables. Gas-fired plants can also be built to run continuously to meet power demand that exists around the clock, or "baseload" demand. The cost of generating electricity with gas is relatively high compared to coal or nuclear power, so gas-fired plants are often the last to be switched on. At the same time, the upfront cost and time to build a gas-fired power plant are less than for a coal or nuclear plant. This makes it an attractive, short-term option for expanding electric generation capacity, especially as new coal-fired power plants are delayed due to climate-

---

[7] Energy Information Administration. Short-Term Energy Outlook. October 2008 <http://www.eia.doe.gov/pub/forecasting/steo/oldsteos/oct08.pdf>.

[8] Chart created using data from the Energy Information Administration, "Table 6.5 Natural Gas Consumption by Sector, 1949-2007" Annual Energy Review 2007. June 2008 <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec6_13.pdf>. Note that *Other* includes transportation and pipeline and distribution losses. Transportation accounted for 0.1% of U.S. natural gas consumption in 2007.

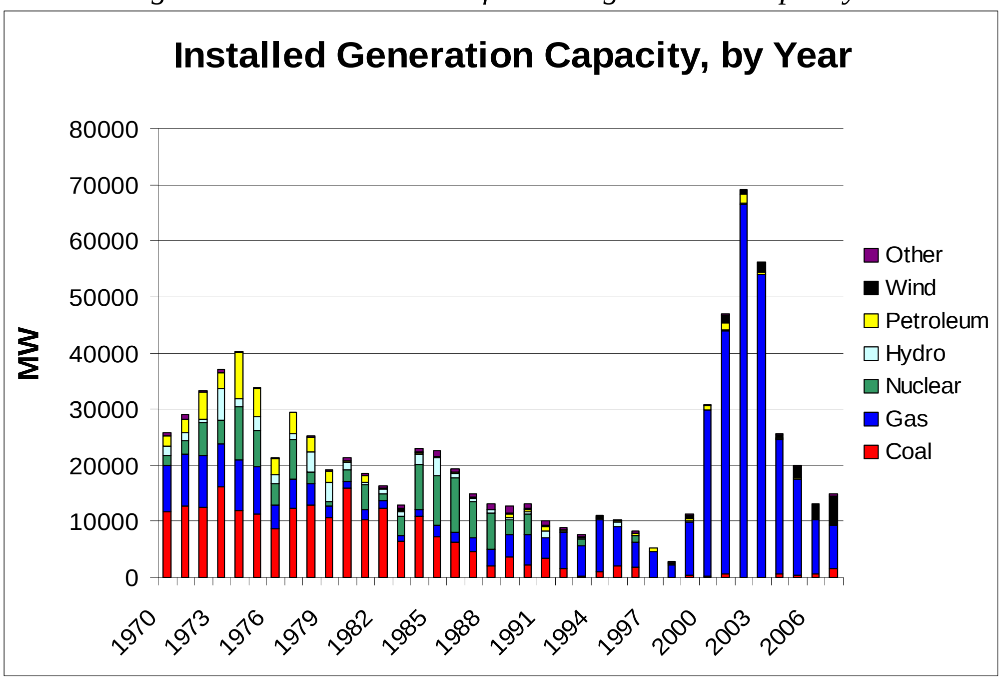
[9] According to the Energy Information Administration's Annual Energy Review June 2008, pipeline and distribution losses (the equivalent amount of energy it takes to transport natural gas through a pipeline) accounted for 2.7 percent of natural gas consumption in 2007. Energy losses during transmission of electricity transmission accounted for 9 percent of consumption of U.S. gross electricity generated in 2007. Technologies to reduce losses from long distance transmission of electricity and to effectively store electric energy are still being developed.

related regulatory uncertainties. Gas is also less carbon intensive than coal, emits fewer traditional air pollutants, and does not bear the waste burden of nuclear power.

Recent trends in the U.S. energy industry reveal a clear preference for building natural gas-fired power plants. From 2005 through 2007, natural gas units accounted for 71 percent of new generation capacity. The previous decade witnessed an even more acute shift to natural gas due to its efficiency and environmental advantages, and uncertainties about the fate of coal-fired power under potential carbon regulation.[10] (See Figure 2) In contrast, coal plants have been facing increasing opposition and delays over the past five years – reflected in the more than 30,000 MW of generation cancelled or deferred.[11]

- **Transportation –** Natural gas is used to a much lesser degree for transportation. In 2008, natural gas used in the transportation sector accounted for less than one-tenth of one percent of total natural gas consumption[12] and met only two percent of transportation demand.[13]

Figure 2. U.S. installation of electric generation capacity[14]



[10] Energy Information Administration. "Capacity Additions, Retirements and Changes by Energy Source" Annual Electric Generator Report (Form EIA-860) 2007. <http://www.eia.doe.gov/cneaf/electricity/page/eia860.htm>.
[11] Schuster, Erik. "Tracking New Coal-Fired Power Plants." National Energy Technology Laboratory January 2009. <http://www.netl.doe.gov/coal/refshelf/ncp.pdf>.
[12] Energy Information Administration. Website data. March 2009 <http://tonto.eia.doe.gov/dnav/ng/ng_cons/sum_dcu_nus)a.htm>.
[13] Energy Information Administration. Website data. March 2009 <http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls>.
[14] Chart created by CSIS with data taken from the EIA Form EIA-860. 2006 Annual Electric Generator Report. <http://www.eia.doe.gov/cneaf/electricity/page/eia860.html>.

The Future for Natural Gas Demand

Under a business-as-usual scenario (i.e., one without a limit on greenhouse gas emissions), the Energy Information Administration projects natural gas demand to grow 50 percent globally and closer to 13 percent in the United States between 2006-2030.[15] In the United States, natural gas demand is projected to increase steadily in the commercial, residential and industrial sectors, where dedicated natural gas infrastructure makes fuel switching difficult.

In the electrical power sector, natural gas demand is much more sensitive to price fluctuations because other fuels, like coal and nuclear fuels, can easily be substituted when gas prices are high. According to current EIA projections in its Annual Energy Outlook, U.S. natural gas demand will decline in the electricity sector due to high prices and volatility between 2007 and 2015, but will then increase by 15 percent (from 2007 levels) by 2030 as new domestic supplies of natural gas are brought online. The current financial crisis and economic downturn could suppress demand in the near-term (the next several years), but over the long-term, growth in demand is likely to recover.[16]

As policymakers become more serious about tackling climate change and energy security, the future role of natural gas becomes more uncertain. The following discussion explores how policies to reduce greenhouse gas emissions and diversify transportation fuels could increase gas use in the electricity and transportation sectors over the next few decades.

Electricity Sector: Coal-to-gas switching?

Since 2003, the U.S. Congress has considered a variety of proposals to place a price on greenhouse gases by capping the total emissions allowed, and then allowing regulated sources to trade permits to emit.[17] This kind of "cap-and-trade" program is emerging as the likely tool for addressing GHG emissions at the federal level, and is already under development in several regions of the country.[18] Creating a price for GHG emissions is expected to have a significant effect on the mix of generating technologies and fuels used by the electric power industry,[19] which produces of approximately 41 percent of U.S. CO_2 emissions.[20]

---

[15] Energy Information Administration. International Energy Outlook 2008 and *Annual Energy Outlook 2009*. <https://eia.doe.gov>.

[16] International Energy Agency. World Energy Outlook 2008 November 2008.

[17] Pew Center on Global Climate Change. Climate Action in Congress <http://pewclimate.org/what_s_being_done/in_the_congress>

[18] While some legislators have expressed a preference for carbon taxes as a tool for reducing emissions, President Obama has stated his support for a cap-and-trade program and included the revenue for such a program in the federal budget. (See http://www.whitehouse.gov/agenda/energy_and_environment/) Cap-and-trade bills have repeatedly received more than 40 votes in the Senate, although none have yet passed in either house of Congress. For regional programs, see the Regional Greenhouse Gas Initiative, <http://www.rggi.org>; Western Climate Initiative, <http://westernclimateinitiative.org>; and Midwest Regional Greenhouse Gas Reduction Accord, http://www.midwesternaccord.org.

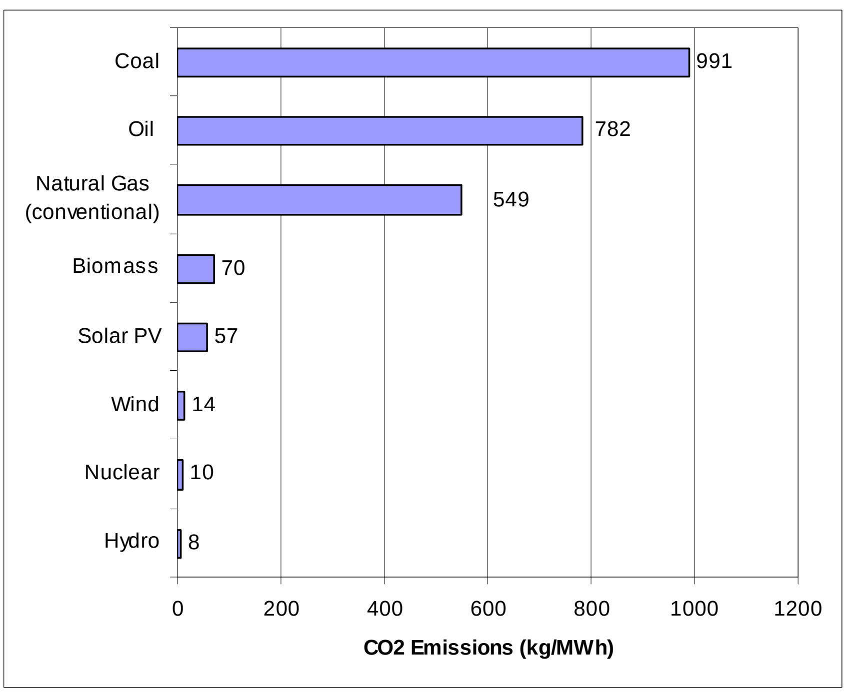
[19] Energy Information Administration. Energy Market and Economic Impacts of S.2191, the Lieberman-Warner Climate Security Act of 2007 April 2008. <http://www.eia.doe.gov/oiaf/servicerpt/s2191/pdf/sroiaf(2008)01.pdf>.

[20] Environmental Protection Agency. "Human Related Sources and Sinks of Carbon Dioxide." 24 Jan 2009. <http://www.epa.gov/climatechange/emissions/co2_human.html>.

This effect will depend on the strength and timing of the carbon price signal, the availability of advanced technologies for cutting emissions and the ability of these substitutes to provide reliable power. Natural gas, however, may continue to be the industry's near-term fuel of choice for producing baseload power and capacity additions, since gas emits half the CO_2 per MWh of coal (see Figure 3), and because gas-fired plants require significantly lower capital expenditures than nuclear power plants. In Europe, climate regulations seem to be spurring a move to natural gas (see Box 1).

Not all utilities will use gas in the same way under a cap-and-trade system. For instance, in regions dominated by coal, switching to gas-fired generation is expected to be less attractive due to the cost of new infrastructure (depending on the cost of alternatives like carbon capture and sequestration, nuclear power, renewables, or efficiency measures).[21] In other areas, favoring gas-fired plants over coal–fired plants will be an obvious near-term strategy with lower costs than other mitigation measures. Utilities and energy analysts alike try to forecast how much of the sector might switch to gas under different climate policies. A wholesale switch from coal to natural gas for U.S. electricity generation would be dramatic: Complete substitution would require an additional 1.4 trillion cubic feet of gas per year; equal to 7 percent of forecasted U.S. production in 2016.[22] Most studies do not envision a switch to gas anywhere near this magnitude, even over timeframes several decades long.

Figure 3. CO_2 Emissions from Electricity by Fuel (kg/MWh)[23]



[21] Victor Niemeyer. "Climate Policy: The Cost of Compliance." EPRI Winter Journal 2008, pp 7-9.

[22] North American Electric Reliability Corporation. Reliability Impacts of Climate Change Initiatives November 2008 <http://www.nerc.com/files/2008-Climate-Initiatives-Report.pdf>.

[23] Daniel Weisser. "A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies," *Energy*. 32 (2007) 1543–1559.

An EIA analysis of one legislative proposal, the Climate Security Act of 2007, illustrates how a carbon cap could increase demand for natural gas. The analysis projects that when clean power generation technologies (renewables, nuclear, and carbon capture and storage) progress quickly and are deployed on a fairly aggressive timeframe (before 2030), total natural gas consumption decreases.[24] However, the analysts conclude that "if new nuclear, renewable, and fossil plants with carbon capture and storage (CCS) are not developed and deployed in a timeframe consistent with the emissions reduction requirements, covered entities are projected to turn to increased natural gas use to offset reductions in coal generation, resulting in markedly higher delivered prices of natural gas". The analysis projects that gas consumption for electricity generation would increase above the reference case by 21 to 72 percent by 2020, and 96 to 142 percent by 2030, if advanced technology and alternative compliance options were not available.[25, 26] In these cases, prices rise and total natural gas demand increases by up to 2.5 trillion cubic feet (tcf) per year (11 percent) in 2020 and by 2.7-4.3 tcf per year (12 to 19 percent) in 2030.

Box 1. Natural gas trends under the European Union Emissions Trading Scheme

The European Union (EU) provides an interesting case study of the near-term effects of climate legislation on natural gas consumption. EU generators operate within the carbon constraints of the EU Emissions Trading Scheme (ETS), begun in 2005.

During the first phase of the ETS, a variety of factors – including political volatility and decreased production from certain suppliers – influenced the European gas market. These factors make it difficult to assess how the cap-and-trade scheme alone affected gas consumption. Research suggests, however, that a meaningful amount of fuel switching occurred in the EU in 2005 and 2006, despite higher gas prices.[27] Utilities complied with GHG caps in part by switching fuels for existing generating units (from coal to gas, and from soft to hard coal), rather than by building new gas-fired generating units.[28] High gas prices in late 2005 and 2006 appear to have slowed the switch to gas, but analysts believe that the price of carbon prevented a widespread reversion back to coal.[29]

In the second phase of the ETS (2008-2012), analysts expect switching will depend on the relative prices of gas and coal, the distribution of emission allowances, and the availability of other options for GHG abatement. Early 2008 results, however, suggested a move to gas in EU states that have gas generation capacity. In the United Kingdom,

[24] Energy Information Administration. Energy Market and Economic Impacts of S.2191, the Lieberman-Warner Climate Security Act of 2007 April 2008. <http://www.eia.doe.gov/oiaf/servicerpt/s2191/pdf/sroiaf(2008)01.pdf>. Note that in the Core Case, natural gas consumption is projected to be below the Reference case by 2020.

[25] Energy Information Administration. Energy Market and Economic Impacts of S.2191, the Lieberman-Warner Climate Security Act of 2007 April 2008. <http://www.eia.doe.gov/oiaf/servicerpt/s2191/pdf/sroiaf(2008)01.pdf.>.

[26] The lower end of these ranges is projected by the Limited Alternatives Case; the higher end of these ranges is projected by the Limited Alternatives/No International Offsets Case.

[27] Delarue *et. al* as quoted in Ellerman and Bucher, Over-Allocation Or Abatement? A Preliminary Analysis of the EU ETS Based on the 2005-06 Emissions Data 2007. Forthcoming in Environmental and Resource Economics. <http://www.ucei.berkeley.edu/PDF/seminar110207.pdf>.

[28] Convery, Frank ."Sustainability and Trading – the EU Emissions Trading Scheme in Ireland," Comhar Sustainable Development Council. <www.comharsdc.ie/_files/**Sustainability**%20and%20**Trading**%20-%20final%20version.doc>.

[29] Convery, Frank. "Reflections on the EU ETS – what can we learn?," California EPA Air Resources Board May 2008. <http://www.capcoa.org/climatechange/upload/documents/Presentation-06-03-2008-convery5-28.pdf>.

for instance, utilities used natural gas to generate 11.2% more electricity in the first quarter of 2008 than they did in the first quarter of 2007, while coal use fell 9%.[30] The UK and Spain[31] may need to switch to gas more aggressively in the future to meet stricter emissions goals in the second and third phases of the ETS.[32] The prospect of increased reliance on natural gas, however, has raised energy security concerns for some EU countries that rely on imports from Russia. Geopolitical tension between Russia and certain members of the EU, as well as questions about whether adequate investments are being made to increase production, have raised concerns about the security of gas supplies to Europe.

Transportation Sector: Oil-to-gas switching?

With some significant limitations, natural gas may also be a near-term option for reducing emissions and providing greater fuel diversity in the transportation sector. In the 1990s, some experts promoted natural gas-powered vehicles as a way to reduce reliance on oil and improve air quality in large cities/urban areas.[33] Natural gas was identified as an alternative transportation fuel in the Energy Policy Act of 1992.[34] Since then, with the help of federal and local partnerships and support, natural gas use increased in urban transit fleets (e.g., local buses and taxi fleets) in the form of compressed natural gas (CNG). According to the American Public Transit Association, natural gas fueled approximately 12 percent of transit buses in 2004 compared to just 1.3 percent just ten years earlier.[35] One reason for the increased attractiveness of CNG use for large buses and vehicles that travel short distance from central refueling sites relates to the relatively large size of fuel tanks, which can safely accommodate compressed gas at lower pressures. This feature diminishes with reduced tank size or longer trip requirements.

While increased natural gas use for transportation is sometimes proposed as a solution to GHG emissions or energy security concerns,[36] a wider shift to CNG would pose significant challenges. One problem is that the existing CNG distribution and refueling infrastructure does not approach the size and scale of the network used to deliver gasoline to customers – the U.S. has approximately 800 CNG refueling stations, compared with close to 175,000 retail gasoline stations.[37] Expanding natural gas's role in the transportation sector would

---

[30] "UK CO2 emissions fall in 2007 on fuel-switching, more renewable" Year-on-year over the same period. PointCarbon 31 July 2008.

[31] These are the only two EU countries with significant fuel switching capabilities.

[32] "Global Markets Research: The EUA Price now implies no fuel switching necessary." Deutsche Bank Aug 2008.

[33] Vehicles running on compressed natural gas (CNG) produce fewer particulate emissions than gasoline-powered vehicles, and emit about 20 percent less CO_2. From the Alternative Fuels and Advanced Vehicle Data Center, "Natural Gas Vehicle Emissions," U.S. Department of Energy. <http://www.afdc.energy.gov/afdc/vehicles/natural_gas_emissions.html>.

[34] H.R. 776, Energy Policy Act of 1992.

[35] Alternative Fuels and Advanced Vehicles Data Center. "Assisting Transit Agencies with Natural Gas Bus Technologies." U.S. Department of Energy <http://www.afdc.energy.gov/afdc/pdfs/37921.pdf>.

[36] Most notably, former oil executive T. Boone Pickens has proposed shifting gas out of power generation (where it would be replaced by wind power) and into transportation. He estimates this shift would provide enough natural gas to reduce oil imports by one-third, although that assertion is highly subjective and has been challenged by a variety of energy analysts. http://www.pickensplan.com

[37] Alternative Fuels and Advanced Vehicles Data Center. "Alternative Fueling Station Total Counts by State and Fuel Type," U.S. Department of Energy. <http://www.afdc.energy.gov/afdc/fuels/stations_counts.html>. Energy Information Administration. "A Primer on Gasoline Prices, DOE/EIA-X040" September 2005. <http://www.eia.doe.gov/bookshelf/brochures/gasolinepricesprimer/eia1_2005primerM.html>

require massive investments in additional delivery infrastructure. In addition, diverting natural gas away from electricity generation sector may introduce reliability issues. Currently, renewables such as wind cannot reliably replace electricity generated with natural gas. Indeed, it is possible that natural gas could make a more significant contribution to the transportation sector if it were used to produce electricity used by electric vehicles. Research suggests that a car using gas-generated electricity would travel twice as far as one that directly burns natural gas.[38]

Natural gas demand is likely to increase in the coming decades. The magnitude of that increase will be affected by the nature and composition of future climate and energy policy, as well as the availability of other affordable, low-carbon fuel options to generate electricity or power transportation. If natural gas demand for either electric power or transportation increases significantly, the availability of supply will become an even more important factor for those concerned with energy security and climate change.

The Future for Natural Gas Supply

The United States is currently the world's second largest producer of natural gas (behind Russia), importing only 13 percent of its total consumption.[39] It has long been a part of an extensive and well-connected North American natural gas market, with 90 percent of its natural gas imports coming from Canada.[40] Conventional natural gas production in North America, however, is expected to decline in coming years,[41] and several other sources of gas are expected to take the place of conventional production. Enormous "unconventional" natural gas resources on the continent could sustain supplies, but the extent of their role will be determined in large part by above-ground issues, including the price of natural gas, the regulatory environment, and environmental concerns, especially as they impact production and infrastructure development. The Arctic is known to hold significant reserves of natural gas, but supplies remain stranded in the absence of delivery infrastructure. Finally, liquefied natural gas (LNG), natural gas that is temporarily liquefied in order to be shipped long distances, is available as an import and is another alternative. Although the U.S. does not currently buy significant amounts of LNG, it could rely on greater LNG imports if North American supplies are unable to keep pace with demand.

The North American Supply Picture

North America is well endowed with natural gas resources, and by some estimates has enough to meet demand for more than a century.[42] These estimates rely heavily on increased production from unconventional sources, which already account for half of U.S. domestic production.[43] Conventional gas production in many North American basins has begun to

---

[38] Climate Progress. "Pickens natural gas plan makes no sense and will never happen," 2008. <http://climateprogress.org/2008/09/26/pickens-natural-gas-plan-makes-no-sense-and-will-never-happen/>.

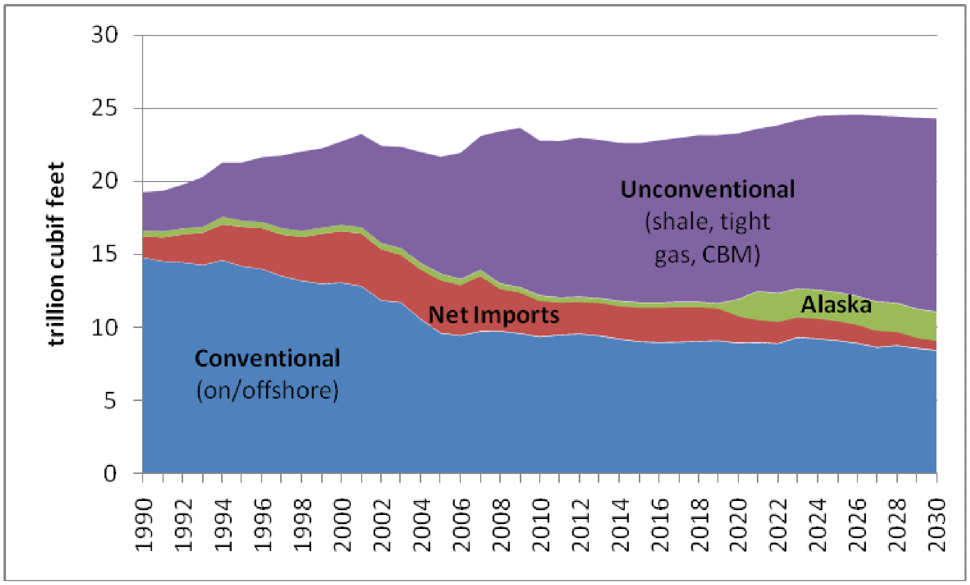
[39] Data for 2008 based on U.S. net imports of natural gas and total natural gas consumption. Energy Information Administration. "Consumption by end use" and "U.S. imports by country," Natural Gas Navigator. <http://tonto.eia.doe.gov/dnav/ng/ng_cons_top.asp>.

[40] Data for 2008. Energy Information Administration."U.S. Natural Gas Imports by Country," Natural Gas Navigator <http://tonto.eia.doe.gov/dnav/ng/ng_move_impc_s1_a.htm.>

[41] Energy Information Administration. "Table A14. Reference Case Oil and Gas Supply," Annual Energy Outlook 2009 Early Release. <http://www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf>.

plateau and is expected to decline over the next few decades. To offset this domestic decline, or even increase the North American supply, a growing share of production would have to come from unconventional resources or untapped reserves in Alaska (illustrated in Figure 4).

Figure 4. Sources of U.S. Natural Gas Supply, 1990 to 2030[44]



Estimates of unconventional gas resources—including shale, as well as coalbed methane and tight sands gas (see Box 2)—indicate a vast potential.[45] Suppliers are increasingly optimistic about their ability to increase supply from these resources, in part due to a growing pool of information generated by exploration and production experience in the United States. Less exploration and production of unconventional gas resources has been carried out elsewhere, but analysts believe there is similarly large potential across the rest of the world.[46]

There is some uncertainty, however, about the ability to produce and deliver unconventional gas due to several "above-ground" issues. Production, particularly from shale, will be more sensitive to the price of gas and availability of credit than conventional gas production. Many producers are independent companies, which unlike major oil and gas companies operate on a cash basis and are more vulnerable to market swings that affect their ability to maintain upstream investments. Further, regulations governing unconventional gas development may pose limitations on access, production techniques, and shipping infrastructure. There are also a number of environmental concerns that may restrict full development of the resource. These concerns include water usage, infrastructure footprint,

[42] Navigant Consulting Inc., North American Natural Gas Supply Assessment July 2008. <http://www.cleanskies.org/upload/MediaFiles/Files/Downloads2/finalncippt2.pdf>
[43] Energy Information Administration. "Natural Gas Production," Annual Energy Outlook 2009, pp 77.
[44] Ibid.
[45] Ibid.
[46] National Petroleum Council. Facing the Hard Truths about Energy, Topic paper on unconventional resources July 2007.

and potentially higher lifecycle GHG emissions than conventional gas due to more energy-intensive production (although this is not well documented).

Box 2. Unconventional Natural Gas

"Unconventional gas" is not a different product from conventional natural gas—it is the same mixture of methane and other gaseous hydrocarbon compounds. The term unconventional refers to the characteristics of the reservoir (rock) containing the gas, especially its permeability, or the ability of the gas to flow through the reservoir. These reservoirs are typically characterized by low permeability, and extracting gas from the formation requires special production techniques and advanced technologies, such as horizontal drilling and hydraulic fracturing.

The term is partly a misnomer, since nearly half of the current U.S. gas supply already comes from sources deemed unconventional. If above-ground challenges can be addressed, there is significant potential for unconventional gas to play a larger role in the North American market given the vast size of the resource, the proximity of some basins to major pipeline infrastructure, and the declining cost of production with greater experience.

Unconventional sources of natural gas include:

- Shale Gas. Natural gas is stored in formations of shale, a sedimentary rock known for extremely low permeability. Estimates of U.S. shale gas potential (existing but not necessarily recoverable) range from 500 to more than 4,000 tcf (technically recoverable resources estimates range between 127 and 841 tcf), with deposits located through the Appalachians (the Marcellus basin), Texas (the Barnett and Haynesville basins), and the Midwest.[47,48] To put these numbers in perspective, the U.S. consumed 23 tcf of natural gas in 2008 and had proven gas reserves of 237 tcf.[49] Currently, gas shale comprises approximately 6 percent of total U.S. production.[50]

- Tight Gas Sands: These low-permeability reservoirs, usually sandstone, already make significant contributions to the domestic gas supply, accounting for close to 30 percent of total U.S. production.[51] Estimated technically recoverable resources in the lower 48 states fall between 177 and 379 trillion cubic feet[52] and are concentrated in the Rocky Mountains and Appalachians, as well as parts of Texas.

- Coalbed Methane: A large amount of methane is trapped in coal. It can be released by "hydraulic fracturing"—pumping fluid into coal seams to crack them and release the gas. Coalbed methane already accounts for a sizeable portion of natural gas production in the U.S. (9 percent) and domestic proven reserves have continuously increased (now listed at 21.8 tcf).[53] Capturing coalbed methane could actually reduce greenhouse gas emissions from coal mining, since the methane otherwise escapes into the atmosphere.

- Methane Hydrates: Methane hydrates are a form of frozen gas found in Arctic permafrost and hundreds of feet beneath the seafloor on continental shelves all over the world. Hydrates are difficult to extract, and currently make no contribution to supply. The U.S. Geological Survey estimates that, if accessible in the future, hydrates could double the world's supply of hydrocarbons (oil, natural gas and coal).[54]

---

[47] Frantz, Joseph H. and Jochen, Valerie. Shale Gas White Paper, Schlumberger 2005. <http://www.slb.com/media/services/solutions/reservoir/shale_gas.pdf >

[48] Navigant Consulting Inc. North American Natural Gas Supply Assessment July 2008 <http://www.cleanskies.org/upload/MediaFiles/Files/Downloads2/finalncippt2.pdf>

[49] Proven gas reserves are those that are technically recoverable and can be brought to market.

[50] Energy Information Administration."Natural Gas Production," Annual Energy Outlook 2009, pp 77.

[51] Ibid

[52] Kruuska,Vello. "UNCONVENTIONAL GAS-2: Resource potential estimates likely to change," Oil and Gas Journal September 2007: 105 (35).

[53] Energy Information Administration. "Coalbed Methane Proved Reserves and Production," Natural Gas Navigator. < http://tonto.eia.doe.gov/dnav/ng/ng_enr_cbm_a_EPG0_r52_Bcf_a.htm>.

[54] Kvenvolden, KA. "Gas Hydrates—Geological Perspective and Global Change," Reviews of Geophysics 31 1993: 173–187.

Attempts to increase supplies of conventional gas from Alaska have faced regulatory hurdles and continue to face commercial difficulties. For example, one pipeline project has been under negotiation for nearly three decades, and by some estimates could cost $30 billion to develop.[55] The outer continental shelf holds potential for expanded conventional supplies, but access remains an open question given environmental concerns about drilling. Without exploration, the exact size of these resources remains unknown.

Any gap in North American supply due to a shortfall of unconventional or Alaskan natural gas would have to be met by imports of LNG. Such a move would expose the U.S. natural gas market to the dynamics of a larger, changing global supply system.

A Globalizing Gas Market

For decades, the uncompetitive economics of transporting natural gas over long distances via pipelines have kept gas markets regionally isolated. Consuming nations met their demand with domestic production and by importing gas via short- and medium-distance pipelines. As a result, some of the world's largest reserves, in the Middle East[56] and Africa, have remained stranded. Gas associated with oil fields in these regions is often released to the atmosphere or flared (burned at the well) because the fields are either distant from demand centers or lacking in adequate transmission infrastructure (see Box 3). As production from basins connected to traditional markets flattens or declines, however – and as significant demand for gas imports emerges within developing economies -- there will be increasing pressure to ship LNG supplies from previously stranded basins.[57]

Box 3: Partnerships and Programs Reduce Flaring and Promote the Use of Vented Gas

Natural gas produced along with oil is often flared (burned) or vented because markets do not exist for the gas, or there are barriers bringing it to market. Both flaring and venting can create health problems in local communities as well as waste a natural resource. The amount of associated gas flared in a year "is equivalent to 25 percent of the United States' gas consumption, 30 percent of the European Union's gas consumption, or more than the combined gas consumption of Central and South America."[58] Flaring gas produces fewer emissions than releasing it directly into the atmosphere, but still results in annual emissions of about 400 million tons of CO_2 globally.[59] Options for using this gas include re-injecting it, burning it for power, moving it to a pipeline, liquefying it for transport as LNG, and converting the gas to liquid fuel (GTL).

There are several partnerships to discourage gas flaring. The **Global Gas Flaring Reduction Partnership** led by the World Bank is a public-private partnership to convene governments and oil companies in order to share best practices and implement country-specific programs to reduce flaring. The initiative promotes effective regulatory frameworks to reduce flaring, and supports building of infrastructure for associated gas utilization.[60]

---

[55] Ling, Katherine. "Dueling Alaska pipeline projects aim to sell capacity in 2010," Greenwire 20 Feb 2009.

[56] Including Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, Syria, U.A.E., and Yemen, the Middle East holds 2,585 trillion cubic feet in proven reserves, or 41.3% of the global total. In 2007, production accounted for only 12.7% of global supply. Data from 2008 BP Statistical Review. <http://www.bp.com/subsection.do?categoryId=9023762&contentId=7044550>.

[57] Trade is projected to increase from 435 bcm in 2006 to 1,022 bcm by 2030., "World Energy Outlook 2009." International Energy Agency.

[58] World Bank ."Learn the Facts," Global Gas Flaring Reduction < http://go.worldbank.org/Q7E8SP9J90>.

[59] World Bank. Global Gas Flaring Reduction. <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTOGMC/EXTGGFR/0,,menuPK:578075~pagePK:64168427~piPK:64168435~theSitePK:578069,00.html>.

[60] *Ibid.*

In 2004, fourteen partner countries joined the **Methane to Markets Partnership**, a multilateral initiative with technical and administrative support from the U.S. EPA that now boasts twenty-one partners. These countries have agreed to undertake cooperative activities to find rational uses for coalbed methane, landfill gas, and oil-associated natural gas. The goal is to reduce venting (release) of methane, a highly potent GHG. The partnership seeks to achieve its goals by helping to attract public and private sector investment to methane capture-and-use projects.[61]

Today, LNG imports comprise roughly 3 percent of U.S. natural gas consumption. Power producers typically purchase LNG when prices are lowest and store it until needed, providing flexibility for power production during seasons of peak demand. Price dynamics in the globalizing natural gas market, however, are complex. Prices for LNG tend to be set in regional markets using different price adjustment formulas and contract terms. For example, LNG prices in Asia are closely tied to oil prices, so when oil prices were rising in early 2008, gas prices were driven by markets in Asia. European contracts also take oil prices into consideration but adjust over longer periods of time, so as oil prices have fallen European markets have tended to remain higher longer due to built-in contract adjustment lags. These price differentials influence the small but growing spot market for LNG and are key considerations for companies (and countries) with new LNG export projects looking to secure a market for their natural gas. Should the U.S. market require a larger and more consistent supply of LNG, it is well positioned to increase imports. The U.S. LNG infrastructure already in place has ample surplus capacity for regasification of the fuel[62] and a robust storage and transmission network to move large volumes easily to demand centers.

Potential Energy Security and Climate Change Issues

Shifting to natural gas is an obvious carbon reduction strategy in the short term, but there may also be risks to relying on it too heavily. Several climate- and security-related issues arise when considering the potential future role for natural gas over the longer term.

Climate-Related Issues

Risk of missing long-term emissions goals

Natural gas can supply important near-term emissions mitigation in the power sector, and potentially (albeit on a more limited basis) in the transportation sector. However, combustion of natural gas still produces GHG emissions. Absent new technologies to capture these emissions, increasing use of natural gas will not achieve the more aggressive long-term GHG emissions reductions needed, on the order of 60 to 80 percent below 1990 levels.[63]

---

[61] Methane to Markets. "Partnership Frequently Asked Questions."<http://www.methanetomarkets.org/about/partner-faq.htm>.

[62] LNG regasification terminals were utilized at less than 10 percent of capacity in 2008. Estimated capacity at the end of 2008 was approximately 10 bcf per day. LNG imports to the U.S. during 2008 averaged 0.96 bcf per day. Information gathered from Energy Information Administration. Natural Gas Navigator and the Annual Energy Outlook 2009.

[63] Levels recommended by the IPCC in its Fourth Assessment Report. Findings of Working Group III <http://www.imgw.pl/attachments/351_LMeyer.pdf>.

These conclusions are supported by a model of economy-wide emissions developed by the Department of Energy's Pacific Northwest National Laboratory (PNNL). The model's scenarios depict several different combinations of technologies and fuels that could meet energy demand while also emitting less CO_2, thereby stabilizing atmospheric CO_2 concentrations at 450 ppm.[64] In all scenarios, natural gas continues to make up a portion of the energy mix out to the end of the century, mainly due to its feedstock and non-electricity uses (ranging from 7 to 17 percent in 2100 compared to 22 percent currently). In scenarios where carbon capture and storage (CCS) technology becomes widely available at reasonable cost, natural gas with CCS provides a share of low-emissions electricity out to 2095 (between 2 and 13 percent of the electricity mix depending on other technology assumptions).[65] Under scenarios without deployment of CCS, the electricity sector's use of gas would peak around 2035, and then provide a decreasing share of the nation's electricity, disappearing from the sector between 2050 and 2065. These scenarios also show a much greater reliance on other sources of energy (nuclear and renewables) and significant demand reduction. While emissions modeling through the end of the century is always imprecise, these results suggest that to meet emissions goals, use of natural gas without CCS will need to start declining in the next 25 years. This implies that policymakers should look beyond the short term, and provide a long-term price signal that is stringent enough to encourage alternatives to natural gas without CCS, while finding ways to manage the costs of the transition.

Lack of information about lifecycle emissions

Natural gas is the least carbon-intensive fossil fuel (meaning it produces less carbon emission per unit of energy than coal or oil). However, the full emissions of natural gas coming from certain production and delivery methods are not well understood. To calculate these lifecycle emissions, several stages must be considered: production, delivery, and combustion. The only ways to reduce the emissions associated with combustion are to increase the efficiency of the plant or sequester the resulting emissions. Emissions incurred during delivery through a pipeline are negligible, resulting only indirectly from electricity used to run pumps and compressors. Production, however, can result in varying levels of emissions depending on the techniques used to extract the gas. In particular, production of unconventional gas resources typically requires application of hydraulic fracturing (pumping of water and other solvents into low permeability rock at high pressure) to create seams that allow the migration of gas toward a well and then the surface. Because the technique requires more energy, the overall energy intensity and lifecycle emissions of unconventional production are likely greater than conventional production; however, available data is limited.

In contrast, researchers have attempted to understand the lifecycle emissions of LNG, although publicly available data are limited. The additional processes required for LNG production and delivery (cooling, pressurizing, shipping, and regasification) can increase its emissions intensity when compared to domestic gas production, but the scale of the increase depends heavily on the liquefaction processes used in producing countries, and on transport

[64] For more information about the PNNL models see: Childs et.al., Evaluating the Energy Security Implications of a Carbon-Constrained U.S. Economy, CSIS and WRI February 2009. <http://www.csis.org/media/csis/pubs/090130_evaluating_energy_security_implications.pdf.>

[65] Note that in these scenarios CCS also allows coal-fired plants to exist as small share of generation out to the end of the century.

distance. A lifecycle analysis (LCA) by Jaramillo, et. al. estimates that emissions per MWh generated from LNG are 5 percent to 35 percent higher than those of generation from domestic natural gas, even when assuming use of high-efficiency combined cycle engines.[66] This difference was not observed in another LCA by the Advanced Resources Institute and ICF International, which showed emissions intensities from domestic gas and LNG to be roughly equal.[67] The study drew on (lower) liquefaction figures from industry reports and also found lower production and transport emissions.[68] Industry reports that LNG processing emissions are reduced significantly in their newer, larger processing trains because they use more efficient, less carbon-intensive onsite power generation, among other improvements.[69]

Security-Related Issues

Overall there are many positive implications of a globalizing market for natural gas. Most importantly, it would spur increased market competition, which should encourage efficiency: producers would be encouraged to develop resources more efficiently; and consumers, competing against each other for supply, would find ways to use the resource more efficiently. In addition, increasing connections between regional markets introduce greater flexibility and a hedge against disruptions. In the event of a shortage in one market, the burden (in the form of higher prices) would spread across participants in a larger global market.

Energy security risks, however, may also emerge from the changing dynamics of the domestic and global natural gas markets. Under some circumstances, greater U.S. demand for natural gas could strain domestic supplies, raise import levels, and thereby increase exposure to a global market with more volatile supplies and risk of higher prices. Potential energy security concerns include the following.

The effect of limited access and market volatility on upstream investment

As markets witnessed over the past several years, demand for energy can easily outpace development of new supply, driving up costs and, in the extreme, leading to shortages. Often this situation is a result of inadequate upstream investment to produce and deliver energy supplies in anticipation of demand. With regard to gas, this risk could be significant due to

---

66 The actual U.S. power generation fleet includes many gas units with significantly lower efficiency engines, which exacerbates this difference, but new units are typically combined cycle.

67 Advanced Resources International, Inc. and ICF International. Greenhouse Gas Lifecycle Emissions Study: Fuel Lifecycles of U.S. Natural Gas Supplies and International LNG Prepared for Sempra LNG 2008. <http://www.cpuc.ca.gov/NR/rdonlyres/430BCFA0-37C6-4E62-AD2C-7C3A34013181/0/ARI_LCA_NOV_10_08.pdf.>

68 Jaramillo, Paulina, *et. al.*, "Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation," Environmental Science and Technology 2007: 41 (17), pp 6290-6296.

69 Researchers have indicated that these figures may not reflect the state of the art in LNG refining, but there is a lack of public data on state of the art LNG trains. Without this, and without knowing how quickly the refining infrastructure will evolve, it is difficult to say how the profile of LNG will change. BP projects that next generation LNG trains will be able to reduce liquefaction emissions by half compared to first generation plants (from 0.33 tCO_2/ton LNG to 1.65). Data verifying these projections has not been made publicly available yet. See BP's Big Green Train: Benchmarking the Next Generation LNG Plant Designs, Presented at 14th International Conference on LNG, Doha March 2004.

several factors. First, unconventional gas supplies are produced at higher cost and therefore sensitive to sustained low prices. In the wake of the recent financial crisis and weak market, production of many unconventional natural gas resources may be less likely or at least significantly delayed. If Congress enacts new climate legislation, industry would likely have time to respond to the increased demand for natural gas that may come with carbon constraints. If demand grows fast enough, however, domestic supplies may have a harder time keeping pace.

Second, another potentially significant source of gas supply, LNG, must be developed by a handful of countries that do not always respond to market signals with necessary upstream investment.   Establishing infrastructure to export LNG is a complex and capital-intensive process that a limited number of companies possess the skills and financial resources to execute.   The entire LNG supply chain – liquefaction plants, tankers, and regasification terminals – must be in place before delivery can occur. With many prospective exporters, capital is available, but expertise is scarce. The fact that many countries restrict access and investment by international companies best suited to develop this infrastructure could be worrisome if gas markets begin to tighten around the globe.

Increased susceptibility to import supply disruptions
As inter-regional trade increases and major consumers' import dependency grows, there will be greater risk for supply disruptions with global effects. In addition, a small group of producers in the Middle East, Central Asia, Africa and Russia are likely to hold disproportionate geopolitical leverage due to their control of a vast proportion of supply. The security dynamics of the natural gas market could become similar to those of oil, with major resource holders in close geographic proximity. Some reports suggest these producers are interested in creating a global gas cartel similar to OPEC. To the extent that physical supply and decision making become concentrated geopolitically, the security of gas supplies and LNG will become an even greater concern. It is also important to consider the physical vulnerabilities of an expanding delivery infrastructure (including pipelines, liquefaction facilities, ships and regasification terminals) to disruptions arising from geopolitical conflict, terrorism, and severe climatic events.

Greater involvement in a global market does not pose an absolute negative security risk. Global markets, to the extent that they operate freely and are well supplied, offer a great deal of security and cost savings. In strict security terms, however, being part of global market comes with risks that should be managed.

Increased exposure to higher and more volatile prices
Greater reliance on natural gas may increase exposure to higher and more volatile prices, particularly if that reliance is in the power sector, or if a larger portion of gas supply comes from high-priced LNG. Gas-fired generation sets prices in the U.S. electricity markets. If, in the future, these markets are more dependent on gas, they will also be more exposed to gas price volatility. Correspondingly, if increased demand from the electricity sector forces gas prices higher, costs will rise for industrial, residential, and commercial gas users, who often have few alternatives.

The Natural Gas Bridge: Policy Recommendations

While natural gas can play an important role in meeting climate and energy security goals, it is not an adequate solution on its own. Natural gas can serve as a "bridging strategy," but the bridge must be structured carefully to ensure that it leads to a future with more diverse technology options. Over the longer term, natural gas without CCS will need to make up a smaller portion of the fuel mix. This raises important questions for how policymakers and companies should view long-term investments in natural gas technologies and infrastructure. Climate and energy policies also must consider how gas is used for residential heating and other non-power processes, where substites are limited and impacts on social welfare can be significant.

The first priority for addressing both energy security and climate goals is greater efficiency. Increased efficiency standards will optimize use of the natural gas that we have. In the near term, the U.S. will also need to develop domestic natural gas resources, with appropriate environmental safeguards, in order to reduce costs and potential concerns about energy security. Also important are policies that promote technologies that can decarbonize natural gas—such as carbon capture and storage—and replace it with zero-emission generation technologies.[70] A price on greenhouse gas emissions will accelerate the use of these non-emitting energy technologies, encourage more efficiency, and alter consumer behavior. It will be increasingly important to understand the full lifecycle emissions of various natural gas supplies in order for such a policy to be effective. If climate legislation is structured correctly, it should stimulate low-carbon power generation technologies and avoid an overly aggressive or abrupt switch to natural gas. The authors therefore recommend the following policies:

Send a clear, long-term carbon price signal:

Carbon prices should send a clear signal to power-sector investors that fuel switching to natural gas without CCS is not a long-term climate compliance strategy. To allow informed investment choices, any policy to limit GHG emissions must include clear targets for emissions beyond 2030, in line with the atmospheric stabilization targets suggested by recent climate science.[71] An efficient cap-and-trade bill must also provide a stable price signal, and avoid keeping that price so low in the short term that it discourages investment in the technologies needed for mid- and long-term mitigation. A carbon price, in combination with other incentives, must reflect the marginal abatement costs of clean-energy technologies. The federal government can also do much to lower those costs and help ensure that such technologies come online (see additional recommendations below).

Promote natural gas end-use efficiency standards and demand reduction:

Natural gas end-use efficiency programs have a dual benefit. They reduce emissions and protect natural gas customers from price shocks and volatility. Fully funding programs targeting residential customers, including the Weatherization Assistance Program (WAP), EnergyStar, and other U.S. Department of Energy best-practice programs, would be an

[70] EIA analyses of Lieberman-Warner Climate Security Act of 2007 show that by 2020, NG consumption would be lower than in business-as-usual reference scenario in three of its five cases.

[71] Intergovernmental Panel on Climate Change, Fourth Assessment Report, November 2007. <http://www.ipcc.ch/ipccreports/ar4-syr.htm>

excellent contribution. Higher efficiency standards on appliances will help make more rational use of domestic natural gas supplies. The federal government can request that DOE accelerate its rulemaking to implement efficiency standards enacted in EPACT2005 for various end-uses, as well as to allow cold weather states to elect higher standards for residential heating appliances.[72] On the buildings front, where new buildings have potential for major improvement in emissions profiles, the DOE should support states in adopting and implementing ambitious building codes.[73]

Pursue an efficient and environmentally sensitive natural gas development strategy:

Improving and maintaining energy security will necessitate the development of domestic and international natural gas resources in order to ensure supplies, mitigate prices, and temper dependence on imports. U.S. natural gas production is projected to flatten over the next several decades, but there remains significant potential to develop untapped unconventional, Alaskan, and offshore natural gas resources, which present an important opportunity to bolster energy security. It is imperative, however, that policymakers and companies pursue development of natural gas resources in ways that do not negatively affect the environment.

Therefore, climate policy should address lifecycle emissions of energy sources, including those from the production and processing of natural gas, which are often not well-documented. In order to reflect the full lifecycle, government and industry must cooperate to develop accurate and standardized methodologies that calculate emissions from the range of alternative natural gas sources, including LNG and all types of unconventional gas. And internationally, the U.S. should promote efforts to reduce or eliminate flaring of natural gas into the atmosphere during the production of oil. This presents a significant opportunity to more efficiently use resources and lessen the environmental impacts of energy production. Flaring often occurs when a producing country's economic conditions and infrastructure are not adequate to make more productive use of gas. The U.S., through a number of dedicated international organizations, should strengthen and expand efforts to promote the rational use of flared or otherwise wasted gas.

Support the development of a flexible and adequately supplied global market:

A functioning and well supplied global natural gas market—one in which supply and demand respond to price signals—will be critical to ensuring global gas security. While it is difficult to steer the development of these markets, policymakers should promote their development by encouraging investment in natural gas production and delivery projects; accessible resources subject to strong environmental protections; multiple, interconnected supply routes and supplies; market-based principles and price signals; and an open trading environment.

---

[72] Elliot, Dr. Neil R. Testimony Submitted to House Government Reform Subcommittee on Energy and Resource 14 Sept 2005 <http://www.aceee.org/tstimony/0509rnereform.pdf>.

[73] One example includes the International Energy Conservation Code (IECC). <http://www.internationalcodes.net/2009-international-energy-conservation-codes.shtml>

Address costs and barriers of low-carbon electricity technologies to ensure a diverse and clean power generation mix:

Aggressive action on renewables, efficiency, CCS, and nuclear power is needed to ensure that a wide range of low-carbon energy options are available as emission reduction targets become more stringent. Therefore, reducing costs and barriers to deploying low-carbon technologies at the required scale are an important part of making sure the shift to natural gas is not too drastic or long-lived without the ability to sequester the emissions. Just as the U.S. should maintain a diverse mix of gas suppliers, we should also diversify our electricity portfolio to balance a variety of sources of low- or no-carbon emissions. Policies that will help ensure development of a portfolio of zero-carbon electricity technologies should seek to:

- Prioritize clean energy infrastructure, especially transmission corridors to enable a greater share of renewable power and CCS pipelines;
- Promote deployment of a diverse set of renewable energy technologies through a strong federal policy such as a renewable portfolio standard and an ambitious package of renewable energy investment incentives;
- Continue R&D to reduce the cost of CCS and support commercial-scale demonstration of integrated CCS projects that employ all capture approaches (pre-combustion, post-combustion and oxy-fuel combustion);
- Improve the safety, waste management, cost, and proliferation risks currently hindering expansion of nuclear power; and
- Increase the support for and effectiveness of energy R&D spending.