Liquefied Natural Gas:

Understanding the Basic Facts

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> "I strongly support developing new LNG capacity in the United States."
>
> *–President George W. Bush*

Natural gas plays a vital role in the U.S. energy supply and in achieving the nation's economic and environmental goals.

Although natural gas production in North America is projected to gradually increase through 2025, consumption has begun to outpace available domestic natural gas supply. Over time, this gap will widen.

One of several proposed supply options would involve increasing imports of liquefied natural gas (LNG) to ensure that American consumers have adequate supplies of natural gas in the future.

Liquefaction enables natural gas that would otherwise be "stranded" to reach major markets. Developing countries with plentiful natural gas resources are particularly interested in monetizing natural gas by exporting it as LNG. Conversely, more developed nations with little or no domestic natural gas rely on imports.

About This Report

This report was prepared by the U.S. Department of Energy (DOE) in collaboration with the National Association of Regulatory Utility Commissioners (NARUC). DOE's Office of Fossil Energy supports technology research and policy options to ensure clean, reliable, and affordable supplies of oil and natural gas for American consumers, working closely with the National Energy Technology Laboratory, which is the Department's lead center for the research and development of advanced fossil energy technologies. NARUC, a nonprofit organization composed of governmental agencies engaged in the regulation of telecommunications, energy, and water utilities and carriers in the 50 states, the District of Columbia, Puerto Rico, and the Virgin Islands, serves the public interest by improving the quality and effectiveness of utility regulation.

Design and editorial support: Akoya

Select photos courtesy of: Anadarko Petroleum Company; Atlantic LNG Company of Trinidad and Tobago; British Petroleum; Chevron Texaco; ConocoPhillips; Dominion Cove Point LNG, LP; Excelerate Energy; HOEGH LNG; Pine Needle LNG, LLC NC; Texaco Production Operations; Tractebel LNG North America; Trunkline LNG

Basic Facts

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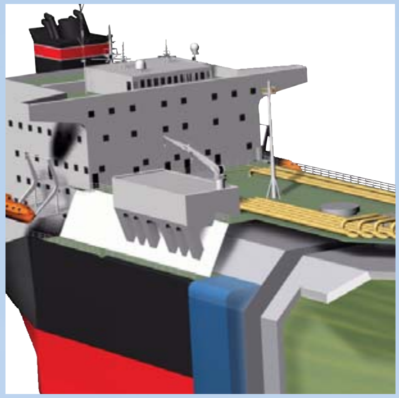
Current Status of U.S. LNG Imports

The United States currently has six LNG terminals—four on the mainland, one in the offshore Gulf of Mexico, and one in Puerto Rico—that receive, store, and regasify LNG. Some economists call for the development of more import capacity to enable the United States to participate fully in world LNG markets.

Expanded LNG imports would likely help to dampen natural gas price volatility in the United States, particularly during peak periods of demand. Such expanded imports would also support U.S. economic growth.



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Components of the LNG Value Chain

If the United States is to increase LNG imports, significant capital investment will be necessary by energy firms across the entire LNG "value chain," which spans natural gas production, liquefaction capacity, transport shipping, storage, and regasification.

Over the past two decades, technology improvements have been key to a substantial increase in liquefaction efficiency and decrease in LNG costs.

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Informed Decision Making

For more than 40 years, the safety record of the global LNG industry has been excellent, due to attention to detail in engineering, construction, and operations. More than 30 companies have recently proposed new LNG terminals in North America, along the U.S. coastline or offshore. Each proposal is rigorously evaluated before an LNG terminal can be constructed or expanded.

Americans face the challenge of making sound and timely decisions about LNG infrastructure to assure an abundant supply of natural gas for homes, businesses, industry, and power generators, in the near and long term.

Growing Demand for

Natural Gas

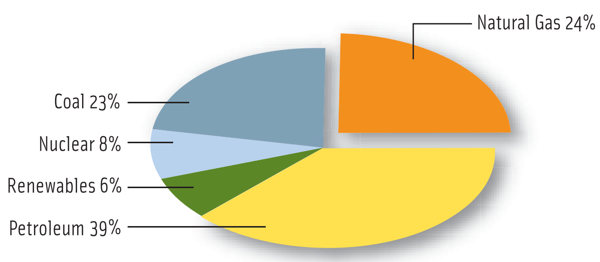
The United States relies on clean-burning natural gas for almost one quarter of all energy used. Natural gas has proven to be a reliable and efficient energy source that burns much cleaner than other fossil fuels. In the last 10 years, the United States produced between 85 and 90 percent of the natural gas it consumed.[1] Most of the balance was imported by pipeline from Canada.

Annual U.S. natural gas consumption is projected to rise from 22.1 trillion cubic feet (Tcf) in 2004 to 30.7 Tcf in 2025.[2] Reasons for the increase include:

- Utilities realize advantages by using natural gas-fired generators to create electricity (lower capital costs, higher fuel efficiency, shorter construction lead times, and lower emissions).
- The residential sector benefits from the higher fuel efficiency and lower emissions of gas appliances.
- The industrial sector relies on natural gas as a feedstock or fuel for manufacturing many of the products we rely on today, including pulp and paper, metals (for computers, automobiles, and telecommunications), chemicals, fertilizers, fabrics, pharmaceuticals, and plastics.
- The transportation sector is beginning to see natural gas as a clean and readily available alternative to other fossil fuels.

FIGURE 1

Natural gas accounted for almost one-quarter of all energy used in the United States from 1998-2003.



Source: Energy Information Administration, *Annual Energy Outlook 2005*

While U.S. demand is rising, production of natural gas in major mature provinces, including North America, is beginning to decline. Lack of a steady supply increases the potential for higher energy prices and price volatility, which affect the profitability and productivity of industry and may spur certain gas-intensive industries to relocate to parts of the world where natural gas is less expensive. This, in turn, could impact jobs, energy bills, and the prices paid for consumer goods.

One way to help meet rising demand would be to increase imports of natural gas from outside North America. Net imports of natural gas are projected to supply 19 percent of total U.S. consumption in 2010 (4.9 Tcf) and 28 percent in 2025 (8.7 Tcf).[3] This natural gas will be transported via ship in the form of liquefied natural gas (LNG). Net imports of LNG are expected to increase from 0.6 Tcf in 2004[4] to more than 6 Tcf in 2025—at that point satisfying almost 21 percent of total U.S. natural gas demand.[5]

Discussions of the benefits and risks of expanding LNG imports will be central to U.S. energy supply decisions in the years ahead. A key consideration is the potential of LNG imports to ensure that adequate and reliable supplies of natural gas are available to support U.S. economic growth.

Numerous recent studies have underscored the importance of LNG in the nation's energy future:

- A 2003 study by the National Petroleum Council conducted at the request of the Secretary of Energy found several keys to ensuring a reliable, reasonably priced natural gas supply to meet future U.S. demand—including increased imports of LNG.[6]
- A 2004 Energy Information Administration (EIA) study, *Analysis of Restricted Natural Gas Supply Cases*, included a forecast scenario based on a "restricted" expansion of U.S. LNG import terminals. The results showed an increase in natural gas prices, dampening consumption and economic growth.
- A 2004 study by the Manufacturers Alliance outlined the critical role of natural gas in manufacturing and the potential contribution of LNG to improve U.S. industrial competitiveness in the global marketplace.[7]

Meeting Future Demand

The United States will not be the only nation competing for natural gas imports in the future. In 2001 the worldwide community consumed about 90 trillion cubic feet (Tcf) of natural gas. Consumption of natural gas worldwide is projected to increase by an average of 2.2 percent annually or 70 percent overall from 2001 to 2025, to about 151 trillion cubic feet.[8]

Fortunately, global natural gas resources are vast—estimated at about 6,079 Tcf in recoverable gas as of 2004, roughly 60 times the recent annual volume consumed.[9] In total, worldwide natural gas resources are estimated at more than 15,000 Tcf, including gas that has yet to be discovered.[10]

The international LNG business connects natural gas that is "stranded"—far from any market—with the people, factories, and power plants that require the energy. It becomes necessary to transport natural gas as LNG because the distribution of the world's supply of natural gas is not consistent with patterns of demand.

Russia, Iran, and Qatar hold 58.4 percent of the world's natural gas reserves, yet consume only about 19.4 percent of worldwide natural gas. Such countries tend to "monetize" their gas resource—converting it into a salable product. LNG makes this possible.

The world's major LNG-exporting countries hold about 25 percent of total natural gas reserves. Two countries with significant reserves (Russia and Norway) are currently building their first liquefaction facilities. At least seven more are considering the investment to become LNG exporters in the near future.

In some cases, conversion to LNG makes use of natural gas that would once have been lost. For example, Nigeria depends on its petroleum exports as a primary source of revenue. In the process of oil production, natural gas was flared—a wasteful practice that adds carbon dioxide to the atmosphere. Converting this natural gas to LNG provides both economic and environmental benefits.

1 Energy Information Administration (EIA), *Annual Energy Review 2003*, September 2004.

2 EIA, *Annual Energy Outlook 2005.*

3 EIA, *Annual Energy Outlook 2005.*

4 DOE, *Natural Gas Imports and Exports*, Fourth Quarter 2004.

5 EIA, *Annual Energy Outlook 2005.*

6 National Petroleum Council, *Balancing Natural Gas Policy–Fueling the Demands of a Growing Economy*, September 2003.

7 Norman, Donald A., *Liquefied Natural Gas and the Future of Manufacturing*, Manufacturers Alliance, September 2004.

8 EIA, *International Energy Outlook 2004.*

9 EIA, *International Energy Annual 2003*, released May 2005.

10 U.S. Geological Survey, *World Petroleum Assessment 2000.*

FIGURE 2

LNG is mostly methane plus a few percent ethane, even less propane and butane, and trace amounts of nitrogen.

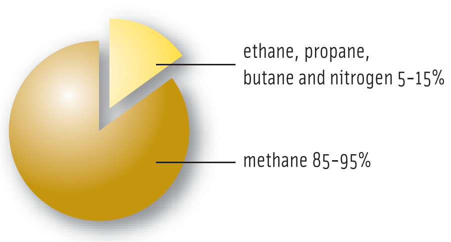
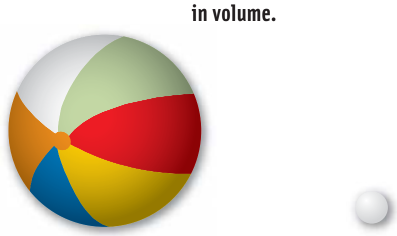


FIGURE 3

When natural gas is liquefied, it shrinks more than 600 times in volume.



When liquefied, natural gas that would fill a beach ball…

…becomes LNG that can fit inside a ping-pong ball.

LNG…A SAFE FUEL IN A SMALL PACKAGE

Natural gas consists almost entirely of methane (CH_4), the simplest hydrocarbon compound. Typically, LNG is 85 to 95-plus percent methane, along with a few percent ethane, even less propane and butane, and trace amounts of nitrogen (Figure 2). The exact composition of natural gas (and the LNG formed from it) varies according to its source and processing history. And, like methane, LNG is odorless, colorless, noncorrosive, and nontoxic.

Natural gas is condensed to a liquid by cooling it to about -260°F (-162°C). This process reduces its volume by a factor of more than 600—similar to reducing the natural gas filling a beach ball into liquid filling a ping-pong ball (Figure 3). As a result, just one shipload of LNG can provide nearly 5 percent (roughly 3 billion cubic feet) of the U.S. average daily demand for natural gas, or enough energy to heat more than 43,000 homes for an entire year![11]

LNG is transported by ship to terminals in the United States, then stored at atmospheric pressure in super-insulated tanks. From storage, LNG is converted back into gas and fed into the natural gas pipeline system. LNG is also transported by truck to satellite storage sites for use during peak periods of natural gas demand—in the coldest weather for heating and in hot weather for fueling electric power generators, which in turn run air conditioners.

11 See LNG conversion tables, page 9.

Emergence of the

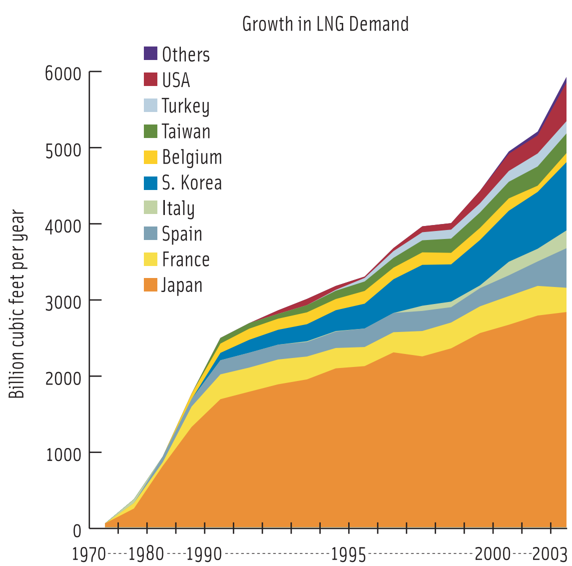
Global LNG Market

Efforts to liquefy natural gas for storage began in the early 1900s, but it wasn't until 1959 that the world's first LNG ship carried cargoes from Louisiana to the United Kingdom, proving the feasibility of trans-oceanic LNG transport. Five years later, the United Kingdom began importing Algerian LNG, making the Algerian state-owned oil and gas company, Sonatrach, the world's first major LNG exporter. The United Kingdom continued to import LNG until 1990, when British North Sea gas became a less expensive alternative.

Japan first imported LNG from Alaska in 1969 and moved to the forefront of the international LNG trade in the 1970s and 1980s with a heavy expansion of LNG imports. These imports into Japan helped to fuel natural-gas-fired power generation to reduce pollution and relieved pressure from the oil embargo of 1973. Japan currently imports more than 95 percent of its natural gas and, as shown in Figure 4, serves as the destination for about half the LNG exported worldwide.

FIGURE 4

Japan has been the major client of the LNG business for 30 years, but the size of the market and the number of importers are growing steadily.



Source: Cedigaz (1970-1992); EIA (1993-2003)

The United States first imported LNG from Algeria during the 1970s, before regulatory reform and rising prices led to rapid growth of the domestic natural gas supply. The resulting supply-demand imbalance (known as the "gas bubble" of the early 1980s) led to reduced LNG imports during the late 1980s and eventually to the mothballing of two LNG import facilities. Then, in the 1990s, natural gas demand grew rapidly, and the prospect of supply shortfalls led to a dramatic increase in U.S. LNG deliveries. In 1999 a liquefaction plant became operational in Trinidad and Tobago, supplying LNG primarily to the United States.

Current LNG Market Structure

International trade in LNG centers on two geographic regions (see Figure 5):[12]

- The Atlantic Basin, involving trade in Europe, northern and western Africa, and the U.S. Eastern and Gulf coasts.
- The Asia/Pacific Basin, involving trade in South Asia, India, Russia, and Alaska.

In addition, Middle Eastern LNG-exporting countries between these regions supply Asian customers primarily, although some cargoes are shipped to Europe and the United States.

LNG prices are generally higher in the Asia/Pacific Basin than in the Atlantic Basin. However, in the United States the price of LNG can rise with peak seasonal demand to attract short-term delivery of LNG cargoes.

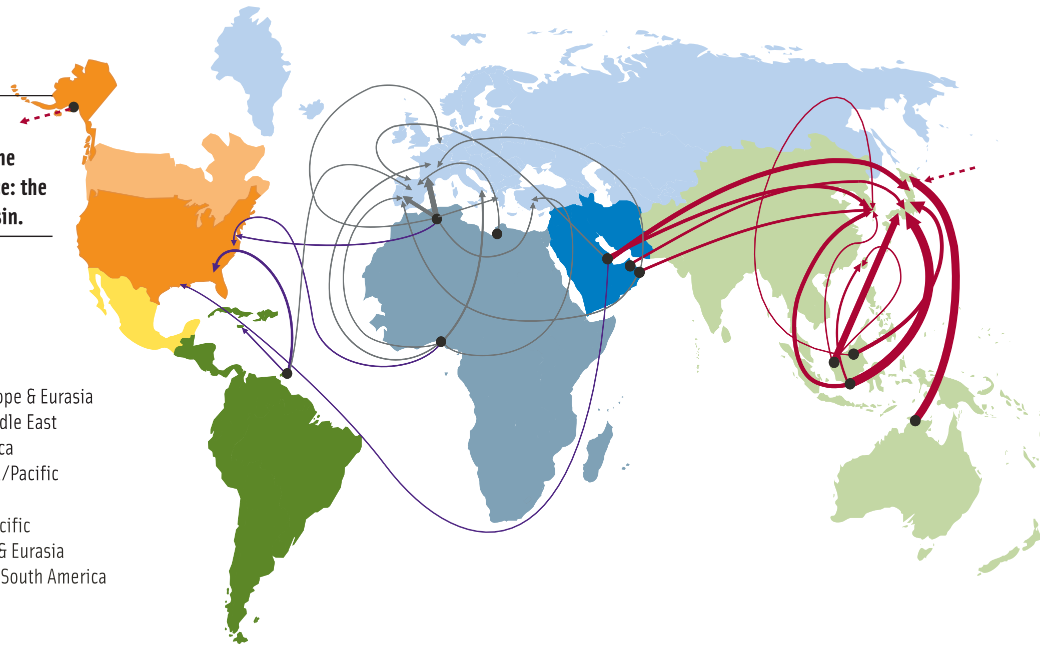
LNG importers. Worldwide in 2003 a total of 13 countries imported LNG. Three countries in the Asia/Pacific Basin—Japan, South Korea, and Taiwan—accounted for 67 percent of global LNG imports, while Atlantic Basin LNG importers took delivery of the remaining 33 percent.[13]

Japan remains the world's largest LNG consumer, although its share of global LNG trade has fallen slightly over the past decade as the global market has grown. Japan's largest LNG suppliers are Indonesia and Malaysia, with substantial volumes also imported from Qatar, the United Arab Emirates, Australia, Oman, and Brunei Darussalam. Early in 2004 India received its first shipment of LNG from Qatar at the newly completed facility at Dahej in Gujarat.

FIGURE 5

LNG trading can be categorized by the geographic region in which it takes place: the Atlantic Basin or the Asia/Pacific Basin.

Source: Energy Information Administration and British Petroleum



Imports by Atlantic Basin countries are expected to grow as many expand storage and regasification terminal capacity. France, Europe's largest LNG importer, plans two new terminals for receipt of gas from Qatar and Egypt. Spain's LNG imports, roughly half from Algeria, increased by 21 percent in 2003. All Spanish regasification terminals are being expanded, with several new terminals starting up by 2007. Italy and Turkey receive LNG from Nigeria and Algeria. Belgium has one regasification terminal and receives most of its LNG from Algeria. In 2003 the Dominican Republic and Portugal began operating regasification terminals. Other potential Atlantic Basin LNG importers include the Bahamas, Canada, Jamaica, Mexico, the Netherlands, and the United Kingdom.

LNG exporters. Asia/Pacific Basin LNG producers accounted for nearly half of total world LNG exports in 2003 while Atlantic Basin LNG producers accounted for about 32 percent. Liquefaction capacity in both regions is increasing steadily.[14]

Indonesia is the world's largest LNG producer and exporter, accounting for about 21 percent of the world's total LNG exports. The majority of Indonesia's LNG is imported by Japan, with smaller volumes going to Taiwan and South Korea. Malaysia, the world's third-largest LNG exporter, ships primarily to Japan with smaller volumes to Taiwan and South Korea. Australia exports LNG from the Northwest Shelf, primarily to supply Japanese utilities. About 90 percent of Brunei Darussalam output goes to Japanese customers. The only liquefaction facility in the United States was constructed in Kenai, Alaska, in 1969. This facility, owned by ConocoPhillips and Marathon Oil, has exported LNG to Japan for more than 30 years.

Russia is becoming the newest Asia/Pacific Basin exporter. Its first LNG plant is under construction on Sakhalin Island off the country's east coast. This large facility is scheduled to begin operation in 2008.

Planned expansions of existing plants could dramatically increase Atlantic Basin liquefaction capacity by 2007. Algeria, the world's second-largest LNG exporter, serves mainly Europe (France, Belgium, Spain, and Turkey) and the United States via Sonatrach's four liquefaction complexes. Nigeria exports mainly to Turkey, Italy, France, Portugal, and Spain but also has delivered cargos under short-term contracts to the United States. Trinidad and Tobago exports LNG to the United States, Puerto Rico, Spain, and the Dominican Republic. An Egyptian facility exported its first cargo in 2005 and is expected to supply France, Italy, and the United States. Beginning in 2006 Norway plans to export LNG from Melkøye Island to markets in Spain, France, and the United States.

12 EIA, *The Global Liquefied Natural Gas Market: Status and Outlook*, December 2003, and other sources.

13 EIA, World LNG Imports by Origin, 2003.

14 EIA, World LNG Imports by Origin, 2003.

Current Status of U.S.

LNG Imports

In 2003 the United States imported 506.5 Bcf of LNG from a variety of exporting countries. Imports in 2004 increased by 29 percent, reaching 652 Bcf.

LNG arriving in the continental United States enters through one of five LNG receiving and regasification terminals located along the Atlantic and Gulf coasts. While these facilities have a combined peak capacity of more than 1.3 Tcf per year, imports in 2004 totaled only a little more than 0.65 Tcf.* However, future demand for LNG will outgrow current and future capacity at the five terminals. By 2008 these terminals should reach a peak capacity of 2.1 Tcf and then level off. On the other hand, EIA projects LNG demand of 6.4 Tcf to meet U.S. natural gas needs by 2025. Clearly, the nation will need to rely on additional import terminals or face a serious natural gas shortfall in coming decades. LNG receiving terminals are located in:

Everett, Massachusetts. Owned and operated by Tractebel LNG North America, the facility began operations in 1971 and now meets 15 to 20 percent of New England's annual gas demand. A recent expansion raised baseload capacity to 265 Bcf per year.**

Cove Point, Maryland. Operated by Dominion Cove Point LNG, the Cove Point terminal began operation in 1978, was mothballed for two decades, and reopened in July 2003. A proposed expansion project will increase baseload capacity from the current 365 Bcf per year to about 657 Bcf by 2008.

Elba Island, Georgia. Owned by El Paso Corporation and the smallest of the continental U.S. terminals, the Elba Island facility began operation in 1978. Like Cove Point, Elba was mothballed during the 1980s and reactivated in 2001. Its current baseload capacity of 161 Bcf per year will be expanded to 292 Bcf per year by 2008.

Lake Charles, Louisiana. Operated by Panhandle Energy/Trunkline LNG, the Lake Charles terminal was completed in July 1981. A two-phase expansion will raise capacity from the current baseload 230 Bcf per year to about 657 Bcf in 2007.[15]

Gulf Gateway, Gulf of Mexico Offshore. Owned by Excelerate Energy, the sub-sea Gulf Gateway Energy Bridge is 116 miles off the Louisiana coast and began operations in March 2005 as the world's first offshore receiving port. The facility has a baseload capacity of 183 Bcf per year and uses converted LNG carriers to regasify LNG through deck-mounted vaporizers.

A sixth terminal, the EcoEléctrica regasification facility (capacity of 33.9 Bcf per year) in the U.S. Commonwealth of Puerto Rico, began importing LNG in 2000 to serve a 540-megawatt natural gas-fired power plant that accounts for about 20 percent of the electricity generated on the island.

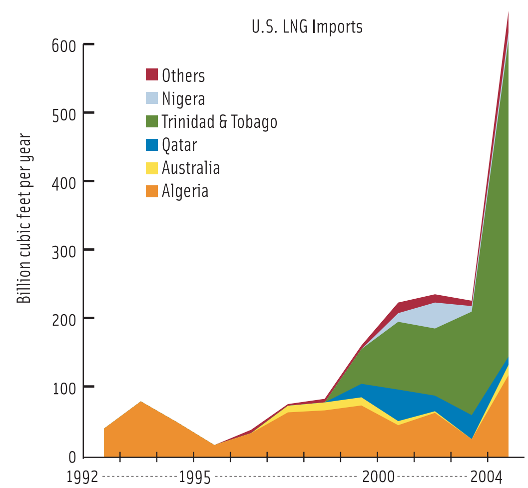
* Sustainable sendout ("baseload") regasification capacity will increase from more than 1.0 Tcf in 2004 to 1.8 Tcf in 2008.

** Does not include about 36 Bcf per year trucked to various New England destinations.

15 Capacities from EIA (*LNG Markets and Uses: June 2004 Update*), FERC, facility websites, and other sources.

FIGURE 6

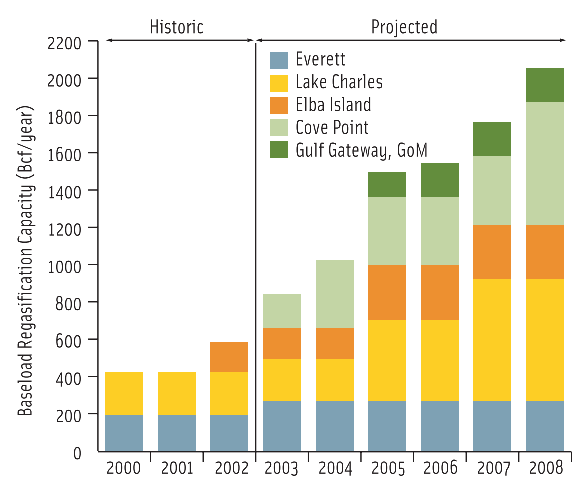
Most U.S. LNG imports come from Trinidad and Tobago. The balance originates from a mix of Middle Eastern, African, and Asian suppliers.



Source: DOE FE-LNG Imports by Country of Origin, 2004

FIGURE 7

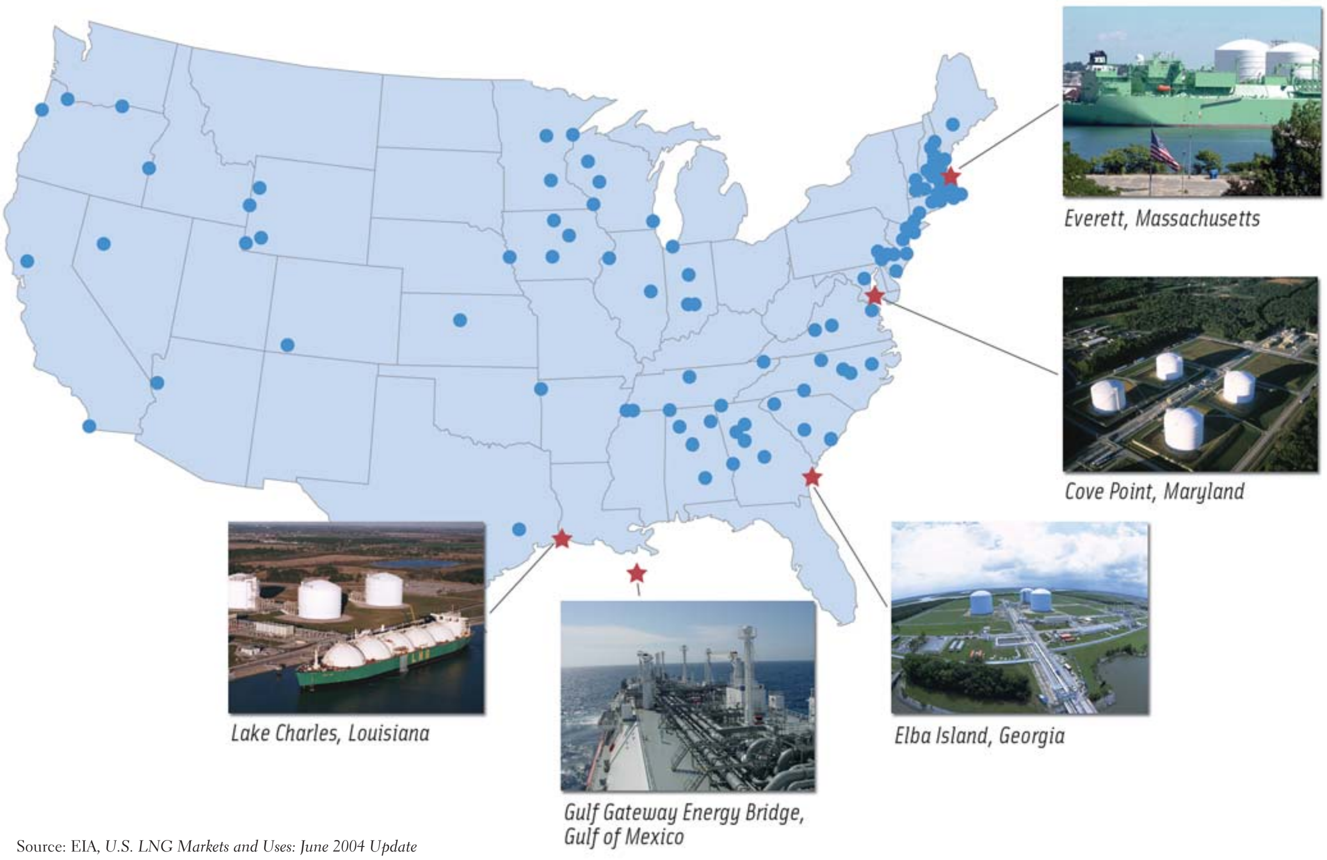
Even with planned expansions, the capacity of existing U.S. LNG terminals will meet less than half of the forecasted 6,400 Bcf LNG demand in 2025.



*Gulf Gateway began was commissioned for operation in April of 2005. 2005 data is pro-rated for 9 months.
Source: Energy Information Administration, FERC, and other sources

FIGURE 8

In addition to onshore and offshore import terminals along the nation's coastline, more than 100 satellite facilities located in the United States store LNG and supply natural gas to rural areas, as well as serving as cost-effective peak shavers at times of high usage.



Source: EIA, *U.S. LNG Markets and Uses: June 2004 Update*

The Pine Needle, North Carolina peak-shaving facility, one of the largest in the nation, has a storage capacity of 4 Bcf. A sendout capacity of .4 Bcfd empties the tanks in 10 days of peak usage.

LNG STORAGE AND "PEAK SHAVING"

Consumer demand for natural gas normally rises and falls within a certain range easily handled by gas utilities and the transmission pipelines that supply them. However, during extremely cold spells or other events or emergencies, demand for natural gas may "peak" sharply above normal baseline demand. Utilities need a reliable supply of gas that can be quickly delivered into the distribution system to flatten out or "shave" peaks in demand. The United States currently has more than 100 active peak-shaving plants and other satellite facilities, most of which were built between 1965 and 1975. The majority of these facilities are found in the Northeast, Upper Midwest, and Southeast. Approximately 55 local utilities own and operate small-scale LNG plants. At such facilities, natural gas is diverted from a pipeline, liquefied, and stored until needed. In some instances the LNG is trucked to satellite storage tanks. LNG is also trucked to satellite storage tanks from the LNG import terminal in Everett, Massachusetts. When demand spikes, the stored LNG is regasified and fed into the distribution system. The total annual LNG turnover in peak-shaving storage ranges between 35 and 68 Bcf per year, compared to the 652 Bcf of LNG imported during 2004. In addition, a small, relatively underdeveloped niche market (about .1 Bcf) uses LNG as a vehicle fuel or as an alternative to propane fuel at isolated industrial facilities.

Components of the LNG

Value Chain

The global LNG business has been described as a "value chain" containing four components: (1) Exploration and Production, (2) Liquefaction, (3) Shipping, and (4) Storage and Regasification, providing natural gas for delivery to several categories of "end user." To attract investors to an LNG project, the price of a unit volume of gas delivered into a pipeline must at least equal the combined costs of producing, liquefying, transporting, storing, and revaporizing the gas, plus the costs of the capital needed to build necessary infrastructure—and a reasonable return to investors. The largest component of the total cost of the LNG value chain is usually the liquefaction plant, while the production, shipping, and regasification components account for nearly equal portions of the remainder.[16]

Technology improvements have reduced costs in all components of the LNG value chain during the last 20 years. Several factors—improved efficiency through design innovations, economies of scale through larger train sizes,[17] and competition among manufacturers—have led to a drop in capital costs for liquefaction plants from $600 per ton of capacity in the late 1980s to about $200 per ton in 2001.[18] Costs have dropped for expansions to existing plants as well. Thus, construction of a new 8.2 million tons-per-year (390 Bcf-per-year) liquefaction plant could cost between $1.5 and $2 billion—50 percent for construction-related costs, 30 percent for equipment, and 20 percent for bulk materials.[19]

LNG companies build most LNG ships for a specific project, then own and operate them thereafter. Construction costs have dropped from $280 million in 1995 (for a 138,000-cubic-meter-capacity ship) to $150 to $160 million today—still more than double the cost of a crude oil tanker. Most added costs relate to the construction of insulated tanks.[20] LNG shipping costs vary based on the ship's operating and amortization costs, the size of the cargo, and the distance transported.[21]

The costs of building and operating receiving terminals (unloading, storage, and regasification facilities) vary by site. In the United States, new onshore terminals built on existing designs are expected to cost $400 million or more.[22] The cost of constructing offshore LNG facilities is substantially higher.

Deutsche Bank has estimated that worldwide capital expenditures in the LNG sector between 2003 and 2010 may total $114 billion.[23] The International Energy Agency has estimated that worldwide investments in LNG liquefaction, shipping, and regasification may total $252 billion between 2001 and 2030.[24] Uncertainties in projecting future LNG investment include the costs of

The LNG Value Chain

	Exploration & Production	Liquefaction	Shipping	Storage & Regasification
	Gas production and preplant processing and transport	Liquefaction plant, including preliquefaction processing, storage, and carrier loading	Shipping	Receiving terminal, including unloading, storage, regasification, and delivery
% Total Capital Costs (EIA, 2003)	15 to 20	30 to 45	10 to 30	15 to 25
Example Capital Costs	Varies widely	$1.5 to $2 billion for a plant that produces 8.2 million tons of LNG per year	$155 million to purchase a single 138,000 cubic meter ship, or $60,000 per day to charter	$400 million for a U.S. terminal capable of delivering between 180 and 360 Bcf per year

LNG infrastructure, natural gas prices, competition from other fuels, technology, environmental requirements, and geopolitical trends.

The magnitude of the total investment required to build and operate a complete LNG value chain (approximately $7–10 billion) requires the sort of economic power historically held by only countries or very large corporations. One way to minimize the substantial risks has been to obtain long-term supply contracts (20–25 years in duration), with a "take or pay" clause that obligates buyers to pay for gas at a certain price, even if markets do not exist.

Complementing long-term contracts, a spot market and short-term contracts[25] have emerged in the last five years. Factors influencing the emergence of the spot market include some global overcapacity in liquefaction, an increase in the number of LNG tankers, and increased contractual flexibility across the various components of the LNG value chain. These factors make it easier for exporters to sell their LNG and for importers to buy LNG, when and where it makes the most economic sense.

In the United States, LNG imports delivered under spot-market contracts represented more than 80 percent of all LNG imports in 2003, and nearly 70 percent in 2004. By contrast, in 1998 only about 25 percent of all LNG imports to the United States were delivered under spot-market contracts. The larger supply of spot-market LNG imports reflects the growing importance of the spot market to supply marginal demands in the United States, with volumes rising and falling in response to natural gas prices.[26] The spot market now accounts for almost 12 percent of the total worldwide LNG market, a number that could rise to 15 to 20 percent during the next 10 years,[27] creating increased opportunity for growth in both the size and efficiency of the LNG business.

16 When the full cost of exploration and production are attributed solely to an LNG opportunity, the cost for this component can see substantial increases.

17 Within the context of LNG, a "train" consists of the series of linked equipment elements used in the liquefaction process.

18 Sen, C. Taylor, Trends and Developments in the LNG Industry, an Appendix of *Potential Supply of Natural Gas 2002*, published by the Potential Gas Committee, pp. 89-98.

19 GTI, as referenced in the *The Global Liquefied Natural Gas Market: Status and Outlook* by the Energy Information Administration DOE/EIA-0637 (2003), p. 43.

20 GTI, DOE/EIA-0637, (2003) p. 44.

21 LNG Shipping Solutions, as referenced in *The Global Liquefied Natural Gas Market: Status and Outlook* by the Energy Information Administration DOE/EIA-0637 (2003), p. 44.

22 *National Gas Intelligence*, Intelligence Press, Inc., October 28, 2004.

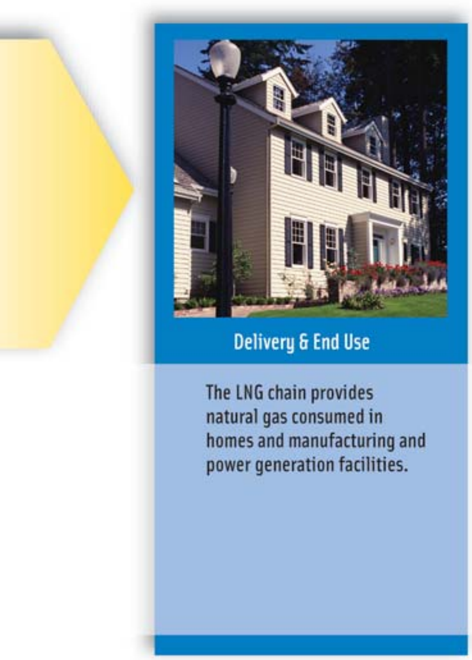
23 Deutsche Bank, *Global LNG: Exploding the Myths*, 2004.

24 International Energy Agency, *World Energy Investment Outlook 2003*.

25 Definitions vary for the duration of short-term contracts, e.g. 2 years or less (DOE, FE) and 4 years or less (International Group of Liquefied Natural Gas Importers).

26 DOE Office of Fossil Energy.

27 GTI, DOE/EIA-0637.



Frequently Used Conversions

To:	Billion Cubic Meters of Natural Gas	Billion Cubic Feet of Natural Gas	Million Tons of LNG	Trillion Btu
From:	MULTIPLY BY			
1 Billion Cubic Meters of Natural Gas	1	35.315	0.760	38.847
1 Billion Cubic Feet of Natural Gas	0.028	1	0.022	1.100
1 Million Tons of LNG	1.136	46.467	1	51.114
1 Trillion Btu	0.026	0.909	0.020	1

Typical Liquid–Vapor Conversions*

To:	Liquid Measures			Vapor Measures		Heat Measure
From:	Metric Ton LNG	Cubic Meter LNG	Cubic Foot LNG	Cubic Meter Natural Gas	Cubic Foot Natural Gas	Btu*
	MULTIPLY BY					
1 Metric Ton LNG	1	2.193	77.445	1,316	46,467	51,113,806
1 Cubic Meter LNG	0.456	1	35.315	600.00	21,189	23,307,900
1 Cubic Foot LNG	0.0129	0.0283	1	16.990	600.00	660,000
1 Cubic Meter Natural Gas	0.000760	0.001667	0.058858	1	35.315	38,847
1 Cubic Foot Natural Gas	0.000022	0.000047	0.001667	0.02832	1	1,100

Conversion Factors

1 million metric tons/year = 1.316 billion cubic meters/year (gas) = 127.3 million cubic feet/day (gas)
1 billion cubic meters/year (gas) = 0.760 million metric tons/year (LNG or gas) = 96.8 mcf/day (gas)
1 million cubic feet/day (gas) = 10.34 million cubic meters/year (gas) = 7,855 metric tons/year (LNG or gas)

Source: DOE Office of Fossil Energy
* Based on a volume conversion of 600:1, LNG density of 456 kg per cubic meter of LNG, and 1,100 gross dry Btu per cubic feet of gas.

The Basics of Natural Gas Production

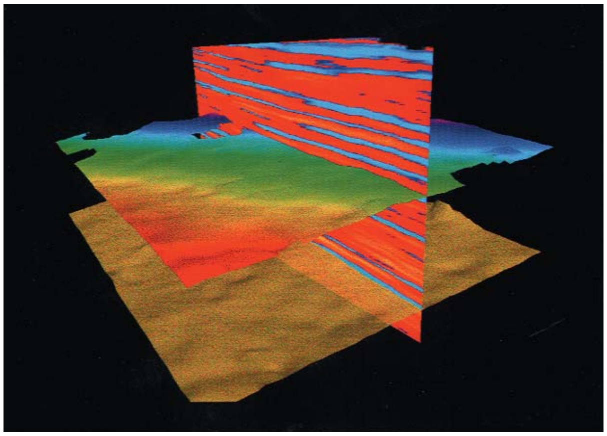
Exploring for natural gas deposits is a high-risk, high-cost endeavor—millions or tens of millions of dollars may be spent by a firm with the result being a "dry hole." Exploration begins when a firm or group of firms acquires an onshore or offshore parcel on which to drill. The firm then develops a prospect—often using sophisticated seismic imaging technologies (as shown below) to identify a target zone with a higher probability of containing hydrocarbons.

Once the necessary environmental assessments and permits are obtained—a process that can take two or more years in many areas—the firm engages a contractor to drill and complete an exploratory well. If tests indicate a possible economic accumulation of natural gas (known as a "discovery"), one or more delineation wells are drilled to confirm the extent of the accumulation and provide additional properties of the rocks and fluids.

Significant financial resources—hundreds of millions to more than one billion dollars—must then be committed to drill wells, design and construct a gas gathering and processing system, and connect the field via pipeline to one or more markets. For an LNG supply project, the pipeline must be laid from the field to a liquefaction plant at a coastal location. Production operating costs and royalty and tax payments are also part of the ongoing cost after a liquefaction plant begins operation. For each million tons per year of LNG (47 Bcf per year) produced by a liquefaction plant during a 20-year period, about 1.5 Tcf of natural gas reserves are required.[28]

FIGURE 9

A seismic image of subsurface features, including petroleum resources.



Source: Texaco Production Operations

Producing LNG by Liquefaction

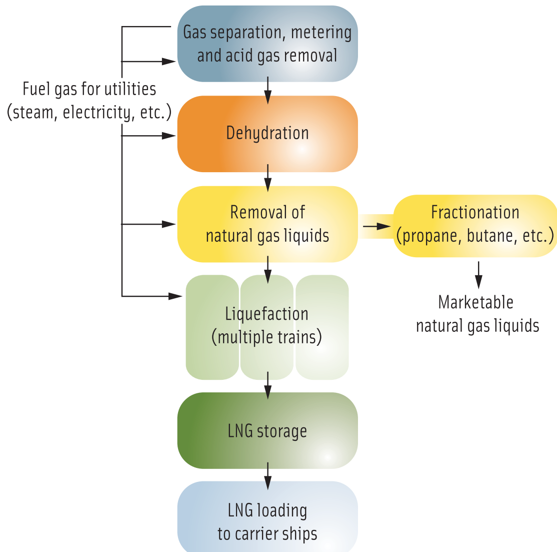
Figure 10 illustrates the components of an LNG liquefaction plant. The raw feed gas supply arriving from a producing gas field must be clean and dry before liquefaction can take place. It is scrubbed of entrained hydrocarbon liquids and dirt and treated to remove trace amounts of two common natural gas contaminants: hydrogen sulfide and carbon dioxide. Next, the gas is cooled to allow water to condense and then further dehydrated to remove even small amounts of water vapor. If mercury is present in the feed gas, it must be removed at this stage. The clean and dry gas may then be filtered before liquefaction begins. It is important that the gas consist primarily of methane with only small amounts of light hydrocarbons to ensure an efficient process.

Liquefaction takes place through cooling of the gas using heat exchangers. In these vessels, gas circulating through aluminum tube coils is exposed to a compressed hydrocarbon-nitrogen refrigerant. Heat transfer is accomplished as the refrigerant vaporizes, cooling the gas in the tubes before it returns to the compressor. The liquefied natural gas is pumped to an insulated storage tank where it remains until it can be loaded onto a tanker.

The liquefaction process can have variations. For example, the Phillips Cascade process, originally developed for the Kenai, Alaska liquefaction plant, employs three heat exchangers with successively colder refrigerants (propane, ethane, methane) and independent compressors for each exchanger-refrigerant combination. Together the series of exchangers comprise a single LNG train. The Mixed Components Refrigerant (MCR®) process developed by Air Products and Chemicals Inc., employs a single large heat exchanger and a single compressor using a mixture of refrigerants in each train. The gas is also pre-cooled using propane as a refrigerant. This system has the advantage of fewer compressors and exchanger elements. A number of variations on these processes have been developed in the past decade.[29]

FIGURE 10

Components of an LNG liquefaction plant.



The Kenai, Alaska liquefaction facility was America's first. It has exported LNG to Japan for more than 30 years.

After liquefaction, the LNG is stored in insulated tanks until it can be loaded onto carrier ships. This photo shows such tanks in Trinidad and Tobago.

LNG is transferred from storage tanks (like these in Qatar) to the carrier ship via specially constructed loading systems.

In the United States, large-scale liquefaction occurs at the Kenai, Alaska facility in preparation for exporting LNG to Japan. Generally, however, liquefaction occurs overseas. A typical LNG liquefaction facility includes three or four trains, although the plant in Bontang, Indonesia has eight. Worldwide, there are currently 18 liquefaction plants that export LNG operating 71 trains. Another 14 trains were under construction as of February 2005.[30]

The LNG production capacity of individual trains has increased from 0.5 to 1 million tons per year for the early plants to 1 to 5 million tons per year for plants under construction. This trend has been matched by a five-fold increase in LNG storage tank size, from 40,000 cubic meters to 200,000 cubic meters. While steam turbines were used as mechanical compressor drivers in early plants, more efficient natural gas turbines are now standard. Continual evolution in both turbine and compressor designs has resulted in a steady decrease in the power required to liquefy natural gas.

LNG formed in each train—the natural gas now at about –260°F—is transferred to insulated tanks for storage at atmospheric pressure. Just as the temperature of boiling water remains constant even if heat is added (thanks to the thermodynamics of steam evaporation), so does the temperature of boiling LNG at atmospheric pressure—as long as the gas vapor (LNG "steam") is removed. This "boil off" gas, about 0.15 percent of the volume per day, fuels the liquefaction facility, LNG transport ships, and receiving terminals where LNG is regasified.

At the liquefaction plant, LNG is transferred from the storage tanks to the ship using specially constructed pumps and jointed loading pipes that are designed to withstand the very low ("cryogenic") temperatures necessary for liquefaction.

28 Sen, C. Taylor, Trends and Developments in the LNG Industry, an Appendix of *Potential Supply of Natural Gas 2002*, published by the Potential Gas Committee, pp. 89-98.

29 Air Products and Chemicals, *LNG Capabilities*, August 2000.

30 DOE Office of Fossil Energy internal analysis.

The Global Business of LNG Transport

Transportation accounts for 10 to 30 percent of the cost of the LNG value chain. Carrier ships often are owned by LNG producers, but also sometimes are built as independent investments separate from specific LNG projects.

The evolution of LNG transport ships has been dramatic. While the first LNG carrier was a converted freighter with aluminum tanks insulated with balsa wood, modern LNG carriers are sophisticated double-hulled ships specifically designed for the safe and efficient transportation of cryogenic liquid. In May 2005, 181 LNG carriers were operating, with another 74 under construction for delivery in the 2005-07 time frame.[31]

About half of the LNG fleet is of the *membrane* design, with the other half of the *spherical* or *Moss*® design.[32] Figure 11 depicts the two types of ships.[33]

As of 2004, about three-fourths of the new LNG ships under construction or planned were of the membrane design due to innovations aimed at increasing cargo capacity in a given hull size, reducing capital costs and overall construction time.[34]

A small number of ships in service, built by the IHI shipyard in Japan, feature a self-supporting *prismatic tank design*. Like the spherical tank, the prismatic tank is independent of the hull. Any leaking LNG evaporates or flows into a pan below the tank.

FIGURE 11

The two basic types of LNG carrier ships have distinctive shapes.

The membrane design tanker introduced in 1970 features multiple tanks with linings made from thin (0.5 mm) nickel steel (Invar®) alloy capable of withstanding extreme temperatures. These tanks are integrated into the hull of the ship.

The spherical design tanker introduced in 1971 features round containment tanks that sit on supports on the hull of the ship and transfer the stress of thermal expansion and contraction onto those supports.

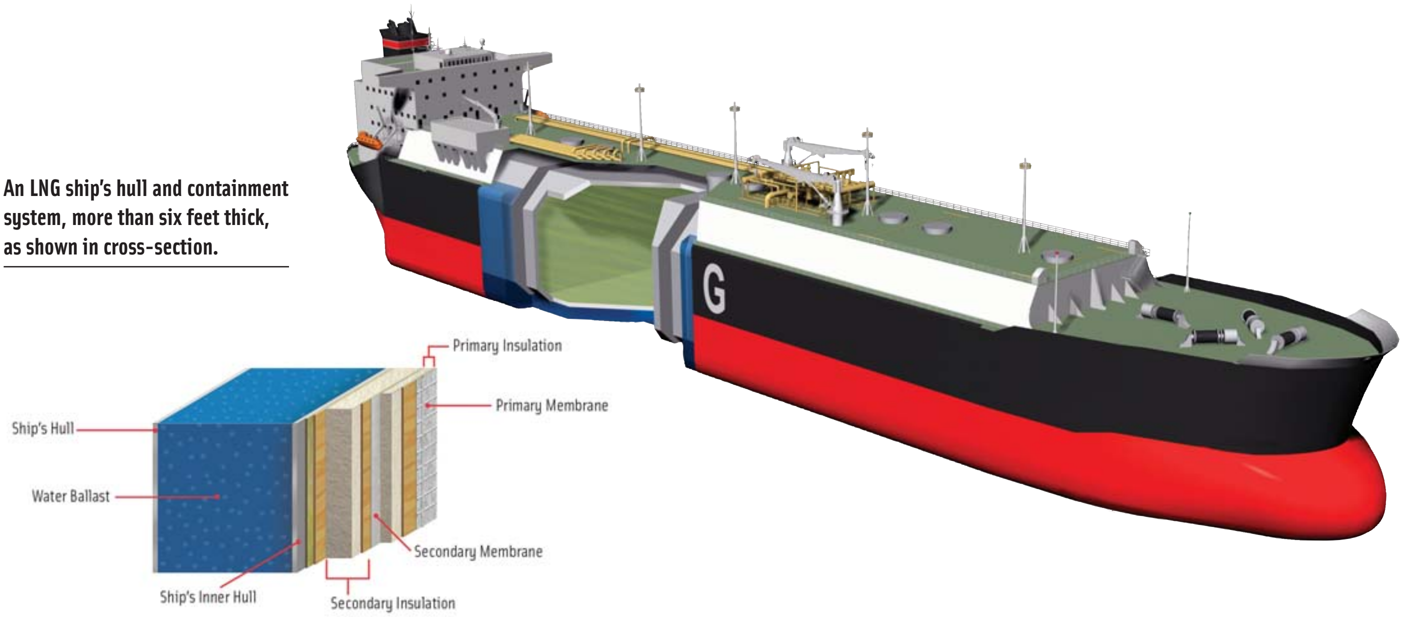
31 Colton Company, Worldwide Construction of Gas Carriers.

32 Data from the Society of International Gas Tanker & Terminal Operators (SIGGTO) show that Moss tankers represented 46 percent of the fleet in 2004, membrane tankers accounted for 51 percent, and 3 percent were other designs. In 2006, 43 percent are anticipated to be Moss, 54 percent membrane, and 3 percent other.

33 South Korea is the world's leading builder of LNG ships, led by Hyundai Heavy Industries Co., Ltd., Samsung Heavy Industries, and Daewoo Shipbuilding & Marine Engineering Co. Japan places second with major firms including Mitsubishi Heavy Industries Ltd., Mitsui Engineering and Shipbuilding Co., and Kawasaki Heavy Industries Ltd. Izari in Spain and Chantiers de l'Atlantique in France are also leading builders of LNG ships. Parker, Leia, *Investors Build Ships, Anticipating Boom in Gas Imports*, Dow Jones Newswire, October 28, 2003.

34 Harper, Ian, *Future Development Options for LNG Marine Transportation*, paper presented at the American Institute of Chemical Engineers, Spring National Meeting in New Orleans, March 10-14, 2002. Also see www.coltoncompany.com.

An LNG ship's hull and containment system, more than six feet thick, as shown in cross-section.



Source: Neil Chapman, BP; image courtesy of BP

SAFEGUARDING MARITIME TRANSPORT

Due to comprehensive safety and security programs for LNG tankers and receiving terminals, more than 33,000 shipments have transported in excess of three billion cubic meters of LNG without a serious accident at sea or in port in the past 40 years. LNG facilities and vessels feature state-of-the-art natural gas, fire, and smoke detection systems that identify hazardous situations and automatic shutdown systems that halt operations.

Security measures for the waterfront portions of marine terminals and LNG ships are regulated by the U.S. Coast Guard, which prevents other ships from getting near LNG tankers while in transit or docked at a terminal. The Federal Energy Regulatory Commission (FERC) also serves as a coordinator with the Coast Guard and other agencies on issues of marine safety and security at LNG import facilities.

In October 2003 the Coast Guard issued final rules to meet new security requirements mandated by the Maritime Transportation Security Act of 2002. These regulations cover vessels and facilities operating on or adjacent to waters under U.S. jurisdiction and require security assessments of ports, vessels, and facilities. Owners or operators of certain marine assets must develop preventive security plans as well as response plans for potential industrial incidents and security breaches.[35] Port-level security committees must focus on security shortfalls and contingency plans that will protect port assets at each threat level.

The Coast Guard has led the International Maritime Organization (IMO) in developing maritime security standards outside U.S. jurisdiction. These new standards, the International Ship and Port Facility Security Code (ISPS Code), contain detailed mandatory security requirements for governments, port authorities, and shipping companies as well as recommended guidelines for meeting those requirements. The ISPS Code is intended to provide a standardized, consistent framework to aid governments in evaluating risk.[36]

In 2004 FERC entered into an agreement with the Coast Guard and the Department of Transportation to establish roles and responsibilities for each agency regarding LNG security and to assure that each agency quickly identifies and addresses problem areas.[37]

35 *Protecting America's Ports*, July 1, 2003, and *Making Our Waters Safer*, October 22, 2003, U.S. Department of Homeland Security press releases related to the Maritime Transportation Security Act of 2002.

36 Parfomak, Paul W., *Liquefied Natural Gas (LNG) Infrastructure Security: Background and Issues for Congress*, Congressional Research Service, CRS Report to Congress, September 9, 2003.

37 *Commission, Coast Guard, DOT Sign Interagency Aagreement to Coordinate Review of LNG Terminal Safety*, Federal Energy Regulatory Commission Press Release, February 11, 2004.

Preparing LNG for Use by Regasification

At a marine terminal or satellite installation, pumps transfer LNG from storage tanks to warming systems, where the liquid rapidly returns to a vaporized state. *Ambient temperature* systems use heat from surrounding air or from seawater (even in cold weather, both are warmer than LNG) to vaporize the cryogenic liquid, while *above-ambient temperature* systems add heat by burning fuel to indirectly warm the LNG via an intermediate fluid bath.[38]

Afterward, the natural gas is ready for delivery into the nation's network of transmission and distribution pipelines for use by residential consumers, industries, or nearby power generation plants, where it fuels natural gas turbines.

The benefits of storing LNG. Stored LNG supplies help to meet consumption needs during the coldest days of winter, particularly for gas utilities with a substantial residential customer base and therefore a highly seasonal demand for gas. On these peak-demand days, LNG storage facilities prove invaluable because of their ability on short notice to regasify and deliver large amounts of natural gas into regional distribution systems. About 82 percent of LNG storage capacity is located in the eastern United States, as reflected in the map on page

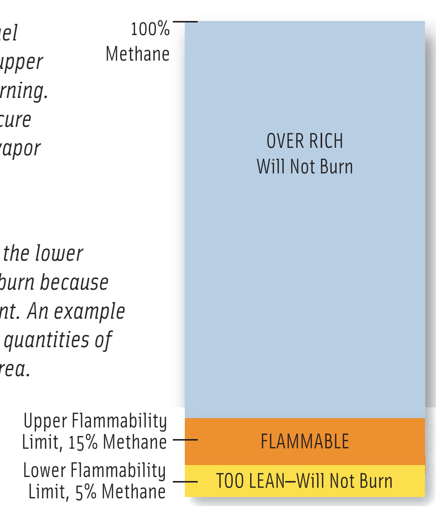
38 *Oil and Gas Journal*, 2003 LNG World Trade and Technology, November 2003.

LNG vapor has a limited flammability range.

The physical and chemical properties of LNG render it safer than other commonly used hydrocarbons.

Lack of oxygen prevents fuel concentrations above the upper flammability limit from burning. An example would be a secure storage tank with an LNG vapor concentration at or near 100 percent methane.

Fuel concentrations below the lower flammability limit cannot burn because too little methane is present. An example would be leakage of small quantities of LNG in a well-ventilated area.



7, with most of this capacity concentrated in the Northeast for use in major population centers such as Boston, New York, and Philadelphia.[39]

Modern LNG storage techniques. Prior to regasification, LNG is stored at atmospheric pressure in double-walled, insulated tanks that feature innovative, highly safe, and stable designs. The walls of the inner tank, composed of special steel alloys with high nickel content as well as aluminum and pre-stressed concrete, must be capable of withstanding cryogenic temperatures. LNG storage tanks are built on a base of concrete blocks with the glassy volcanic aggregate perlite added to Portland cement and special admixtures, reinforced with steel bars. These blocks insulate the cryogenic tank from the ground itself. Perlite is also used as insulation in the walls of the tank.

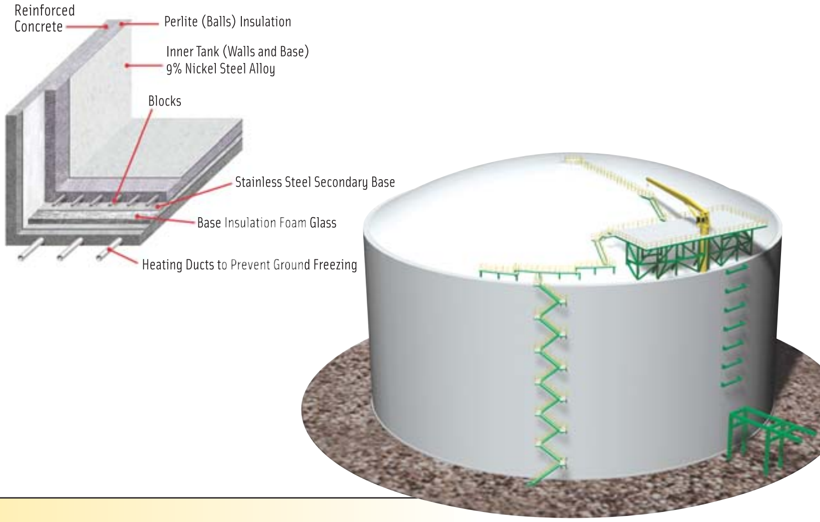
To safeguard against leaks, some storage tanks feature a double-containment system, in which both the inner and outer walls are capable of containing LNG. Another approach, utilized by most LNG tanks at existing U.S. import and satellite storage facilities, surrounds a single-containment tank with an earthen dam or dike that provides secondary containment, safely isolating any LNG spills.

39 EIA, *LNG Markets and Uses: June 2004 Update.*

Regasification system at the Lake Charles, Louisiana LNG terminal

A cross-section of storage tank walls totaling about five-and-a-half feet thick

Source: Neil Chapman, BP; image courtesy of BP



HOW ARE LNG FACILITIES KEPT SECURE AND SAFE?

Security for land-based LNG facilities and onshore portions of marine terminals is regulated by the Federal Energy Regulatory Commission (FERC) and U.S. Department of Transportation (DOT). Requirements include security patrols, protective enclosures, lighting, monitoring equipment, and alternative power sources. Federal regulations also require exclusion zones surrounding LNG facilities to protect adjacent sites from heat in the event that vapor clouds are formed in a release and are ignited.

LNG security is multifaceted. Interstate natural gas companies receive security updates and alerts from the Federal Bureau of Investigation and other federal agencies. DOT's Office of Pipeline Safety provides guidelines to LNG operators for security procedures at onshore facilities. A federal security task force works to improve pipeline security practices, facilitate communications within industry and government, and lead public outreach efforts. FERC works with other federal agencies and industry trade groups on regional contingency planning for interrupted service from the main natural gas pipeline. Security is also a prime consideration in the approval process for new or expanded facilities. Depending on the specifics of a project, FERC may convene special technical conferences with other government and law enforcement agencies to address safety and security issues. The Department of Homeland Security is the nation's lead federal agency for protecting critical infrastructure, working closely with state and local government, other federal agencies, and the private sector, which owns ands operates the lion's share of the nation's critical infrastructure and key assets.[40]

Comprehensive safety procedures and equipment found at all LNG facilities help to maintain an outstanding record of worker safety. Precautions include avoiding asphyxiation (which can result if LNG vapors deplete breathable oxygen in a confined space), preventing lung damage (which can result if LNG vapors are inhaled), and preventing cryogenic burns (which can occur if LNG contacts human skin).

40 U.S. Department of Homeland Security, *The National Strategy for the Physical Protection of Critical Infrastructures and Key Assets*, February 2003.

Ensuring Consistent Quality for End Use

Raw natural gas intended for use in the United States today contains nonmethane components such as ethane, propane, and butane that must be "stripped" to leave pure methane. Methane then flows through the pipeline to end users. Recently, with U.S. natural gas supplies tightening and prices on the rise, pressure has mounted to allow natural gas to flow into the grid with some impurities remaining. This "richer" gas with higher heating values can produce a flame that is too large or too hot in certain applications, making it incompatible with U.S. appliances and industrial processes as well as the gas quality standards of local utilities and pipelines.[41]

The composition of LNG received in the United States varies by country of origin, as shown in Table 1, and must be modified before delivery. This variation limits deliveries to certain terminals and also must be factored into the development of new facilities. LNG importing facilities deal with this problem by mixing domestic and imported gas or injecting nitrogen or air into the gas stream.

At Lake Charles, Louisiana, Southern Union successfully mixes high-heat-content natural gas with relatively low-heat-content gas common to the region's substantial processing infrastructure. Therefore, LNG deliveries with high Btu content occur more often at Lake Charles than at the three East Coast terminals.

TABLE 1

Typical Composition of LNG Imports by Country

Origin	Methane (C1) %	Ethane (C2) %	Propane (C3) %	Butane (C4+) %	Nitrogen (N2) %
Algeria	87.6	9.0	2.2	0.6	0.6
Australia	89.3	7.1	2.5	1.0	0.1
Malaysia	89.8	5.2	3.3	1.4	0.3
Nigeria	91.6	4.6	2.4	1.3	0.1
Oman	87.7	7.5	3.0	1.6	0.2
Qatar	89.9	6.0	2.2	1.5	0.4
Trinidad & Tobago	96.9	2.7	0.3	0.1	0

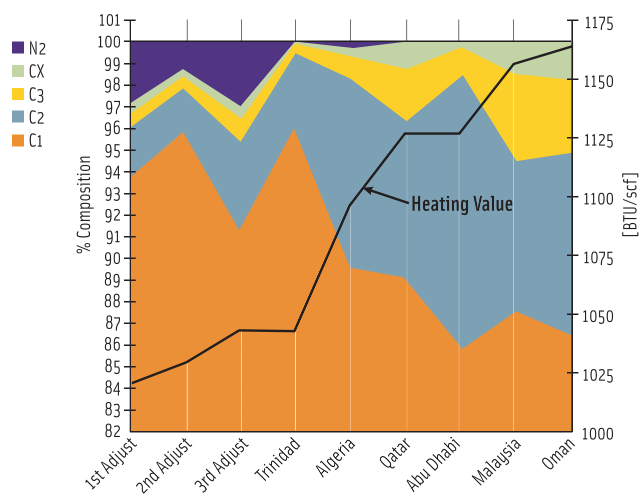
Source: Groupe International Des Importateurs De Gaz Natural Liquéfié

At the Everett, Massachusetts facility, Distrigas uses in-tank blending of pipeline gas with LNG to meet standards. Btu levels can also be reduced by injecting nitrogen or air into the vaporized gas stream at sendout. This method can be costly: approximately $18.5 million to equip a facility with air injection devices and about $28 million for nitrogen separation equipment. Dominion is in the process of installing a nitrogen separation plant at its Cove Point facility. Installation of liquid-stripping facilities at marine terminals also would effectively allow Btu reduction, but at a cost of $30 million or more per facility.

Since February 2004 FERC and DOE have been working with industry to address concerns about LNG interchangeability and current natural gas quality standards, particularly in light of expected increases in LNG imports. Natural gas industry stakeholders involved in this collaborative process include producers, pipelines, local distribution companies, process gas consumers, liquefied natural gas importers, equipment manufacturers, turbine manufacturers, and electric utilities.

FIGURE 12

Imported LNG can have a composition and heating value that differ from average U.S. pipeline gas.



LNG cargos imported into the U.S. exhibit a range of heating values.

Source: Rue, David, GTI Gas Technology Conference, Phoenix, February 11, 2004

41 Foss, Brad, The Associated Press, *Inconsistent Quality of Natural Gas Raises Safety Concerns*, 2004.

Informed

Decision Making

As U.S. demand for natural gas continues to grow, the nation is likely to turn more and more to natural gas found in other parts of the world. LNG provides access to this large global natural gas supply. Today, the United States has only six LNG receiving terminals—four on the mainland, one offshore, and one in Puerto Rico. In the future, new and expanded LNG terminals will be necessary to ensure clean, reliable, and affordable supplies of energy for American consumers.

Although significant progress has been made to streamline the LNG permitting process, it remains complex and lengthy. As many as 100 permits and approvals may be required from federal, state, and local government agencies for a new onshore LNG terminal. These agencies rigorously examine the benefits of the proposed project, and take into account facility design, location, safety, and security as well as environmental concerns to arrive at the best, most informed decisions. Without significant delays, it may take up to seven years to bring a new onshore terminal on-line, from initial design to the first delivery of LNG imports, including up to three years for obtaining necessary permits and approvals.[42]

KEY ISSUES FACING DECISION MAKERS

- Security and safety
- Need to streamline permitting
- Siting, land use, and environmental issues
- National, regional, and local economic benefits
- Gas quality/LNG interchangeability
- Return on investment/Financing
- Sustainable development, including societal implications of LNG trade
- Technology innovation
- Communication/Public understanding

Federal, State, and Local Decision Makers

Numerous federal agencies oversee the nation's LNG infrastructure, working with the states and local authorities. For example:

The Federal Energy Regulatory Commission (FERC) asserts approval authority over the place of entry and exit, siting, construction, and operation of new terminals as well as modifications or extensions of existing LNG terminals (see 18 CFR 153). FERC requirements include detailed site engineering and design information, evidence that an LNG facility will safely receive or deliver LNG, and delineation of a facility's proposed location and geologic risk, if any. Facilities to be located at the Canadian or Mexican border for import or export of natural gas also require a Presidential Permit. Every two years, FERC staff members inspect LNG facilities to monitor the condition of the physical plant and review changes from the originally approved facility design or operations. FERC has jurisdiction over all existing LNG import terminals and 15 peak-shaving plants involved in interstate gas trade.

The U.S. Coast Guard (USCG) is responsible for assuring the safety of marine operations in U.S. coastal waters under provisions of the Ports and Waterways Safety Act of 1972 (P.L. 92-340) and also the Maritime Transportation Security Act (MTSA). The latter was signed into law in November 2002, amending the Deepwater Port Act of 1974 (DWPA) to include offshore natural gas facilities. The USCG implements a streamlined application process mandated by the DWPA that is designed to yield a decision within one year of receipt of an application for construction of an offshore LNG terminal. The USCG also regulates the design, construction, and operation of LNG ships and the duties of LNG ship officers and crews.

42 National Petroleum Council, LNG Subgroup Report, updated August 2004.

The Department of Transportation Office of Pipeline Safety regulates the siting and safety of LNG pipeline facilities, including LNG peak-shaving plants, under the Pipeline Safety Act of 1994 (P.L. 102-508), as amended. Implementing regulations for the Act, including provisions on facility siting, are found in 49 CFR 191-199. Standards for operation, maintenance, fire protection, and security at such facilities are chiefly found in 49 CFR 193 and incorporate National Fire Protection Association (NFPA) standards.

The Department of Energy (DOE) Office of Fossil Energy coordinates across federal agencies that have regulatory and policy authority for LNG. The Natural Gas Act of 1938 requires that anyone seeking to import or export natural gas across U.S. borders must be authorized by DOE. DOE monitors LNG shipments to ensure the integrity of American energy supplies via a certification process. In addition, the Office of Fossil Energy and the National Energy Technology Laboratory fund LNG technology research and work to eliminate or minimize potential impediments to LNG facility siting and operations.

Jurisdiction among federal agencies with LNG oversight responsibilities is sometimes a point of contention, and memorandums of understanding are established to delineate respective agency roles. For example, in May 2004 a final memorandum of understanding for interagency coordination on licensing of deepwater ports, pursuant to the Deepwater Port Act, was established involving the Departments of Commerce, Defense, Energy, Homeland Security, Interior, and Transportation, the Environmental Protection Agency (EPA), FERC, the Council on Environmental Quality, and the U.S. Corps of Engineers.

Protecting Our Environment

The National Environmental Policy Act (NEPA) requires that federal agencies consider impacts to the environment of all proposals for major federal actions and, when appropriate, consider alternatives to those proposals. FERC—as the lead agency for the permitting of natural gas pipelines, compressor

Organizations involved in LNG facility decisions

Federal Agencies

Onshore/Marine
- U.S. Department of Energy
- Federal Energy Regulatory Commission
- U.S. Coast Guard
- U.S. Department of Transportation
- U.S. Environmental Protection Agency
- U.S. Minerals Management Service
- U.S. Fish and Wildlife Service
- U.S. Dept. of Labor/Occupational Safety & Health Administration
- U.S. Army Corps of Engineers

Offshore
- U.S. Department of Energy
- U.S. Coast Guard
- U.S. Department of Transportation
- U.S. Fish and Wildlife Service
- National Oceanic and Atmospheric Administration
- U.S. Dept. of Labor/Occupational Safety & Health Administration
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Minerals Management Service
- U.S. Maritime Administration

State and Local Agencies

- State departments of environmental protection
- Local governments
- Fire departments
- Police

Non-Governmental Standards Organizations

- National Fire Protection Association
- American Society of Mechanical Engineers
- American Society of Civil Engineers
- American Petroleum Institute
- American Concrete Institute
- American Society for Testing and Materials

stations, storage facilities, and onshore LNG terminals—implements NEPA requirements. Several other federal agencies are also involved.

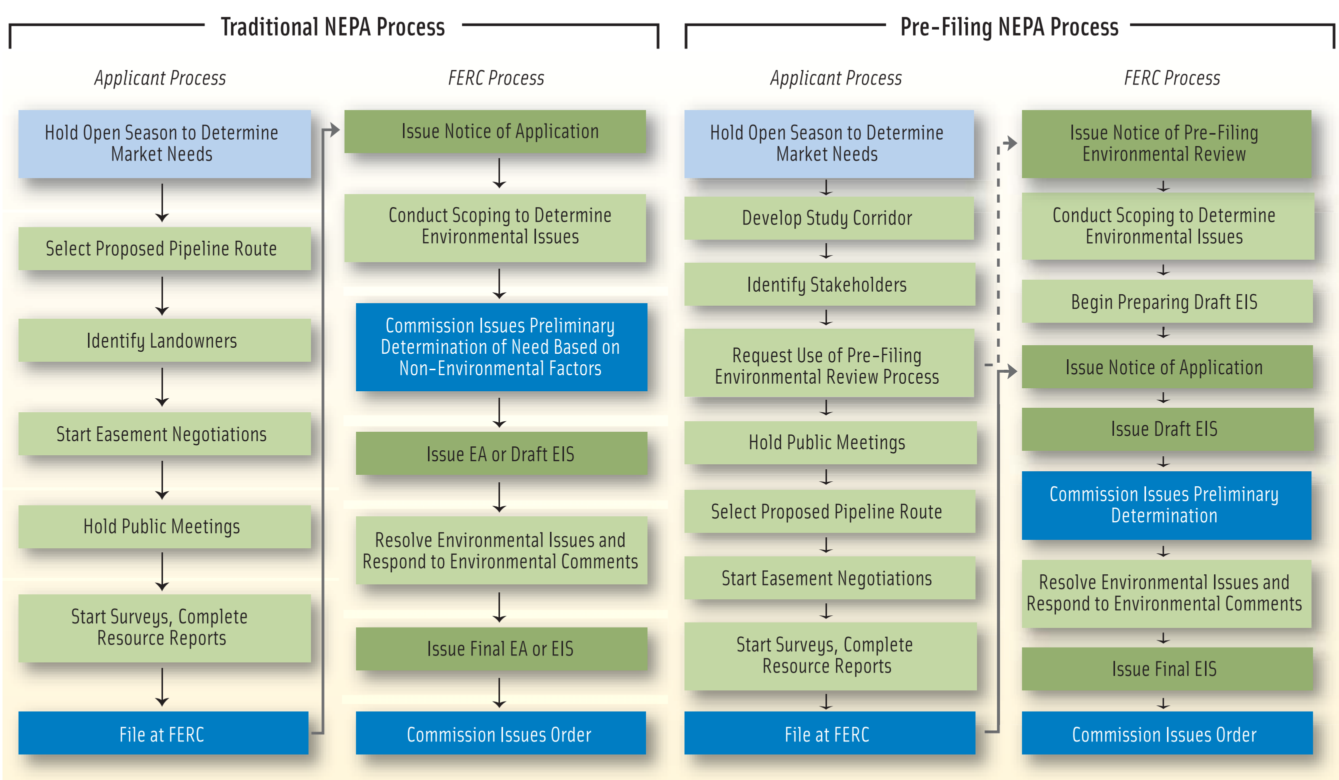
The NEPA process includes open consultation with relevant agencies and the public. Although most applicants notify and meet with the public in advance, the traditional NEPA process begins after an application is filed. In 2002 FERC implemented the optional NEPA pre-filing process, bringing stakeholders together earlier in project review and development to uncover disagreement and work toward resolution before the formal application is filed. The pre-filing NEPA process can accelerate the permitting process by more than six months. Similarly, the DWPA requires NEPA compliance for the permitting of offshore LNG terminals. The Coast Guard is the lead federal agency for the environmental review process and ensures that the application complies with all aspects of NEPA.

State and Local LNG Regulation

The regulation of LNG facilities by states varies from comprehensive to fragmented, and many states are striving to address the evolving interest in LNG. Some state agencies, such as state public utility commissions, govern commerce and trade. Other state regulatory agencies (for example, state departments of environmental protection), together with the U.S. EPA, grant permits for specific activities to minimize environmental impacts. The California Energy Commission provides the leadership for an LNG Interagency Permitting Working Group to ensure close communication among, and support for, agencies potentially involved in the permitting process of any LNG facility.[43]

State and local government agencies are also involved in zoning, construction, operation, and maintenance of LNG terminals. Local fire and police departments have jurisdiction on the basis of protecting the safety and security of the surrounding area.

NEPA pre-filing can expedite the permitting process for onshore LNG facilities by more than six months (blue indicates FERC staff activities; green indicates applicant activities).



Source: Adapted from schematics found at www.ferc.gov/for-citizens/my-rights/process.asp

Safety and security systems rely on personnel who are well trained on operational and maintenance procedures. Organizations such as the Society of International Gas Tanker and Terminal Operators, Gas Processors Association, and National Fire Protection Association (NFPA) have guidelines and provide training based on industry best practices. NFPA, for example, has developed fire safety codes and standards drawing on the technical expertise of diverse professionals—and on technical standards developed by organizations such as the American Society of Mechanical Engineers and the American Society of Civil Engineers.[44]

The Citizens' Role in Facility Location Decisions

Regulatory processes for LNG facility siting and expansion encourage open public consultation and comment, which are key to successful project planning and development. Informed decision making increases certainty that safer and more secure projects with a high degree of environmental integrity are approved.

Opportunities for public participation exist at many stages of the permitting process. Generally, the public first receives notice of a facility project when the company proposing the project begins to prepare environmental studies as required for the FERC application, or when a company seeks easement or purchase of land from private landowners or local governments. Once an application is filed, FERC publishes a notification of application in the Federal Register.[45]

Public meetings are required under both the old and revised (pre-filing) FERC approval processes. Such meetings provide a public forum for questions and concerns about proposed projects. The public can also express views in writing directly to FERC. The Environmental Assessment (EA) and Environmental Impact Statement (EIS) processes allow for a public comment period. All comments received during this open comment period, announced in the Federal Register, are addressed in the final EA or EIS.[46]

Individuals can take a more active role by becoming intervenors—a type of formal involvement that requires adherence to FERC regulations. Whether formally or informally, many government agencies encourage the public to stay informed and to participate in the permitting process. Similar opportunities exist for citizen involvement in state and local government decision making. Examples include participating at public hearings, and providing comments on new regulations, the issuance of permits, or regional development plans.

43 See www.energy.ca.gov/lng/working_group.html.

44 University of Houston, *LNG Safety and Security*, October 2003.

45 See www.gpoaccess.gov/fr.

46 More information on the FERC process and public involvement can be found at www.ferc.gov. Two particularly useful documents available at www.ferc.gov/for-citizens/my-rights.asp are *An Interstate Natural Gas Facility On My Land? What Do I Need To Know*, and *Ideas for Better Stakeholder Involvement in the Interstate Natural Gas Pipeline Planning Pre-Filing Process*.

RECENT REGULATORY CHANGES SPUR LNG INVESTMENTS

The Maritime Transportation Security Act of 2002 transferred jurisdiction for offshore natural gas facilities from the FERC to the U.S. Coast Guard, streamlined the permitting process, and allowed owners of offshore LNG terminals access to their entire capacity rather than requiring them to offer capacity to others through an open-season bidding process, known as "open-access." The December 2002 ruling known as the "Hackberry Decision" has the same effect for new onshore facilities under FERC jurisdiction. These rulings acknowledge that LNG import terminals are supply sources rather than part of the interstate gas transportation system. Both rulings also allow LNG terminals to charge for services based on current market conditions rather than based solely on the terminals' cost for providing the services, as previously required. These new policies are intended to encourage the construction of LNG facilities.

Summary

The United States will continue to rely on natural gas even as domestic production is projected to decline. Significant growth in LNG imports can prevent imbalances in future supply and demand that could adversely affect consumers and the U.S. economy. Such growth must include major increases in LNG infrastructure through expansion of existing import terminals and the construction of new facilities. The United States will need more capacity to meet ever-rising natural gas demand.

The focus of the natural gas industry, the public, and federal, state, and local governmental agencies on major upgrades to LNG infrastructure has raised awareness about relevant siting and operational issues. Such dialogue is needed to assure that the use of LNG will be safe and secure and will maintain the integrity of the human and natural environment.

APPENDIX: INFORMATIONAL RESOURCES

Further information on LNG issues can be obtained from a variety of government, industry, and organization sources as represented in the sampling below.

LNG-Related Websites

The *Energy Information Administration (EIA)*, created by Congress in 1977, is a statistical agency of the U.S. Department of Energy (DOE). A variety of LNG statistics and other information can be found on the EIA website, including the latest updates of the *Global Liquefied Natural Gas Market: Status and Outlook* and *U.S. LNG Markets and Uses*. ***www.eia.doe.gov***

The *Federal Energy Regulatory Commission (FERC)* is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity. FERC also regulates natural gas and hydropower projects. The LNG portion of the FERC website includes an LNG overview and provides answers to important questions about all aspects of the value chain and LNG security and safety. ***www.ferc.gov/industries/lng.asp***

The *National Association of Regulatory Utility Commissioners (NARUC)* is a nonprofit organization of governmental agencies engaged in the regulation of U.S. utilities and carriers. The NARUC website contains comprehensive information on its activities and programs (including those related to LNG), testimony and publications, news, upcoming events, and links to state regulatory commissions. ***www.naruc.org***

The *National Energy Technology Laboratory*, the newest of DOE's national laboratories, works to develop breakthrough technologies and approaches that will assure the safe, clean, and affordable use of U.S. fossil energy resources through the 21st century. A search of the website using the keyword LNG reveals papers, presentations, and other information related to a basic understanding of LNG. ***www.netl.doe.gov***

DOE's *Office of Fossil Energy* supports research and policy options to ensure clean, reliable, and affordable supplies of natural gas for American consumers. The Fossil Energy website contains many features concerning natural gas and LNG, including the web feature, *Liquefied Natural Gas–a Basic Understanding.* ***www.fossil.energy.gov***

The *California Energy Commission* serves as the state's primary energy policy and planning agency for keeping historical energy data and meeting future energy needs. This website includes LNG news, FAQs, state energy policy, proposed projects within the state, and guidance on public participation, security, and safety. ***www.energy.ca.gov/lng***

The *Center for Energy Economics at the University of Texas-Austin, Bureau of Economic Geology* hosts a website on the role of LNG in North American energy security. This website provides a variety of LNG reference reports in English and Spanish, such as *Introduction to LNG*, *LNG Safety and Security*, and *The Role of LNG in North American Natural Gas Supply and Demand*. ***www.beg.utexas.edu/energyecon/lng***

The *Center for Liquefied Natural Gas* has attracted more than 50 members, including LNG asset owners and operators, gas transporters, and natural gas end users. The Center's website contains FAQs, quick facts, a historical perspective, discussion of issues, and a multimedia area. ***www.lngfacts.org***

Dominion, headquartered in Richmond, Virginia, is one of the nation's largest producers of energy. This website provides information on Dominion's Cove Point LNG receiving terminal. ***www.dom.com/about/gas-transmission/covepoint/index.jsp***

The *Gas Technology Institute (GTI)* is an independent, not-for-profit technology organization that works with its customers to find, produce, move, store, and use natural gas. A search of the keyword LNG on the GTI website provides visitors with a list of links, including descriptions of LNG research and development at GTI, and other useful documents and information sources. ***www.gastechnology.org***

The National Gas Company of Trinidad and Tobago and four international partners formed the *Atlantic LNG Company of Trinidad and Tobago* in 1995. This website provides information on the company's LNG facilities, the liquefaction process, and natural gas and LNG-related information. ***http://atlanticlng.com***

The *International LNG Alliance* (ILNGA) is sponsored by the United States Energy Association (USEA), the U.S. Member Committee of the World Energy Council (WEC). It works to promote and advance the safe, reliable, cost-effective, and environmentally sound use of LNG, as well as the development of LNG infrastructure. The ILNGA website includes information on the various education, policy, and trade and business development aspects of LNG. ***www.ilnga.org***

Other LNG Information Available Online

Liquefied Natural Gas (LNG) *Infrastructure Security: Background and Issues for Congress* by Paul W. Parfomak of the Congressional Research Service (September 9, 2003; document RL32073) provides an overview of recent initiatives and key policy issues associated with LNG security. ***www.pennyhill.com/infrastructure.html***

The Next Prize by Daniel Yergin and Michael Stoppard is an article in *Foreign Affairs* magazine, Volume 82, No. 6 (Nov/Dec 2003), pp. 103-114, published by the Council on Foreign Relations. This article provides an overview of the newly emerging global gas market and issues related to LNG. ***www.foreignaffairs.org***

Protecting America's Ports, Maritime Transportation Act of 2002 is a brief document published by the U.S. Department of Homeland Security that describes the new regulations of the Maritime Transportation Act of 2002. Included in this document is a fact sheet outlining the implementation requirements and other security initiatives of the new Act. ***www.dhs.gov/interweb/assetlibrary/MTSA_Presskit.doc***

Trends and Developments in the LNG Industry by Dr. Colleen Taylor Sen of the Gas Technology Institute is a 10-page summary included as an appendix to the Potential Gas Committee's 2002 issue of a biennial report: *Potential Supply of Natural Gas*. This summary describes changes in the U.S. LNG market. ***www.mines.edu/research/pga/index.html***

A short video on LNG is available from British Petroleum p.l.c. ***http://www.bplng.com/environment/video.asp***

U.S. Department of Energy
Office of Fossil Energy
www.fossil.energy.gov

National Energy Technology Laboratory
www.netl.doe.gov

August 2005

DOE/FE-0489

Printed on recycled paper