TOPIC PAPER #13

LIQUEFIED NATURAL GAS (LNG)

On July 18, 2007, The National Petroleum Council (NPC) in approving its report, *Facing the Hard Truths about Energy,* also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the Task Groups and their Subgroups. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached Topic Paper is one of 38 such working document used in the study analyses. Also included is a roster of the Subgroup that developed or submitted this paper. Appendix E of the final NPC report provides a complete list of the 38 Topic Papers and an abstract for each. The printed final report volume contains a CD that includes pdf files of all papers. These papers also can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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LNG

I. Introduction

Liquefied natural gas, commonly referred to as LNG, is natural gas that has been cooled to its liquid state. This is done primarily as a means to facilitate delivery of natural gas from the wellhead to consumers, particularly when the wellhead is remote from the end-user and the gas cannot practically or economically be transported in its gaseous state via pipeline. Thus, LNG provides a means of linking remote gas to markets.

Despite its rapid growth in recent years, LNG remains a relatively small contributor to world gas demand (under 7% of the total in 2005) and even to total internationally traded gas, (about 22% of gas trade). Pipeline gas still dominates international trade, notably supply to Western Europe from Russia, North Africa and Norway; and supply to the US from Canada.

With regard to the regional breakdown of LNG trade, Pacific Basin and Asian markets are still almost double the size of Atlantic Basin and Mediterranean markets. Nevertheless, the Atlantic Basin market has grown much faster than the Pacific market over the past ten years, growing by 12% per year compared to 5.5% per year in the Pacific Basin market.

To produce LNG, natural gas is piped from the wellhead to a liquefaction plant at a coastal location, and there transformed from gaseous to liquid form by cooling to very low temperatures. Once cooled, LNG occupies approximately $1/600^{th}$ of the volume of gas at atmospheric conditions, making shipment in specialized low-pressure tankers possible. The liquefied gas is then loaded on to specialized LNG tankers and shipped to one of the major gas consuming countries. Upon reaching its destination, the LNG is offloaded at a receiving terminal and regasified for delivery into the local pipeline and storage network, where it becomes completely integrated with natural gas produced locally or imported by pipeline.

The process of moving LNG from the wellhead, through liquefaction, shipping and regasification, and ultimately to the pipeline network creates value that is otherwise unattainable. This LNG "value chain" is thus comprised of wellhead production, pipeline to a coastal location, coastal liquefaction plant, LNG tanker, coastal regasification terminal, and pipeline to a distribution grid and consumers.

The LNG value chain is usually more capital intensive than gas transport by pipeline. To begin, the liquefaction plant can cost up to $3-5 billion per train (where "train" is the common term used for the linear chain of equipment which lowers the temperature of the gas to the liquid point). Then, the specialized LNG tankers cost $150-$250 million each, and multiple vessels are generally required to offtake production from each liquefaction plant in order to maintain a steady flow of gas through the liquefaction facility. Finally, the regasification terminals can cost $500 million to $1.5 billion. Since all these investments have to be in place before the gas can move to market, LNG developments usually require long-term contracts with

specific customers to secure financing. These contracts normally specify delivery of gas to a particular location for a duration of 20-25 years. Historically, these contracts have usually been structured on a take-or-pay basis for specified volumes, with pricing linked either to crude oil or a basket of crude oil and refined products. In this way, risk is shared between the LNG supplier and the buyer where the supplier assumes the price risk and the buyer assumes the volume risk.

Until recently, fairly rigid contractual terms were the dominant form of commercial arrangement in place, but in recent years other arrangements have begun to appear in the market. Some LNG projects have sold less than 100% of projected output to specific buyers, leaving LNG available for short-term trade to take advantage of the ability to sell to higher priced markets at any given time. Some LNG developers are selling their output to the gas trading arms of project participants, with flexibility to choose markets, based on a portfolio of throughput positions in regasification terminals in various markets. In this way, a spot market for LNG is emerging in both Atlantic Basin and Pacific Basin markets, with a small but growing volume of LNG being traded this way, helping to link different regional markets around the world.

The number of countries involved in the LNG trade has expanded significantly in recent years and this trend is continuing. In 1995, there were 8 LNG exporting countries and 9 LNG importing countries. By 2005, this had increased to 13 exporting countries and 15 importing countries, with even more countries in the process of developing infrastructure to either export or import LNG in the near future. The market also saw significant expansion in delivered quantities of LNG during this time period, growing by 7.3% per year, or almost doubling to 189 billion cubic metres, or 18.3 bcf/day in 2005.

In 2005, the LNG exporting countries were the UAE (Abu Dhabi), Algeria, Australia, Brunei, Egypt, Indonesia, Libya, Malaysia, Nigeria, Oman, Qatar, Trinidad and the USA. Equatorial Guinea, Norway and Russia (from Sakhalin) are expected to join those countries already exporting LNG by the end of this decade. Projects for LNG export are also in various phases of development in Peru, Yemen, Angola and Iran. Significant expansions and new greenfield projects are also being developed in existing exporting countries, principally Algeria, Australia, Nigeria, Qatar, Trinidad, Indonesia, and Libya, and several other countries are in the early stages of planning LNG export projects.

LNG importing countries, in 2005, consisted of Belgium, Dominican Republic, France, Greece, India, Italy, Japan, Portugal, Puerto Rico, South Korea, Spain, Taiwan, Turkey, UK and USA. The UK, India and Portugal are recent additions to the list of importing countries, all starting up new import facilities within the past three years in order to meet growing demand and diversify sources of supply. Mexico and China also recently began importing LNG and will likely increase imports in coming years, with China, in particular, expected to become a significant importer. In addition, several existing importers, such as the US, India and the UK, are expected to increase the contribution of LNG to their gas supply mix, with several additional countries such as the Netherlands, Germany, Brazil and Pakistan, indicating an interest in beginning LNG imports.

In general, imports to the US, Canada and Mexico can be considered as part of an integrated North America supply mix as the three countries have strong pipeline interconnections. In fact, it is highly likely that some LNG imported to Canada, which is expected to become an LNG importer by the end of the decade, or Mexico will be shipped by pipeline to US markets.

The following tables show LNG trade in 1995 and 2005:

1995

	Exporters:	**USA**	**UAE**	**Algeria**	**Libya**	**Australia**	**Brunei**	**Indonesia**	**Malaysia**
Importers:	*Bcf/day*								
USA				0.06					
Belgium			0.06	0.37					
France			0.05	0.73					
Italy				0.01					
Spain			0.04	0.47	0.14	0.03			
Turkey				0.09		0.02			
Japan		0.16	0.53			0.89	0.72	2.28	1.12
South Korea						0.01	0.09	0.69	0.14
Taiwan								0.25	0.07

Source: Cedigaz

2005

	Exporters:	**USA**	**Trinidad & Tobago**	**Oman**	**Qatar**	**UAE**	**Algeria**	**Egypt**	**Libya**	**Nigeria**	**Australia**	**Brunei**	**Indonesia**	**Malaysia**
Importers:	*Bcf/day*													
USA			1.20	0.01	0.01		0.27	0.20		0.02				0.02
Dominican Republic			0.02											
Puerto Rico			0.67											
Belgium			0.01				0.28							
France				0.01			0.73	0.10		0.41				
Greece							0.04							
Italy							0.24							
Portugal										0.15				
Spain			0.05	0.16	0.44	0.03	0.47	0.34	0.08	0.48	0.01			0.02
Turkey							0.37			1.00				
UK			0.01				0.04							
India				0.01	0.56						0.02			
Japan		0.18		0.12	0.81	0.65	0.01				1.26	0.81	1.84	1.71
South Korea				0.57	0.80	0.01		0.03			0.11	0.08	0.73	0.62
Taiwan				0.16							0.04		0.48	0.40

Source: BP Statistical Review of World Energy, 2006, based on Cedigaz

Some clear regional patterns emerge from the data presented in these tables. Suppliers located in the Atlantic Basin and Mediterranean region dedicated over 99% of their supply to markets in the same region, just as suppliers in the Asia/Pacific region dedicated over 99% of their supply to markets in the same region. Suppliers in the Middle East, however, are able to place volumes to the Atlantic, Mediterranean and Asia/Pacific markets, either as dictated by long-term contracts or by using the growing spot market. In 2005, Middle East suppliers sent 15.5% of their LNG output to Atlantic Basin and Mediterranean markets. As the Middle East grows in importance as a source of LNG, with large expansions in capacity from Qatar and potential new developments in Iran, this could introduce greater flexibility to the global LNG market, allowing for more inter-regional trade and thus more globally connected markets.

As will be discussed below, trends in the US will likely play an important role in the future of LNG trade. This is distinctly different from the history of the LNG business, which developed primarily to serve markets in Japan and South Korea. Until recently, LNG imports to the US have provided a very small portion of total supply. Imports of LNG to the US began in the 1970s, and four regasification terminals were built between 1971 and 1982 in anticipation of rapid growth in LNG imports.This failed to materialize, resulting in two of the four terminals (at Cove Point and Elba Island) being removed from service until the early 2000s. Only the terminal at Everett, in Boston harbour continued to operate through this time, receiving cargoes of LNG primarily from Algeria. The fourth terminal, at Lake Charles in Louisiana, remained in service but saw very little activity. During this period, LNG imports made up a small portion of supply to the US, averaging 0.2-0.3 bcf/day, or about 0.5% of supply.

The situation began to change in the early 2000s, when US natural gas prices increased sharply from their 1990s average of $2 - $3 per MMBTu. This raised fears of an inability for maturing North American production to keep pace with strong demand growth, and sparked a strong commercial interest in LNG imports. By the summer of 2003, all four US LNG import terminals were again in operation, and new Atlantic Basin LNG suppliers, such as Trinidad and Nigeria were sending cargoes to the US. For the past three years, LNG imports to the US have been about 1.6-1.7 bcf/day, representing about 2.7% of total gas supply to the US. While this is still a relatively small share, it is significantly higher than that witnessed in previous decades.

Strong prices in recent years have also triggered a large number of proposals to develop new LNG import terminals in the US, Mexico and Canada, all of which could deliver gas to the US market. These proposals have generally been based on the assumptions that LNG will be able to competitively provide a growing share of supply to the US market over the next 25 years and that more than adequate economic incentives will drive the development of sufficient international LNG supply capacity. As of early 2007, regulatory authorities in North America had permitted almost 40 bcf/day of new capacity (36 bcf/day in the US and 2 bcf/day in each of Canada and Mexico – these are stated on a peak send out basis – annual average capacities are likely to be somewhat lower). Although several of these projects are unlikely to be developed, there is already a further 13.1 bcf/day under construction and expected to be in service by 2012 (with more increments expected later in the next decade). These developments provide the capability for significant expansions in US and North American imports over the next few years.

The following table lists existing terminal capacity, planned expansions and facilities currently under construction with their expected in-service date.

Terminal	Location	Capacity	In-Service date	Comments
U.S. Existing		*mmcf/day*		
Everett	New England	500	1971	
Cove Point	Mid Atlantic	750	1978	
Elba Island	South Atlantic	800	1978	
Lake Charles	Gulf Coast	1800	1982	Expansion from 1200 in 2007
Gulf Gateway	Gulf Coast	500	2005	
US Expansions				
Cove Point	Mid Atlantic	800	2009	Additional capacity
Elba Island	South Atlantic	1300	2012	Additional in phases
US Construction				
Cameron	Gulf Coast	1500	2008	
Freeport	Gulf Coast	1500	2008	
Sabine Pass	Gulf Coast	4000	2008/9	
Golden Pass	Gulf Coast	2000	2009	
Mexico				
Altamira	Mexico East Coast	500	2006	In operation
Costa Azul	Mexico Baja California	1000	2009	
Canada				
Canaport	Atlantic Coast	1000	2009	

Thus, if we consider only the existing terminals, planned expansions and those currently under construction, North American LNG import capacity will reach almost 18 bcf/day by early in the next decade. Many additional facilities have been proposed and permits have been issued but firm plans for construction do not yet exist. These include projects on the Gulf Coast and the North Atlantic Coast, as well as a few proposals on the Pacific Coast. It is, however, highly unlikely that this level of development will be needed.

Indeed, existing terminal capacity is still operating at relatively low utilization rates, particularly when compared to what was expected. In 2006, the US LNG imports were about 1.6 bcf/day. With an available import capacity of about 4.6 bcf/day, this resulted in a load factor of only 35%. Similar load factors were seen in 2005. Low utilization rates are the result of a lack of contracted supply and strong demands for spot LNG cargoes in markets in Asia and Europe that resulted from events such as severe weather, adverse hydroelectric conditions and reduced nuclear power station availability.

Very little LNG is contracted to end-use entities in the US. Thus, even if US gas prices are significantly above prices in other markets supplies may not be released if demand is sufficiently high so as eliminate any potential gains from trade. As for swing cargoes, if demands abroad exceed baseload contracted supply, consumers will be willing to pay prices higher than those prevailing in the US market, thus leaving LNG terminals in the US unutilized. This is, in fact, a positive sign that the LNG market is working correctly and has the capacity to alter cargo destinations when market conditions dictate it. A potential external benefit to holding regasification capacity in excess of baseload requirements is that US markets will be able to receive adequate gas supplies in the event of severe winter weather or hurricane disruptions to domestic supply. In the future, the US may well be the swing market to balance global supply and demand unless US buyers commit to long-term LNG supply contracts for a large percentage of total LNG imports.

II. LNG Outlooks

We have examined the following primary references to analyse the outlooks for LNG to 2030, where possible on a global basis, but particularly with respect to the potential for LNG supplies to North America and the US.

- Global Outlooks
  - IEA *World Energy Outlook* 2006 (*WEO2006*)
  - EIA *International Energy Outlook* 2006 (*IEO2006*)
  - Cedigaz, *LNG Trade and Infrastructure* 2004 (*CDZ2004*)
- US/North America Outlooks
  - EIA *Annual Energy Outlook* 2006 (*AEO2006*)
  - EIA *Annual Energy Outlook* 2007 advance summary (*AEO2007*)
  - NPC *Balancing Natural Gas Policy* 2003 (*NPC2003*)

Among the outlooks examined, the most complete global perspectives on prospects for LNG are provided by the *WEO2006*. More limited information is provided by the *IEO2006* and by *CDZ2004*. Nevertheless, all of the aforementioned sources agree that global LNG growth is very likely to accelerate over the next 25 years.

Global Outlooks

WEO2006

In the reference case of the IEA *WEO2006*, it is stated that gas resources are more than sufficient to meet projected gas demand growth to 2030. However, because the majority of resources are in the Middle East and Russia with the traditional gas markets in OECD countries accounting for less than 10% of the global reserve base, future gas market development favors a significant expansion in global gas trade. A significant portion of the increase in internationally traded gas is projected to take the form of LNG. The IEA expects LNG trade to grow by 6.6% per year between 2004 and 2030, from 90 bcm (8.7 bcf/day) to 470 bcm (45.5 bcf/day). By comparison world natural gas demand is

projected to increase by 2% per year, meaning the contribution of LNG to meeting demand is expected to grow substantially. In fact, the IEA projects that LNG will account for 70% of the increase in gas trade by 2030. If this were to happen, LNG would make up 50% of internationally traded gas by 2030, compared to around 22% in 2004.

The IEA forecast does not provide a full representation of expected LNG flows in the future compared to pipeline flows. Both forms of traded gas are consolidated in the outlook for inter-regional gas trade. Also, the quantitative outlooks are consolidated at the regional level, and country detail is generally not provided. Nevertheless, some important trends in the changing LNG supply mix are identified:

- The Middle East and Africa account for over 70% of the increase in gas exports by 2030, and mainly supply Europe and North America
- Russia will begin supplying gas to Asian markets by LNG
- Australia and the Middle East will supply LNG to China
- Venezuela is projected to emerge as an important supplier to North America and Europe

The following table details the IEA Reference Case Outlook for inter-regional gas trade (pipeline and LNG). (Note: negative numbers represent net imports, positive numbers represent net exports and the world total sums all inter-regional traded gas. The numbers do not include internationally traded gas within a region, such as flows from Canada to the US or from Norway to Germany, for example).

	2004		**2015**		**2030**	
	bcm	*bcf/day*	*bcm*	*bcf/day*	*bcm*	*bcf/day*
OECD	**-328**	**-31.7**	**-526**	**-50.9**	**-764**	**-73.9**
North America	-18	-1.7	-77	-7.4	-159	-15.4
Europe	-214	-20.7	-333	-32.2	-488	-47.2
Pacific	-96	-9.3	-116	-11.2	-117	-11.3
Transition Economies	**145**	**14.0**	**152**	**14.7**	**190**	**18.4**
Russia	202	19.5	194	18.8	222	21.5
Developing Countries	**183**	**17.7**	**374**	**36.2**	**574**	**55.5**
Developing Asia	60	5.8	11	1.1	-15	-1.5
China	*0*	*0*	*-27*	*-2.6*	*-56*	*-5.4*
India	*-3*	*-0.3*	*-10*	*-1.0*	*-27*	*-2.6*
Middle East	40	3.9	189	18.3	232	22.4
Africa	70	6.8	137	13.3	274	26.5
Latin America	13	1.3	37	3.6	82	7.9
World	**413**	**39.9**	**634**	**61.3**	**936**	**90.5**

IEA WEO Reference Scenario, from Table 4.2, p 118

In the 2006 WEO, the IEA also published an Alternative Policy scenario in which a large number of policies are applied to capture environmental and efficiency benefits. This scenario does not explicitly deal with LNG, but the results imply that there would be lower need for growth in international gas and LNG trade than in the Reference Case.

- Global natural gas demand growth is 0.5% per year lower than in the Reference Case
- Relative to the Reference Case, there is reduced production in 2030 of 478 bcm (46.2 bcf/day) from the Middle East, Russia and Africa because of a drop in export demand
- Relative to the Reference Case, there is reduced interregional gas trade in 2030 of 187 bcm (18.1 bcf/day).

IEO2006

The EIA's *IEO2006* provides a less detailed view of LNG developments to 2030. The report projects natural gas demand growth by region but does not attempt to detail supply sources, or to distinguish quantitatively between the contributions of pipeline gas and LNG. The EIA projects global natural gas demand to grow by 2.4% per year, on average, to 2030, slightly faster than the IEA's projected growth rate of 2.0%. The forecast also contains sensitivity cases for high economic growth and low economic growth. In the high economic growth case, world gas demand grows by 3% per year, yielding an increase in demand of 75 bcf/day relative to the reference case. In the low economic growth case, world gas demand grows by 1.9% per year, yielding an decrease in demand of 64 bcf/day relative to the reference case. There is no analysis supplied of how supply patterns could change in these cases, but it is likely that traded LNG would need to account for a significant portion of the swing in demand.

Discussion of LNG and gas trade developments in this outlook includes the following main points:

- Global reserves of natural gas are increasingly concentrated in Russia and the Middle East making these regions the most likely sources of supply growth
- There is expected to be strong growth (4.9% per year) in African natural gas production through 2030, mainly for exports.
- Central and South America will have a surplus of gas, with Peru and Venezuela eventually joining Trinidad as LNG exporters.
- Russia, Norway, Equatorial Guinea and Peru are likely to be new LNG exporting countries over this period.
- China, Canada, Mexico, Germany, Poland, Croatia, Singapore and Chile are potential new LNG importing countries.
- OECD countries' reliance on gas supplies from other regions will increase from 22% in 2003 to over one-third in 2030.

CDZ2004

Cedigaz' *LNG Trade and Infrastructure Report* published in 2004 includes projections of LNG demand to 2020 under two scenarios. It does not project a breakdown of supply sources. Its expected rates of growth of LNG trade are quite similar to the IEA outlook, ranging from 5.9% per year in the low scenario to 7% per year in the high scenario. The following table summarizes the Cedigaz outlook for LNG demand.

	2002		**2010 Low**		**2010 High**		**2020 Low**		**2020 High**	
	bcm	*bcf/day*	*bcm*	*bcf/day*	*bcm*	*bcf/day*	*bcm*	*bcf/day*	*bcm*	*bcf/day*
North America	7.3	0.7	50.1	4.8	64.0	6.2	113.6	11.0	140.1	13.6
Latin America	0	0	0	0	0	0	4.1	0.4	6.9	0.7
Europe	40.4	3.9	78.5	7.6	97.6	9.4	118.7	11.5	146.6	14.2
Asia & Oceania	106.4	10.3	140.1	13.6	156.1	15.1	193.9	18.8	227.0	21.9
Middle East	0	0	0	0	0	0	0	0	2.8	0.3
World	**154.0**	**14.9**	**268.7**	**26.0**	**317.7**	**30.7**	**430.3**	**41.6**	**524.0**	**50.7**

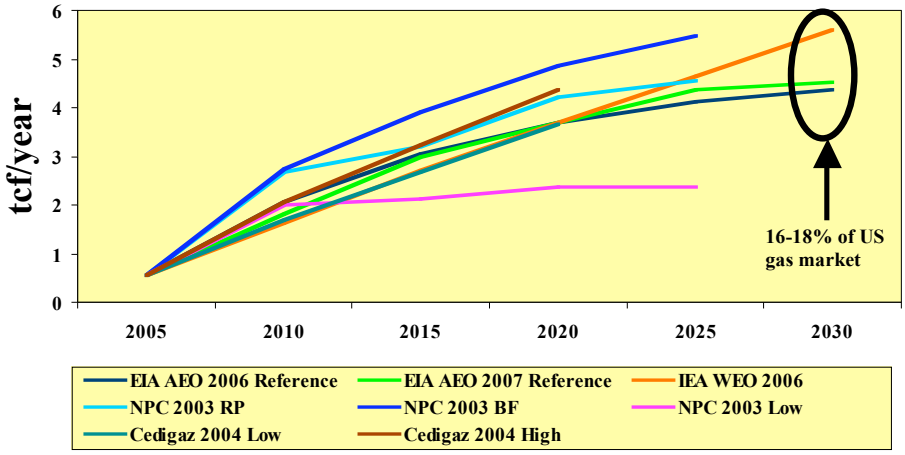
Like the IEA, Cedigaz comments that LNG trade is expected to grow faster than gas trades by pipeline, growing from 22% of traded gas in 2002 to about 35-40% in 2020. This is primarily driven by the increasing concentration of global gas reserves in the Middle East and Russia.

US/North America Outlooks for LNG

All of the forecasts analyzed herein consider the future role of LNG in the US. The forecasts referenced in the previous section deal with this in the context of *global* gas supply and demand, while the EIA's Annual Energy Outlook takes a more detailed look at the factors specifically affecting the US gas market.

The following chart compares the outlooks for the volume of LNG to be imported to the US over the next 25 years. The figure reveals that LNG supply is expected to increase from about 2.5% of US supply to about 16-18% by 2030, depending on the outlook.

US LNG Imports



WEO2006

The IEA *WEO2006* identifies North America, and particularly the US, as a major source of demand growth for LNG. Despite continued success in unconventional gas drilling and the assumed commissioning of a major natural gas pipeline from Alaska after 2015, the IEA projects that indigenous production will level off after 2015, leading to a need for higher imports to keep pace with market growth.

IEO2006

The EIA *IEO2006* uses the same assumptions for US gas demand and LNG requirements as the EIA *AEO2006*, which will be discussed below.

CDZ2004

The Cedigaz forecast has US demand for LNG growing from 0.6 bcf/day in 2002 to between 10.2 and 12 bcf/day by 2020, depending on the scenario. No context is given relative to total US demand growth over that period. Furthermore, there is no discussion of either LNG supply sources or other components of the US gas supply mix.

AEO2006 and *AEO2007*

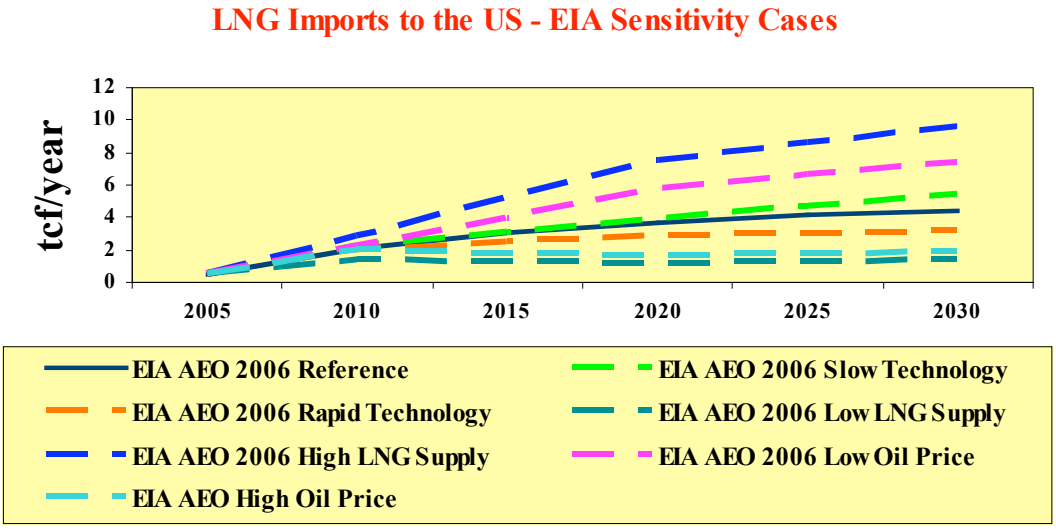
The EIA's *AEO2006* and *AEO2007* show similar reference case projections for LNG imports to the US. The primary difference between the two forecasts is that slower development of upstream LNG projects tends to reduce imports in the early years of the *AEO2007*. LNG imports are, however, slightly higher post 2020 in the *AEO2007*.

The *AEO2006* reference case projects that LNG imports to the US will grow by 8% per year through 2030. This rapid increase is facilitated by a domestic gas production profile that only increases by 0.5% per year, and in fact begins to decline after 2020. Moreover, pipeline imports from Canada decline throughout the forecast horizon at an average rate

of -3.2% per year. Thus, despite relatively slow demand growth of 0.7% per year, a high rate of LNG imports is needed to balance the market. LNG is assumed to be attracted to the US market by high domestic gas prices and the availability of sufficient import infrastructure. However, the pace of US LNG import growth is projected to slow after 2015, as other markets compete more heavily for available supplies. Another contributing factor to the slowdown is expansion of clean coal generation capacity. (If, for environmental or economic reasons, coal-fired power generation capacity does not grow as expected, it is likely that natural gas, and thus imported LNG would grow faster to partially fill the gap.)

As a cautionary note, it should be noted that the *AEO 2006* projection does not integrate US requirements for LNG into a global market balance where LNG competes against indigenous gas to find the best netback opportunities.

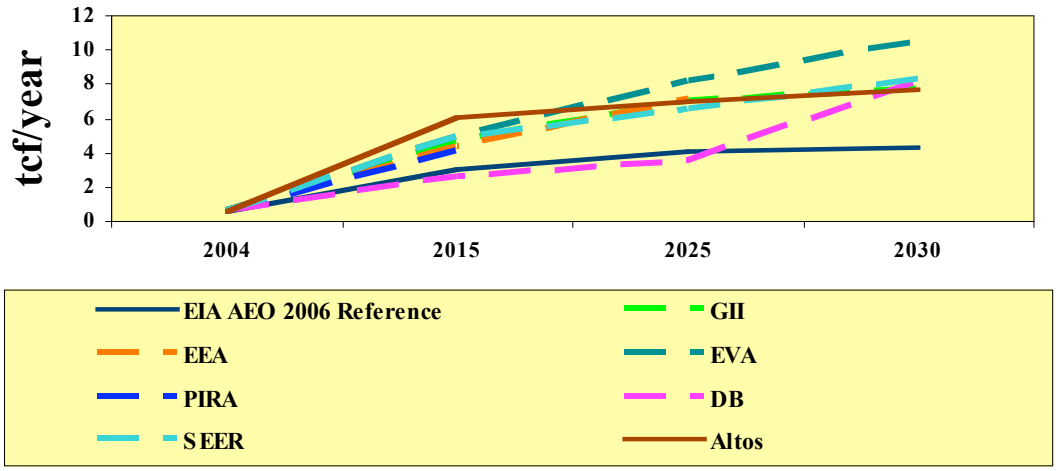
The *AEO2006* also includes several sensitivity cases built around high or low oil price paths, high or low penetration of new technology that favours indigenous gas production and thereby lower gas prices, and high or low LNG supply based around the uncertainty of some upstream developments in the LNG supply chain. The following chart shows the range of outcomes from these cases. As indicated, by 2030 the projections range from more than double the reference case (in the high LNG supply case) to only 30% of the reference case (in the low LNG supply case). Moroever, the spread between the high and the low cases is close to 23 bcf/day, indicating the scope for very different outcomes according to the assumptions used. There will be further discussion of the nature of these uncertainties later in this paper.



Another component of the work published by the EIA in the *AEO2006* is a set of comparisons of the EIA's own forecast with other available independent forecasts. EIA benchmarked the *AEO2006* reference case outlook with seven other outlooks, five of which allow comparisons across the complete forecast time horizon to 2030. All of these benchmark forecasts show LNG imports to the US at significantly higher levels than the

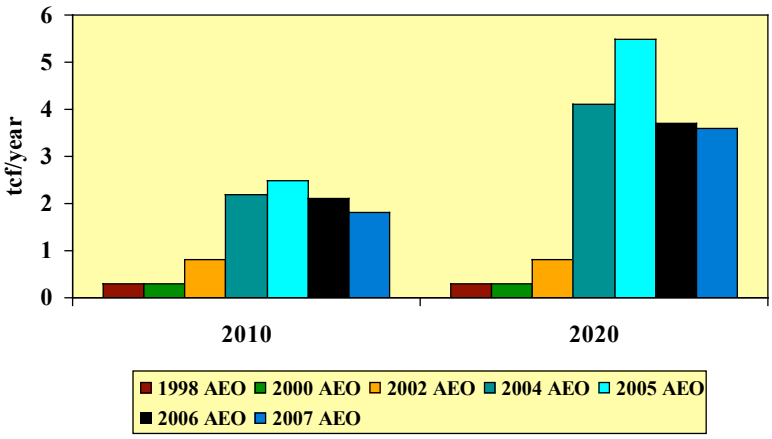
EIA, with 2030 volumes ranging from 21 bcf/day to 28.7 bcf/day (compared to the *AEO2006* reference case projection of 12 bcf/day). When put in the context of the total US gas market, these other forecasts give LNG a share of supply ranging from 20% to 32% (compared to the *AEO2006* reference case share of 16%). The higher import projections can be explained in part by the fact that most of these other projections forecast higher US natural gas demand than the *AEO*, particularly in the electric power generation sector. The results for domestic production and pipeline imports from Canada are mixed. The comparison of LNG imports is shown in the chart below. This type of comparison argues that the EIA's projection is somewhat conservative with regard to the potential for the contribution of LNG to US gas supply.

LNG Imports to the US - Forecast Comparison



Finally, with respect to the projections prepared by the EIA in various editions of the *AEO*, it should be noted that the LNG forecast has fluctuated over quite a wide range. The chart below illustrates a sample of recent *AEO* forecasts of LNG imports to the US, as published between 1998 and 2007. The main reasons for this variability relate to the development of the consensus view on LNG. In the late 1990s and early 2000s, it was generally thought that it would be very difficult to develop LNG import infrastructure in the US and that the domestic gas resource was sufficient to support continuing demand growth. Both of these assumptions were increasingly called into question between 2001 and 2003 as current prices and future price expectations began to rise. More recent forecasts have adopted the new reality of high US gas prices, integrated possible constraints on growth in domestic gas production, and recognized the potential abundance of international gas supplies. Accordingly, the forecasts published in 2004 and 2005 led to quite high expectations for LNG imports. In 2006 and 2007, however, these expectations appear to have been scaled back due to a realization that the pace of LNG supply development is slower than previously anticipated, and that competition for supplies will attract incremental gas away from North America. As future forecasts are developed, with a closer examination of the dynamics of global gas market integration, we expect to see further changes in the outlook for LNG imports to North America.

US LNG Imports 2010 and 2020



NPC2003

The 2003 NPC Natural Gas Study, *Balancing Natural Gas Policy*, also included an outlook for LNG as a critical emerging component of the US gas market. The objective of that study was to provide a robust view of future prospects and policy options for the US natural gas market in response to growing perceptions of high and volatile gas prices and increasing uncertainty about the future of domestic gas production. The LNG chapter in that study provides an excellent overview of the history and prospects of LNG, both globally and in the US, with perspectives and data covering the whole value chain. The study also provided an outlook for LNG imports to the US, based on the best available expert knowledge at that time.

The 2003 NPC study looked at LNG imports to the US under three scenarios:

- The Reactive Path scenario, in which expected "business as usual" developments gradually increased LNG capacity along the value chain.
- The Balanced Future scenario, in which policy makers and regulators streamlined the process for infrastructure permitting and construction thereby removing impediments to the development of LNG import capacity.
- The Low Sensitivity Case, in which regulatory delay and public opposition significantly constrain LNG infrastructure development.

It is worth noting that all three of these futures assumed that the primary constraint on LNG imports to the US would be the development of regasification terminals. The underlying perception was that there were plenty of upstream LNG projects with a high chance of realization. More recently, industry consensus has shifted to a focus on *upstream* constraints in the LNG value chain, which is a stark contrast to the scenarios in *NPC2003*.

The results of the three cases were a 2025 volume of LNG imports into the US ranging from 6.5 bcf/day (in the Low Sensitivity Case) to 15 bcf/day (in the Balanced Future Scenario). These represented 6.5% and 15% of US gas supply, respectively, somewhat below the more recent outlooks referenced earlier.

III. Observations on the Outlooks

Consideration of the outlooks analysed leads to several common observations having to do with global LNG markets more generally, and US LNG imports more specifically. They are:

1. Observations on the Global LNG market

The consensus is that LNG trade will grow faster than natural gas demand

The traditional consuming natural gas markets in Asia (Japan, Taiwan and South Korea) have virtually no indigenous production, and, as a result, those countries rely principally on LNG for gas supply. This has not been the case in the consuming natural gas markets in North America and Europe, where indigenous production has been relatively plentiful, as in the case of North America, or there has been an adequate availability of pipeline supplies, as in the case of Europe. However, production in these regions has either begun to decline or slowed considerably in recent years. As a result, continued expansion of demand has motivated an interest in expanding the role of LNG imports.

More specifically, in North America, production in the US, Canada and Mexico has remained almost flat. This is especially telling given the continuous increases in drilling activity in recent years, and higher gas prices providing incentive to develop more costly unconventional natural gas resources in significant quantities. In Western Europe, the North Sea gas fields and the onshore fields in France, Germany and Italy are in decline, and of course, there is virtually no production in the main Asian gas consuming markets. Therefore, all three traditional OECD natural gas markets are faced with the need to secure gas supplies from other sources in order to satisfy growth in demand.

A large proportion of the World's proven and probable natural gas resources are located in Russia, Central Asia and the Middle East, with other pockets of significant resources in Africa, Latin America and Southeast Asia. However, each of these regions is distant from the major consuming markets in North America, Europe and Asia. Bringing supplies to each of the major consuming markets is challenging because they are distant from the regions with the most ample supply, and, therefore, require major investments in infrastructure – either LNG liquefaction, shipping and regasification or long-haul, high capacity pipelines. Consumers in OECD Europe have an additional incentive to diversify sources of supply to LNG imports, driven by fears of over-reliance on gas supply from Russia. Concerns arise from potential supply disruptions caused by Russian disputes with transit countries as well as longer term concerns over whether Russia will be able to invest sufficiently to maintain export capacity, particularly if its domestic consumption continues strong growth.

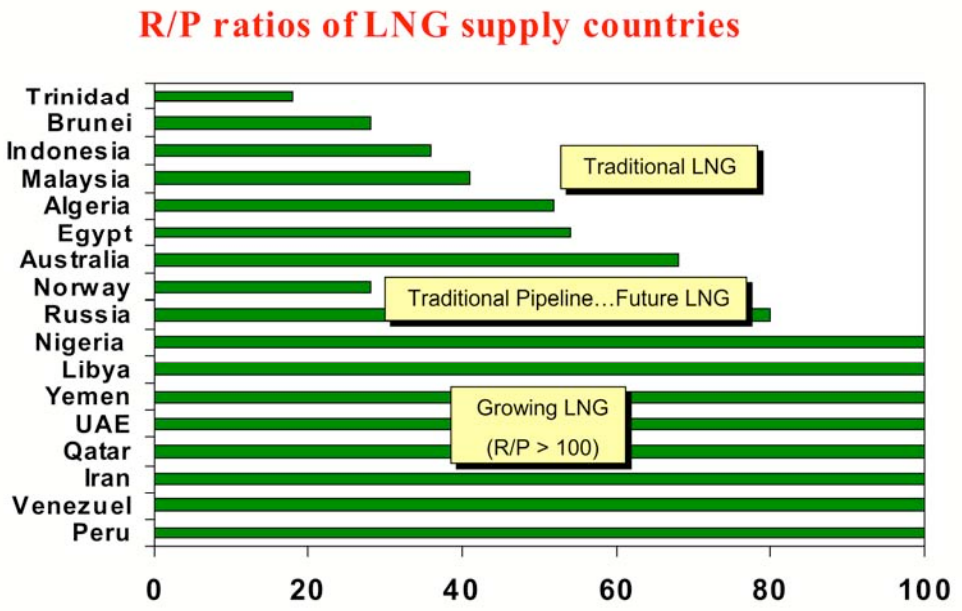
Emerging natural gas markets, such as China and India, are set to grow rapidly, albeit from a low base, and will also require increases in imports. Both have LNG and pipeline options, but geopolitical pressures make it probable that LNG will represent a significant share of supply to each of these emerging gas markets.

Longer supply chains from a relatively concentrated number of suppliers may lead to an increase in vulnerability to supply disruption because of technical, logistical or geopolitical incidents. However, the shipborne oil market has handled a larger share of global oil trade than natural gas for many years and such disruptions have been quite rare events. Appropriate responses could include:

- maintaining sufficient diversity of supply,
- ensuring adequate gas storage close to market,
- maintaining good relations with gas supply countries,
- entering long-term contracts for LNG supply
- and continuing to do everything possible to maintain domestic gas production at a sustainable level.

The natural gas resource base is sufficient to support the projected expansion of LNG supply over the next 25 years

The countries that currently supply LNG, or plan to do so, generally have very large reserves relative to current production. Even with expansion of gas production to support growing exports, there seem to be sufficient gas supplies to support the projected LNG trade. Moreover, market growth should provide incentives for further development of resources in these countries thereby leading to an expansion of the resource base.



The main implication is that the focus of securing gas supply should not be on the sufficiency of resource endowments, but on other factors involved in investment in and maintenance of robust gas supply chains. Ensuring access to resources, developing new technology, promoting a sustainable investment environment and geopolitics could all be more pressing considerations than potential constraints regarding the natural gas resource base.

The global LNG market has many new entrants

As indicated in the introductory paragraphs of this paper, several important new entrants have begun to supply LNG in the past few years, including Trinidad, Egypt and Oman. Moreover, there are a number of potential new LNG exporters that could emerge over the next ten years to make an important contribution to satisfying world gas demand. Such new LNG exporting countries that are likely to emerge over the next decade include Peru, Equatorial Guinea, Norway, Yemen, Angola and Russia (from Sakhalin). In the longer term we could also see supplies from Iran, Papua New Guinea and Venezuela.

In addition to the greenfield LNG developments in countries that *do not* currently export LNG, expansions of liquefaction and export capacity in several countries that *do* currently export LNG are expected. These will occur either with the addition of new liquefaction trains to existing projects (typically deemed more certain), or with the development of new greenfield projects (typically deemed less certain). Potential expansions are slated for Qatar, Nigeria, Australia, Indonesia, Egypt, Algeria and Malaysia.

This report will not comment on specific projects, but it is very difficult to predict with a high degree of accuracy how many or which of these increments to LNG capacity will eventually occur. We will examine the possible barriers to full realization of capacity potential below, but, in general, there is an increasing amount of uncertainty about capacity expansion as forecasts look further ahead in time. Nevertheless, assuming that there are at least some new entrants into the market, there will be greater opportunity for gas consuming countries to secure diversity of supply. In addition, there will be greater opportunities for market participants to optimize supply chains and lower costs, to the benefit of consumers and of prospects for further supply development.

Major uncertainties exist regarding liquefaction development in key supply countries

In the previous section we alluded to uncertainty (and implied risk) regarding the development of upstream supply projects. In particular, if projects are not completed on time, or not at all, this could lead to tighter supply with potential shortages, and higher prices, perhaps for extended periods.

Establishing an LNG supply chain is a complex process. To begin, economies of scale dictate that projects be large in order to reduce per unit costs of investment and operation. Moreover, the large capital investments needed for LNG projects are front-end loaded, and require technical assurances that gas reserves are sufficient to assure 25 years of operation, security of market access with acceptable pricing terms, and an equitable sharing of risk and return between the project's partners, which typically include a host government or national oil company (NOC). In addition, some countries that could serve

as LNG suppliers are perceived to carry greater geopolitical risk, which can inhibit investment. All of these factors together mean that the establishment of a new LNG project is subject to greater risk than a traditional upstream gas development that is close to the consuming market and can tie into existing infrastructure. In fact, given the scale of LNG projects, it is likely that, in the LNG supply context, decisions regarding the development of future capacity in only a few countries could have a disproportionate impact on the long-term adequacy of LNG supply into the global market.

We have categorized some of the major risks or uncertainties relative to major suppliers in the following chart. As can be seen, most of the risks concern above-ground factors rather than the resource endowment or reserves profile. The categories of uncertainty include:

- Access – can organizations with a track record of successful LNG development secure access to resources? Are long term development plans of host governments or NOCs compatible with commercial project development criteria or market needs? What geopolitical risks may get in the way of timely and adequate project development?
- Investment – does the investment climate ensure equitable returns for all participants in the project, and are there non-economic barriers to investment?
- Infrastructure – can stranded gas resources be economically aggregated at a suitable export location;
- People/Equipment – is there sufficient service sector capacity to successfully execute a project?

Gas Supply – Emerging Risks and Challenges

	Comments	Access	Investment	Infrastructure	People/Equipment
LARGE PRODUCERS					
• **Russia** (~100 BCFD)	Supply reliability? Domestic market?	X	X	X	
• **USA** (~50 BCFD)	Unconventional/Arctic growth?	X		X	X
• **Indonesia** (10 BCFD)	Cost of supply? Domestic market?	X	X		
	»				
PRODUCTION GROWTH					
• **Russia** (+30 BCFD)	Supply reliability?	X	X	X	
• **Qatar** (+15 BCFD)	Pace development?				X
• **Iran** (+15 BCFD)	Geopolitics	X	X	X	X
• **Nigeria** (+10 BCFD)	Geopolitics		X		
• **Australia** (+10 BCFD)	Costs		X		

- **Key sources of gas supply growth face increasing risk of underperformance relative to potential gas production and exports**

LNG supply development is becoming slower and more complex

Like many large energy infrastructure projects, LNG developments in recent years have seen increasing costs and longer lead times as demands on global engineering capacity and construction materials have outpaced their availability. These pressures will likely ease over time, but projects currently under development are subject to experience what could be significant delays and cost escalation. This could also lead to delays in sanctioning, or even undertaking, new projects as participants reevaluate costs and returns. The cost inflation seen in recent years is worrisome to project developers as it tends to reverse some of the significant cost improvements achieved in the LNG value chain over the previous ten years. In particular, prior to the acceleration of activity in project development over the past few years, a combination of increased scale (in both liquefaction and shipping) and replication of technology allowed significant unit cost improvements. This, in turn, made LNG a viable, competitive option into all major markets. But, cost pressures are leading some project developers to reconsider their investment strategies.

2. Observations on LNG supply to the US

LNG imports will grow to 16% - 18% (or more) of the US gas market by 2030

The US EIA projects that LNG imports to the US will grow from about 2.6% of total supply in the past two years to 16-18% by 2030. Other forecasts show a larger market share of LNG by 2030, with some up to around 30%. A key variable in any of these projections will be the extent to which gas demand for power generation continues to

grow. Although *current* investment economics favour coal-fired generation, if US policy dictates a move to constraining carbon emissions, the investment economics could swing toward favoring natural gas. Nuclear power, of course, is a wild card in this sort of future, as it is a carbon free choice in the portfolio of power generation capacity option. Nevertheless, unless there is a strong public policy push towards nuclear, natural gas demand would grow substantially, pushing import needs up toward the high end of the range of projections.

While the forecasts presented may span the range from conservative to aggressive, all of the projections portray a supply mix to the US that is very different from what has been observed in the past, in which indigenous US and Canadian production represented 98% or more of supply. Naturally this can raise concerns about security of supply, particularly as many of the potential supplies are located in countries that are located in historically volatile regions. Given that security of supply may always be an underlying concern, a comparison with oil may be useful. Oil imports to the US represent about 60% of supply, which is more than double what is expected to be the import contribution of natural gas 25 years hence. Security of oil supply has been maintained through a combination of supply diversity, shared investments with producing countries, and open and cooperative trade relationships. Similar strategies should be available to help maintain security of natural gas supply.

Markets or supply chains are not the current limiting factor in LNG growth - investment in tankers and regasification terminals is occurring ahead of liquefaction capacity investment

Although the construction of regasification terminals and LNG tankers are major capital budget items, they are less capital intensive than upstream gas development and the construction of the liquefaction plant. In recent years, with the prospect of unprecedented growth in LNG markets, investors have been more willing to commit capital to value chain infrastructure downstream of the liquefaction plant in order to be able to offer market options to supplying entities. Thus, at least in the current wave of investment, downstream investments are occurring at a faster pace than the upstream and are unlikely to represent a bottleneck to market development.

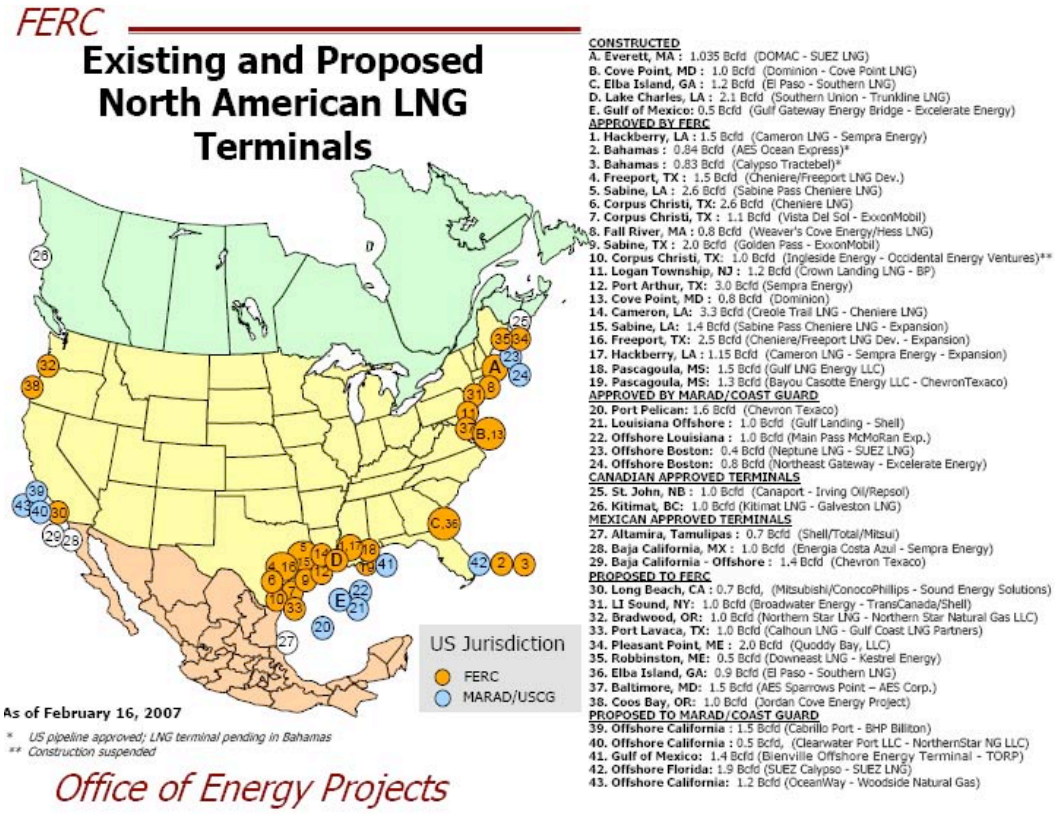
With respect to regasification terminal investment, the current total of North American capacity installed and likely to be in place by around 2012 is about 18 bcf/day. In addition, an additional 20 bcf/day or so of capacity has received permits for construction. This level of development is above the projected market needs in the outlooks we have analysed. Therefore, it seems likely that there will be adequate import capacity and, hence, flexibility of destination for suppliers, so that LNG can be diverted to regional locales where it is most needed.

With regard to the LNG shipping fleet, the existing fleet consists of just over 200 ships dedicated to LNG service, but this is set for very significant expansion over the next few years as a backlog of orders and vessels under construction reaches the market. About 150 new vessels are due to come into service over the next 4 to five years, and since many of these are larger than existing vessels, this should represent an almost doubling of

global LNG fleet capacity, and will be more than sufficient to handle all projected increases in LNG trade over the next decade.

The permitting regime for regasification terminals in the US has allowed project development, although the process is complex, costly and time-consuming

Several years ago, prior the LNG "boom", conventional wisdom was that it would be very difficult, perhaps impossible, to build new LNG import capacity in the US, with the exception being, perhaps, expansion of existing facilities. Even today, the permitting and construction of regasification terminals is a lengthy, complex process challenged by a myriad of local issues. Nevertheless, the approach taken by the FERC in expediting permitting and ensuring terminals would not be "open-access" has raised the promise of adequate returns to potential terminal development and has resulted in many developers seeking and receiving construction permits, with some terminals already entering the construction phase. As stated above, by early 2007, over 35 bcf/day of new LNG regasification capacity had received the necessary permits for development. Although many of these will probably not be developed for other reasons, the permitting regime has generally been robust enough to meet projected market needs.



However, the overall permitting process is far from streamlined and has significant room for improvement. Unnecessarily lengthy permitting processes and the inability to permit terminals where needed, in particular close to load centers in the northeast and west US, ultimately increase the cost of supplying gas to US consumers.

Going forward, continuous attention to ensuring fair and transparent regulation should be encouraged, along with an ongoing effort to educate stakeholders and the public at large of the importance of LNG as part of a viable and sustainable energy supply portfolio that will contribute to mitigating volatility and upward pressure on natural gas and electricity prices. In addition both industry participants and regulators need to reassure local stakeholders that delivery of LNG on a regular basis in large volumes over a long period has an outstanding safety and environmental record in all markets where it has been an important supply component.

Another concern, which has been expressed with respect to increasing US natural gas imports from a variety of different sources, is the question of gas quality. Gas from different suppliers can have varying heat content (or BTU content), because some sources of gas are richer in natural gas liquids than others. In some cases this means that imported LNG could fall outside the parameters of US pipeline specifications. Fortunately, there are a number of solutions to this problem. These can include processing to remove liquids either at source or at market, blending with market area pipeline gas to bring the imported gas within local specifications, and injection of nitrogen to dilute the high BTU content imported gas. All of these options are being explored on a project specific basis, and the FERC has taken a proactive approach to working with industry to propose gas quality standards that take into account the changing US supply mix. It is, therefore, likely that this concern will be resolved as LNG grows in importance in the North American supply mix.

IV. Policy Implications for the U.S.

As an increasing proportion of US natural gas supply originates from sources outside the US domestic market, the US producers will have reduced influence on the pace and scale at which those supplies are developed. Moreover, competition for global supplies will link previously unconnected gas markets, so that events in one part of the world will have ramifications for supply availability and price in other parts of the world. Therefore, security of supply considerations beget the following recommendation:

- To the extent that is possible, foster the development of domestic gas resources by addressing access and leasing moratoria and restrictions, providing fiscal certainty, and ensuring a fair and transparent regulatory process that does not discourage continuing drilling activity.

With respect to the development of new supplies outside the US, limited direct influence on development may be bolstered by indirect strategies, such as:

- foster open trade in energy and other traded goods;
- foster mutually open investment regimes to allow capital to flow freely to major infrastructure and energy projects;
- seek areas of broad economic cooperation with key gas supply countries;
- explore opportunities for partnership with other key consuming gas markets, such as the EU or Japan, to develop a mutually cooperative approach to suppliers.