The Annapolis Center For Science-Based Public Policy

Natural Gas: It Is Not a Pretty Picture!

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Major Summary Points:

- Natural gas is a broadly accepted fuel because of its convenience, environmental attractiveness, safety, and historically low cost.

- A number of factors impact natural gas prices. Since many are not predictable, price forecasting is extremely difficult.

- North American natural gas production has likely peaked, so U.S. supply shortages are almost certain until LNG imports materially contribute. Over time, Canadian exports to the U.S. will decrease.

- Liquefied Natural Gas (LNG) is absolutely necessary to satisfy current as well as future U.S. demand. Related investments are huge. Project delays mean longer periods of shortage and volatility in prices. The U.S will be in competition for available LNG with growing demands in Western Europe, Japan, and Korea, among others.

"Our greatest responsibility is to be good ancestors."
Jonas Salk

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EXECUTIVE SUMMARY

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- LNG presents safety questions that must be adequately and promptly addressed, so that ten or more LNG receiving facilities can be built and brought into operation as soon as possible.

- Alaskan natural gas is unlikely to provide new supply for 10-15 years.

- Natural gas demand, imports and prices may rise even further if new policies are enacted to implement the Kyoto Protocol, limit coal use, or greatly increase the use of ethanol fuels.

- U.S. natural gas supply and prices could be dramatically impacted by the peaking of world oil production, but the date of oil peaking is uncertain.

- One way or another, the U.S. will manage its way through the forthcoming natural gas shortages and price escalations, but the transition will likely require the better part of a decade.

Natural Gas:
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Introduction

In the 1990s natural gas emerged as a highly preferred fuel. Recently, the natural gas outlook changed dramatically. In the following, we review

- The attractiveness of natural gas
- Current uses
- Natural gas prices
- Supply
- Policy changes that could drive demand
- The outlook

Our emphasis is on current status and likely future trends.

Attractiveness of Natural Gas

Natural gas burns cleaner than any other fossil fuel. It does not create significant sulfur oxide or particulate emissions. Some nitrogen oxides are produced, but related volumes can be suppressed by changes in combustion conditions and the use of exhaust treatment. Because of its high hydrogen content, carbon dioxide emissions from natural gas combustion are the lowest of the fossil fuels, which makes natural gas use attractive from a global warming perspective.

Natural gas prices were remarkably low and relatively stable from the mid 1980s until the late 1990s. Supplies were plentiful in most parts of the U.S. because of a competitive market and a well-developed transmission and distribution system.

Natural gas is relatively safe to use in general practice, and consumers are comfortable with it in their home and businesses. For process heat and chemical processes, natural gas has been a convenient, low cost staple for decades.

Natural gas was the fuel of choice for new electric generation capacity prior to recent price increases.

Natural gas is a broadly accepted fuel because of its convenience, environmental attractiveness, safety, and historically low cost.

Uses

Natural gas satisfies roughly 25 percent of U.S. energy needs. Fractional use is as follows (2002):[1]

Industrial	43%
Residential	22%
Commercial	14%
Electric Power	18%
Transportation	3%

Roughly 85 percent of all industrial natural gas use is in the following industries: pulp and paper, metals, chemicals, petroleum refining, stone, clay and glass, plastic, and food processing. Applications are largely for heating, cooling, waste treatment, and incineration. Natural gas is also used as a feedstock for the manufacturing of a number of chemicals and pharmaceuticals. While consumption for electric power production was recently 18%, related demand has been the most rapidly expanding.[2]

Natural gas demand is significantly impacted by the severity of winter weather. Until relatively recently, summer and fall were typically periods for replenishing natural gas storage in preparation for the winter heating season. In the past decade, however, more and more natural gas has been consumed in electric power production, which tends to peak in the summer due to air conditioning demands. Accordingly, the severity of summer weather has become an added weather-related driver of natural gas use.

Some industrial consumers and electric power generators are able to utilize either natural gas or distillate oil. During periods of abnormally high natural gas prices, some users switch from natural gas, thus decreasing its demand and moderating prices.[3]

The health of the U.S. economy also impacts the demand for natural gas, especially industrial consumption. When the economy is expanding, natural gas demands in industry typically increase, while during recessions, industrial demand typically declines. For instance, industrial natural gas consumption fell by 6 percent in 2001 due to the economic downturn**.**

Prices

Important factors that impact natural gas prices are listed in Table I. They are grouped according to time frame: Short-Term (Months), year-to-year (Annual), and Long-Term (5+ years). Price effects are as indicated. Terrorism is a new wildcard, the potential of which could be minor or major.

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[1] EIA - Annual Energy Outlook 2002.
[2] http://www.naturalgas.org/index.asp - A site sponsored by the Natural Gas Supply Association.
[3] Ibid.

Department of Energy data show that U.S. natural gas prices were relatively stable in constant dollars from 1987 through1998.[4] Thereafter, prices began to escalate, and in the year 2000, they were roughly 50 percent higher than in 1998.[5] Skipping over the recession years of 2001 and 2002, prices in late 2003 and early 2004 further increased roughly 25 percent over 2000.[6] What has changed over recent years is natural gas supply, which is deteriorating and which will almost certainly push natural gas prices higher in future years. Current prices are in the $5.00-6.00 per thousand cubic feet (Mcf), compared to $2 / Mcf in the mid-1990s. In the extreme, natural gas prices could exceed $20 / Mcf by the end of this decade, due to increased demand and falling supply."[7] But many of the factors influencing natural gas prices are unpredictable, so price projections are necessarily no more than educated speculation.

A number of factors impact natural gas prices. Since many are not predictable, price forecasting is extremely difficult.

U.S. Dependence on Imports Will Grow

North American (U.S., Canada, Mexico) natural gas supply is currently in transition from a supply-rich era to a period of geologically determined domestic production shortage. For decades, the U.S. supplied the majority of its needs from domestic production with growing imports from Canada and some exports to Mexico. Forecasts of plentiful future supplies and associated low prices were major factors in the expanded use of natural gas. To the surprise of many that situation has changed dramatically. The U.S. became a net importer of natural gas from Canada in 1958. Imports broke the 1 Tcf barrier in 1979, 2 Tcf in 1993, and 3 Tcf in 1999. In 2003, imports were 15% of consumption.[8] There is no prospect for the U.S. becoming self-sufficient in natural gas in the future.

The U.S. Supply Picture: Reality Sets in

Reputable forecasters had been projecting ample future North American natural gas supplies. For example:

- In 1999, the National Petroleum Council stated "U.S. production is projected to increase from 19 trillion cubic feet (Tcf) in 1998 to 25 Tcf in 2010 and could approach 27 Tcf in 2015…. Imports from Canada are projected to increase from 3 Tcf in 1998 to almost 4 Tcf in 2010."[9]

[4] Natural Gas Markets and EIA's Information Program March 2000.
[5] U.S. Department of Energy, Energy Information Administration, *Natural Gas Annual 2002*.
[6] U.S. Department of Energy, Energy Information Administration, "Natural Gas Navigator." May 6, 2004.
[7] Powers, B. Arctic Natural Gas. Canadian Energy Viewpoint. September 1, 2004.
[8] EIA Nat Gas Monthly August 2004
[9] National Petroleum Council. Meeting the Challenges of the Nation's Growing Natural Gas Demand. December 1999.

- Also in 1999, the U.S. Department of Energy (DOE) Energy Information Administration (EIA) projected that U.S. natural gas production would grow continuously from a level of 19.4 Tcf in 1998 to 27.1 Tcf in 2020.[10]

The current outlook (mid-2004) is very different:

- According to Cambridge Energy Research Associates (CERA), "Gas production in the United States (excluding Alaska) now appears to be in permanent decline, and modest gains in Canadian supply will not overcome the US downturn." "The North American natural gas market is set for the longest period of sustained high prices in its history..." [11] Disappointing drilling results in the United States in 2000–2001 were an early indicator that the geological base in North America is mature, and it is not possible "to drill our way out."[12]

- The Wall Street firm Raymond James & Associates opines "Natural gas production continues to drop despite a 20 percent increase in U.S. drilling activity since April 2003."[13] " Our survey results … bring into question the data from the Energy Information Administration showing U.S. natural gas production on the rise…"[14]

- Investment banker Lehman Brothers "now expects full-year U.S. production to decline by 4% following a 6% decline in 2003. Domestic production is forecast to fall to 41.0 billion cubic feet a day by 2008 from 46.8 in 2003 and 52.1 in 1998. After a sharp 12% fall in 2003, Canadian imports are seen dropping..."[15]

- The National Petroleum Council now states, "Current higher gas prices are the result of a fundamental shift in the supply and demand balance. North America is moving to a period in its history in which it will no longer be self-reliant in meeting its growing natural gas needs; production from traditional U.S. and Canadian basins has plateaued."[16]

Canadian Imports in Question

Canada has been a reliable supplier of natural gas to the U.S. for decades, but their situation has also recently changed for the worse. For example: "Natural gas production in Alberta, the largest (Canadian export region) to the huge U.S. market,

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[10] U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook 2000. December 1999.
[11] CERA Advisory Services. The Worst is Yet to Come: Diverging Fundamentals Challenge the North American Gas Market. Cambridge Energy Research Associates, Inc. Spring 2004.
[12] Forty in Eight - The 2004 Update of CERA's LNG Scenarios. 2004.
[13] Industry Trends (quoting Raymond James & Associates). OGJ. June 7, 2004.
[14] Adkins, J.M. et al. "Energy Industry Brief". Raymond James & Associates. May 17, 2004.
[15] "Lehman Says US 1Q Gas Production Fell By 5.3%". Dow Jones. May 12, 2004.
[16] National Petroleum Council. *Balancing Natural Gas Policy – Fueling the Demands of a Growing Economy: Volume I – Summary of Findings and Recommendations*. September 25, 2003.

slipped 2 percent last year despite record drilling and may have peaked in 2001… (Sources) forecast flat production in 2004 and an annual decline of 2.5 percent through at least 2013."[17] Another knowledgeable observer opines, "Canadian and Lower 48 natural gas production is in permanent and irreversible decline, regardless of price."[18] EIA noted that Canadian imports to the U.S. dipped nearly 8% in 2003.[19]

Federal Reserve Chairman Alan Greenspan (See the Appendix).

"Canada, which has recently supplied a sixth of our consumption, has little capacity to significantly expand its exports, in part because of the role that Canadian gas plays in supporting growing oil production from tar sands."

In 2003, the Canadian National Energy Board made a significant downward reassessment of expected natural gas production in both 2015 and 2025:

	2015	2025
1999 Estimates	8.1-9.0 Tcf	7.7-9.9 Tcf
2003 Estimates	5.9-7.1 Tcf	4.3-6.1 Tcf Reduction
	2.0 Tcf	3.2 Tcf

The change in forecasts has shifted from growing production to declining production.

The dramatic decrease in Canadian natural gas production, coupled with growing demand in Canada for natural gas to support oil sands production will dramatically reduce the amount of gas available for export to the U.S. This includes the Canadian MacKenzie Delta Pipeline, which could move the roughly 10 Tcf of known reserves the 1000+ miles to the existing Canadian natural gas transmission system. The cost has been estimated at $3.8 billion.

Most of the MacKenzie Delta gas (initial flow in 2009, peak flow in 2012 of 0.7 Tcf) is likely to be committed to oil sands production.[20]

Mexico is a Net Importer of Natural Gas from the U.S.

Mexico has been dependent on the U.S. for exports of natural gas since 1985. It's growth in demand for natural gas will continue to outpace it domestic production, with imports projected to grow to 40% in 2025. Mexico will also become dependent on LNG imports.

[17] Reuters. "Alberta Gas Output Falling Despite Record Drilling". June 6, 2004.
[18] Powers, B. Arctic Natural Gas. Canadian Energy Viewpoint. September 1, 2004.
[19] U.S. LNG Imports Soared in 2003. Inside Energy Extra. September 1, 2004.
[20] EIA International Energy Outlook 2004

North American natural gas production has likely peaked, so U.S. supply shortages are almost certain until LNG imports materially contribute. Canadian exports to the U.S. will likely decrease as its supplies dwindle and its demands increase.

LNG – Delayed Salvation

With North American natural gas production now in decline, hopes of meeting demand have turned to imports of liquefied natural gas (LNG). For example, both the Secretary of Energy and the Chairman of the Federal Reserve Board called for a massive buildup in LNG imports to meet growing U.S. natural gas demands.

There are currently four operating LNG receiving terminals in the U.S., and additional terminals have been proposed for the U.S., Canada and Mexico. But the construction of new terminals has encountered considerable state and local opposition. Because of NIMBYism[21] and fear of terrorism, many of the proposed terminals have been delayed or outright rejected. Objections have also arisen from Mexico, which has been proposed as a host for LNG terminals to support west coast natural gas demands.[22] In the Boston area, there is an ongoing debate as to whether the nation's largest LNG terminal in nearby Everett ought to be shut down, because of terrorist concerns.[23] Decommissioning of that terminal would exacerbate an already tight national natural gas supply situation.

LNG receiving terminals are expensive, complicated and difficult to construct. Technical and permitting challenges are a combination of those faced by petrochemical plants, gas-storage facilities, and seaports. Receiving terminals cost of the order of $300-$500 million. Add to that roughly $2 billion for associated tankers to bring LNG from foreign ports. The tankers must be filled by natural gas liquefaction plants, whose costs are in the $2 billion range. And those liquefaction plants must be supplied with natural gas from developed reservoirs, whose costs can vary dramatically, but always add additional costs.[24]

[21] NIMBY "Not In My Back Yard" is popularly used to describe local opposition to the siting of new energy facilities.
[22] Flalka, J.J. & Gold, R. "Fears of Terrorism Crush Plans For Liquefied-Gas Terminals." The Wall Street Journal. May 14, 2004.
[23] Bender, B. "DistriGas Contests Hazard Study Findings." Boston Globe. June 2, 2004.
[24] Banaszak, S. Natural Gas Seems Headed the Way of Oil: More Demand, Less Supply, Higher Cost. PFC Energy. August 20, 2004.

Recently, the Chairman of ChevronTexaco noted that 10-14 new import terminals will be needed by 2015 to meet projected U.S. demand.[25] The problem is that few are now under construction, according to Cambridge Energy Research Associates.[26] They project that there will not be a new plant in operation in North America before 2007 at the earliest. “Optimistically, new LNG could affect prices by 2008, but likely, it will be after that." [27] LNG projects tend to get delayed, since the supply chain is a complex set of interdependent enterprises in which delay in one can affect the whole.

Major foreign sources of natural gas include Russia and the Middle East (Iran, Abu Dhabi, Saudi Arabia, and Qatar). In principle, natural gas from those sources can be delivered as LNG to any coastal point in the world for less than $4.00 per million British thermal units (MMBtu), and sometimes less.[28] On the other hand, with world demand for LNG on the rise, current delivered gas cost estimates could be overly optimistic, because they tend to be based on an assumption of smooth market development. Competition for LNG imports will come from Western Europe, Japan, and Korea among others.

LNG is absolutely necessary to satisfy U.S. demands. Related investments are huge. Project delays mean longer periods of shortage and higher price volatility. The U.S will be in competition for available LNG with growing demands in Western Europe, Japan, and Korea among others.

LNG Safety

A significant trade in LNG has been ongoing for decades, and the related safety record has been excellent. Projected increases in LNG volumes, coupled with the threat of terrorism at any point in the LNG supply chain, have, however, lead to new scrutiny of LNG safety.

Two important LNG disasters illustrate the potential dangers. The first occurred in 1944 in Cleveland, Ohio, and the second occurred in Algeria in early 2004.

A relatively small LNG facility was built in Cleveland in 1941 to provide natural gas during periods of peak demand. On Oct. 20, 1944, while filled to capacity, a tank failed due to a structural defect. LNG spilled, spread onto nearby streets and storm sewers, and subsequently ignited. The ensuing fire and sewer explosions killed 128 and injured

[25] O’Reilly, D. J. Global Energy: The New equation. American’s Independent. July/August 2004.
[26] LNG – If We Build It… NGI’s Daily Gas Price Index. August 23, 2004.
[27] Ibid.
[28] Forty in Eight - The 2004 Update of CERA’s LNG Scenarios. 2004

many more.[29] One square mile was devastated. The volume of LNG involved was roughly 5% of the volume of a present-day average LNG tanker.[30] While today's structural materials make a repeat of that kind of accident very unlikely, the incident does illustrate the seriousness of uncontrolled LNG release.

The second notable LNG accident occurred at the Skikda liquefaction facility in Algeria in January 2004. While the sequence of events is still not completely understood, the incident is believed to have occurred as follows.[31] A large amount of gas appears to have escaped and formed a cloud of flammable and explosive vapor. Upon contact with a flame source, the cloud exploded. The fire burned for eight hours, which was considered unusual. James Fay, professor emeritus at the Massachusetts Institute of Technology, was surprised. "I would have thought it would have burned up more quickly. Maybe there wasn't anyone to shut the equipment down. Maybe all of the workers perished in the blast, and the equipment just kept running, spewing LNG out so it just kept burning and burning…" Whatever the sequence, the resulting damage and loss of 27 lives was significant.

Both of these incidents highlight the importance of locating LNG facilities in places where the fewest possible people will be at risk, but LNG safety analysis is not easy. A few years ago DOE commissioned an LNG safety study that was frequently cited as a basis for believing that LNG facilities were inherently safe. Roughly a year ago, it came to light that the study was in fact done in a matter of days at very low cost, e.g., it was unacceptably superficial. Recently, both DOE and FERC commissioned much more comprehensive LNG safety studies.

The Department of Homeland Security has warned that terrorists could target LNG tankers. Current regulations do not require detailed consideration of the surrounding areas that might be affected by an LNG tanker accident. The consequences of LNG spills or an effective terrorist attack might require an exclusion zone of a mile or more.[32]

A just-published hazards study by Sandia National Laboratory dealt with LNG on releases from LNG tankers on open water.[33] The analysis appears to be soundly based, but it nevertheless includes caveats related to a number of unknowns. It concludes that in extreme situations, damage from an intentional attack on an LNG tanker on open water could extend for a mile or more. The study did not consider hazards associated with onshore regasification facilities, which still require serious attention, if existing facilities are to be allowed to continue to operate and new ones are to be properly licensed.

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[29] Report on the Investigation of the Fire at the Liquefaction, Storage, and Regasification Plant of the East Ohio Gas Co. Cleveland, Ohio, October 20, 1944. U.S. Bureau of Mines. February 1946.
[30] Kern, K. Private communication.
[31] Raines, B. Documents Suggest that Deadly Explosion Was Caused by Gas Vapor, Not Boiler. Mobile Register. April 14, 2004.
[32] Ibid.
[33] Hightower, M. et al. Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water. Sandia Nationa Laboratories. SAND2004-6258. December 2004.

The purpose of this brief discussion is to underscore the importance of proper LNG safety planning. If the U.S. is to facilitate LNG importation, which it must, it is essential that the U.S. quickly develop prudent criteria for LNG facility siting. The longer these questions drag out, the more severe will be U.S. natural gas shortages, and the higher the ensuing prices.

LNG presents safety questions that must be adequately and promptly addressed so that a number of LNG receiving facilities can be built and brought into operation.

Alaska Natural Gas Pipelines

Large quantities of natural gas exist on the Alaskan North Slope. Various pipeline proposals have been advanced to move that gas into southern Canada and the U.S. But the proposals have been bogged down in issues of permitting and government involvement.[34]

One proposal to bring Alaskan North Slope gas to the U.S. is based on construction of a 1700 mile pipeline that would run south through Alaska and then east into Canada, where it would connect to the Trans-Canada natural gas system. Cost has been estimated at $8.3 billion. Known reserves to feed the pipeline are roughly 30 Tcf (the throughput in the pipeline would be roughly 1.0 Tcf per year at its peak), and there is hope for additional reserves in the region, yet to be discovered. Some project partners want government guarantees in case of cost overruns or plunging natural gas prices, which are conceivable over the next 10-20 years. Other partners are against government involvement. Start of pipeline construction is projected to be at least 4-5 years in the future. On that basis, there is little chance of gas flowing before 2013, and the Department of Energy is not projecting Alaskan gas to enter the Lower 48 market before 2018.[35]

Building large pipelines through the extremely difficult terrain and the very harsh winters of Alaska and Canada is risky and costly. A prime example is the Trans Alaska (Oil) Pipeline from the North Slope of Alaska south, roughly 900 miles, to the port of Valdez. It was originally estimated to cost $800 million but ended up costing $8 billion, equivalent to roughly $20 billion in 2004 dollars.[36]

Alaskan natural gas is unlikely to provide new supply for 10-15 years.

[34] Ibid.
[35] Annual Energy Outlook With Projections to 2025. DOE/EIA-XO53. November 2002.
[36] Bezdek, R. Private communication.

The Supply / Price Outlook

According to Federal Reserve Board Chairman Alan Greenspan, “Today's tight natural gas markets have been a long time in coming, and futures prices suggest that we are not apt to return to earlier periods of relative abundance and low prices anytime soon.” [37]

The U.S. natural gas enterprise has never faced problems like those that are now apparent:

1. U.S. natural gas production has peaked and moved into geologically controlled decline.

2. Canada has found itself in the same, limited production situation as the U.S. Since Canada has its own, long-term needs for natural gas, it is by no means certain that it will continue to expand its exports to the U.S. Canada has ratified the Kyoto Protocol so its internal demand for gas will likely be even greater than estimated based on previous market drivers.

3. Delays in permitting and constructing new LNG facilities in the U.S. mean that LNG imports will not soon be available to satisfy increasing U.S. demands, let alone make up for dwindling U.S. production.

From these facts, it is difficult not to conclude that the U.S. will be faced with natural gas shortages for roughly the next 5-10 years. Shortages mean higher prices, maybe well above $10 / Mcf, compared to $2 / Mcf only a few short years ago. “Before the next generation of LNG terminals begins receiving fuel from abroad, the North American gas market is almost certain to go through a difficult period. The main questions now involve how long this period will be, and how to get through it as painlessly as possible.”[38] It is not a pretty picture.

Gas to Liquids: Competition for Transportation Fuels

One of the demands for “stranded” gas that could compete for LNG sources is to convert the natural gas to liquid fuel for use in the transportation industry and for petrochemical feedstocks. For instance, ExxonMobil has announced a gas-to-liquids project in Qatar that will produce roughly 150,000 barrels/day, with half of the production a low sulfur high quality diesel.[39]

[37] Greenspan, A. Natural Gas Supply and Demand Issues. June 10, 2003.
[38] Burr, M. T. Gas Supply: Too Little, Too Late? Public Utilities Fortnightly. September 2004.
[39] ExxonMobil, “State of Qatar and ExxonMobil Announce Signing of Gas-To-Liquids Heads of State Agreement”, July 14,2004

Natural gas prices will almost certainly escalate until imports materially contribute.

Policies that could Drive Demand Higher

The outlook for natural gas demand, increased imports, and even higher prices will be affected by various proposals which may come before the new Congress:

- **Kyoto.** Ratification of the previously-rejected Kyoto Protocol could have a significant impact on the use of coal and would drive extraordinary demand for natural gas.[40]

- **Multi-emission legislation.** Various proposals introduced by supporters of the Kyoto Protocol would severely reduce CO_2 emissions. The resulting limits on coal use would severely impact natural gas use and price. The NPC 2003 study ran a sensitivity case that projects a $1.75 difference in the price of gas for a reduced CO_2 scenario.[41]

- **Mercury rule.** The EPA's proposed rule on mercury emissions could have an impact on natural gas use if the rule requires removal of more mercury than currently achievable with available technology.

- **Ethanol mandates.** Proposals for increasing the use of ethanol as a transportation fuel would add additional demand for natural gas as it is the feedstock for fertilizer to grow corn as well as the fuel of choice for drying and distilling corn.

Natural gas demand, imports and prices will rise even further if new policies are implemented to limit coal use or to dramatically increase the use of ethanol fuels.

[40] EIA "What Does the Kyoto Protocol Mean to U.S. Energy Markets and the U.S. Economy?" October 1998, www.eia.doe.gov/oiaf/kyoto/kyotobrf.html, International Council on Capital Formation "The Impact of EU Climate Change Policy on Economic Competitiveness", November 29, 2003, www.iccfglobal.org
[41] EIA "Analysis of S. 139, The Climate Stewardship Act 0f 2003", June 2003, NPC 2003, Chapter 9

Wildcards

Because the profitability of many industries are sensitive to natural gas costs, the high natural gas price outlook might cause some companies to scale down their U.S. operations or to completely move offshore. Such moves could moderate natural gas demand and ease prices somewhat, but at the cost of U.S. jobs and industrial base. Identifying which companies might be so inclined would require careful study.

One factor noted in Table I is worthy of special consideration. It is the peaking of world oil production. Oil, like natural gas, is a finite resource found in discrete geological packages, called reservoirs. Hard minerals exist in the earth's crust in varying concentrations, which means that higher prices can more readily yield higher production. Oil and natural gas are inherently geologically different from minerals.

The prices of oil and natural gas are loosely coupled. Nevertheless, when world oil production reaches its maximum (called peaking), ensuing world oil shortages and exponentiating oil prices will almost certainly impact natural gas markets. No one knows for certain when world oil production will peak, but it could be within the next decade or so, as illustrated in Table II, which shows a number of credible peaking predictions. Without crash program mitigation starting a decade or more in advance, oil peaking will catapult the world economy into a decade long recession or worse.[42]

Like oil, world production of natural gas will also peak. Unlike oil, however, fewer credible studies exist pointing to when that might happen, but indications are that it will not occur for decades.[43]

The peaking of world oil production will dramatically impact natural gas supply and prices, but the date of oil peaking is uncertain.

Concluding Remarks

Supply and demand determine commodity prices, and natural gas is a commodity. Natural gas prices have risen by more than a factor of two in the last 5-6 years, largely because production in North American has reached a peak and started to decline. While a number of factors can and will cause fluctuations in the decline rate, the decline is almost certainly real and irreversible.

Canada has been a long-time, reliable supplier of imported natural gas to the U.S., but Canada will have less gas available to export to the U.S. and, thus, will not be able to

[42] Hirsch, R. L., Bezdek, R., Wendling, R. Peaking of World Oil Production: Impacts, Mitigation and Risk Management. DOE NETL. To be published.
[43] Laherrère, J. It's the same story for Natural Gas. ASPO Newsletter. No 44 - August 2004.

meet growing U.S. supply short falls. Natural gas resources in Alaska and possible some of the gas in the northern reaches of Canada could help, but pipelines to move that gas to U.S. markets are at least a decade away.

The great hope for future natural gas supplies are imports in the form of liquefied natural gas (LNG). The four existing LNG terminals in the U.S. do not have adequate capacity to meet growing demand for very long, and one or more of those terminals could be shuttered due to safety concerns. A number of new LNG terminals have been proposed, but safety concerns and local opposition have inhibited their progress. Eventually, a number of terminals will have to be constructed and operated to receive large quantities of imported LNG. At that time, possibly with contributions from Alaska and northern Canada, U.S. natural gas supplies may once again reach adequacy, and natural gas prices may then return to more reasonable levels. In the meantime, expect a great deal of turmoil in natural gas markets over the next 5-10 years.

One way or another, the U.S. will manage its way through the forthcoming natural gas shortages. Within a decade, shortages should disappear as LNG imports increase, enhancing supply and returning prices to more reasonable levels.

Table I. Factors Impacting Natural Gas Prices

	FACTOR	CONDITION	PRICE IMPACT
ANNUAL	Weather	Mild	Lower
		Hot summer	Higher
		Cold Winter	Higher
	The Economy	Healthy	Higher
		Recession	Lower
	Supply (Storage)	Normal	Lower
		Below Normal	Higher
	U.S. Production	Expanding	Lower
		Declining	Higher
SHORT TERM (Months)	Accidents		Higher - Short term, regional
	Speculation		Higher or Lower
	Fuel Switching		Higher or Lower
LONG TERM (5+ Years)	Canadian Imports	Higher	Lower
		Same	Higher
		Lower	Much Higher
	LNG	Current Levels	Higher
		Somewhat Greater	Lower
		Much Greater	Much Lower
WILD CARDS	U.S. Industry	Expanding	Higher
		Moving offshore	Lower
	Oil Peaking		Huge
	Terrorism		Higher

Table II. Projections of the Peaking of World Oil Production

Projected Date	Source of Projection	Background & Reference
2006-2007	Bakhitari, A.M.S.	Iranian Oil Executive[44]
2007-2009	Simmons, M.R.	Investment banker [45]
After 2007	Skrebowski, C.	Petroleum journal Editor [46]
Before 2009	Deffeyes, K.S.	Oil company geologist (ret.) [47]
Before 2010	Goodstein, D.	Vice Provost, Cal Tech [48]
Around 2010	Campbell, C.J.	Oil company geologist (ret.) [49]
After 2010	World Energy Council	World Non-Government Org.[50]
2010-2020	Laherrere, J.	Oil company geologist (ret.) [51]
2016	EIA nominal case	DOE analysis/ information[52]
After 2020	CERA	Energy consultants [53]
2025 or later	Shell	Major oil company [54]
No visible peak	Lynch, M.C.	Energy economist[55]

[44]Bakhtiari, A.M.S. "World Oil Production Capacity Model Suggests Output Peak by 2006-07." OGJ. April 26, 2004.
[45]Simmons, M.R. ASPO Workshop. May 26, 2003.
[46]Skrebowski, C. "Oil Field Mega Projects - 2004." Petroleum Review. January 2004.
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Appendix Added by the Annapolis Center

Excerpts from Testimony of Federal Reserve Chairman Alan Greenspan

"Natural Gas Supply and Demand Issues"

before the House Committee on Energy and Commerce, June 10, 2003

... **Canada, our major source of imported natural gas, has had little room to expand shipments to the United States, [emphasis added]**

...and our limited capacity to import liquefied natural gas (LNG) effectively restricts our access to the world's abundant supplies of gas.

Our inability to increase imports to close a modest gap between North American demand and production (a gap we can almost always close in oil) is largely responsible for the marked rise in natural gas prices over the past year. Such price pressures are not evident elsewhere.

In the United States, rising demand for natural gas, especially as a clean-burning source of electric power, is pressing against a supply essentially restricted to North American production.

Given the current infrastructure, the U.S. market for natural gas is mainly regional, is characterized by relatively longer term contracts, and is still regulated, but less so than in the past. As a result, residential and commercial prices of natural gas respond sluggishly to movements in the spot price. **Thus, to the extent that natural gas consumption must adjust to limited supplies, most of the reduction must come from the industrial sector and, to a lesser extent, utilities. [emphasis added]**

Yesterday the price of gas for delivery in July closed at $6.31 per million Btu. That contract sold for as low as $2.55 in July 2000 and for $3.65 a year ago.

Futures markets project further price increases through the summer cooling season to the peak of the heating season next January. Indeed, market expectations reflected in option prices imply a 25 percent probability that the peak price will exceed $7.50 per million Btu.

Today's tight natural gas markets have been a long time in coming, and futures prices suggest that we are not apt to return to earlier periods of relative abundance and low prices anytime soon.

Since 1985, natural gas has gradually increased its share of total energy use and is projected by the Energy Information Administration to gain share over the next quarter century, owing to its status as a clean-burning fuel.

Moreover, improving technologies have also increased the depletion rate of newly discovered gas reservoirs, placing a strain on supply that has required increasingly larger gross additions from drilling to maintain any given level of dry gas production.

Depletion rates are estimated to have reached 27 percent last year, compared with 21 percent as recently as five years ago.

Canada, which has recently supplied a sixth of our consumption, has little capacity to significantly expand its exports, in part because of the role that Canadian gas plays in supporting growing oil production from tar sands. [*Does not mention impact of ratification of Kyoto Protocol...Canadian gas must also be used to display current coal use and for electricity growth]* [emphasis added]

The updrift and volatility of the spot price for gas have put significant segments of the North American gas-using industry in a weakened competitive position. Unless this competitive weakness is addressed, new investment in these technologies will flag.

Increased marginal supplies from abroad, while likely to notably damp the levels and volatility of American natural gas prices, would expose us to possibly insecure sources of foreign supply, as it has for oil. [emphasis added]

But natural gas reserves are somewhat more widely dispersed than those of oil, for which three-fifths of proved world reserves reside in the Middle East. Nearly two-fifths of world natural gas reserves are in Russia and its former satellites, and one-third are in the Middle East.

Creating a price-pressure safety valve through larger import capacity of LNG need not unduly expose us to potentially unstable sources of imports. **There are still numerous unexploited sources of gas production in the United States. [emphasis added]** We have been struggling to reach an agreeable tradeoff between environmental and energy concerns for decades. I do not doubt we will continue to fine-tune our areas of consensus.

But it is essential that our policies be consistent. For example, we cannot, on the one hand, encourage the use of environmentally desirable natural gas in this country while being conflicted on larger imports of LNG. Such contradictions are resolved only by debilitating spikes in price. [emphasis added]

In summary, the long-term equilibrium price for natural gas in the United States has risen persistently during the past six years from approximately $2 per million Btu to more than $4.50. The perceived tightening of long-term demand-supply balances is beginning to price some industrial demand out of the market. It is not clear whether these losses are temporary, pending a fall in price, or permanent.

If North American natural gas markets are to function with the flexibility exhibited by oil, unlimited access to the vast world reserves of gas is required. Markets need to be able to effectively adjust to unexpected shortfalls in domestic supply. Access to world natural gas supplies will require a major expansion of LNG terminal import capacity. Without the flexibility such facilities will impart, imbalances in supply and demand must inevitably engender price volatility.

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