

# Introduction to LNG

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## What is LNG?

Liquefied natural gas, or LNG, is natural gas in its liquid form. When natural gas is cooled to minus 259 degrees Fahrenheit (-161 degrees Celsius), it becomes a clear, colorless, odorless liquid. LNG is neither corrosive nor toxic. Natural gas is primarily methane, with low concentrations of other hydrocarbons, water, carbon dioxide, nitrogen, oxygen and some sulfur compounds. During the process known as liquefaction, natural gas is cooled below its boiling point, removing most of these compounds. The remaining natural gas is primarily methane with only small amounts of other hydrocarbons. LNG weighs less than half the weight of water so it will float if spilled on water.

## Where does LNG come from?

A majority of the world's LNG supply comes from countries with large natural gas reserves. These countries include Algeria, Australia, Brunei, Indonesia, Libya, Malaysia, Nigeria, Oman, Qatar, and Trinidad and Tobago.

## What countries import LNG?

There are 60 LNG receiving terminals located worldwide. Japan, South Korea, the United States and a number of European Countries import LNG.

## Where are LNG import terminals located in the United States?

LNG terminals in the United States are located in Everett, Massachusetts; Cove Point, Maryland; Elba Island, Georgia; and Lake Charles, Louisiana; Offshore Boston; Gulf of Mexico; Freeport, Texas; Sabine, Louisiana; and Peñuelas, Puerto Rico.



LNG Vessel  
Photo courtesy of CH-IV International  
<http://www.ch-iv.com>

## How is LNG transported?

LNG is transported in double-hulled ships specifically designed to handle the low temperature of LNG. These carriers are insulated to limit the amount of LNG that boils off or evaporates. This boil off gas is sometimes used to supplement fuel for the carriers. LNG carriers are up to 1000 feet long, and require a minimum water depth of 40 feet when fully loaded. There are currently 136 ships which transport more than 120 million metric tons of LNG every year. (Source: University of Houston IELE, *Introduction to LNG*.)

### **How is LNG stored?**

When LNG is received at most terminals, it is transferred to insulated storage tanks that are built to specifically hold LNG. These tanks can be found above or below ground and keep the liquid at a low temperature to minimize the amount of evaporation. If LNG vapors are not released, the pressure and temperature within the tank will continue to rise. LNG is characterized as a cryogen, a liquefied gas kept in its liquid state at very low temperatures. The temperature within the tank will remain constant if the pressure is kept constant by allowing the boil off gas to escape from the tank. This is known as auto-refrigeration. The boil-off gas is collected and used as a fuel source in the facility or on the tanker transporting it. When natural gas is needed, the LNG is warmed to a point where it converts back to its gaseous state. This is accomplished using a regasification process involving heat exchangers.



LNG Storage Tanks  
Cove Point Import Terminal, Maryland  
Photo courtesy of Dominion © 2003, [www.dom.com](http://www.dom.com)

### **How is natural gas stored?**

Natural gas may be stored in a number of different ways. It is most commonly stored underground under pressure in three types of facilities. The most commonly used in California are depleted reservoirs in oil and/or gas fields because they are more available. Aquifers and salt cavern formations are also used under certain conditions. The characteristics and economics of each type of storage site will dictate its suitability for use. Two of the most important characteristics of an underground storage reservoir are its capability to hold natural gas for future use and its deliverability rate. The deliverability rate is determined by the withdrawal capacity of the associated valves and compressors and the total amount of gas in the reservoir. In other states, natural gas is also stored as LNG after the natural gas has been liquefied and placed in above-ground storage tanks. (Source: U.S. Department of Energy, Energy Information Administration.)

### **How is LNG used?**

LNG is normally warmed to make natural gas to be used in heating and cooking as well as electricity generation and other industrial uses. LNG can also be kept as a liquid to be used as an alternative transportation fuel.

### **Why use LNG?**

Natural gas is the cleanest burning fossil fuel. It produces less emissions and pollutants than either coal or oil. The North American supply basins are maturing and as demand for natural gas increases in California and throughout the United States, alternative sources of natural gas are being investigated. Natural gas is available outside of North America, but this gas is not accessible by pipelines. Natural gas can be imported to the United States from distant sources in the form of LNG. Since LNG occupies only a fraction (1/600) of the volume of natural gas, and takes up less space, it is more economical to transport across large distances and can be stored in larger quantities. LNG is a price-competitive source of energy that could help meet future economic needs in the United States.

### **Is LNG flammable?**

When cold LNG comes in contact with warmer air, it becomes a visible vapor cloud. As it continues to get warmer, the vapor cloud becomes lighter than air and rises. When LNG vapor mixes with air it is only flammable if it's within 5%-15% natural gas in air. If it's less than five percent natural gas in air, there is not enough natural gas in the air to burn. If it's more than 15 percent natural gas in air, there is too much gas in the air and not enough oxygen for it to burn.

### **Is LNG explosive?**

As a liquid, LNG is not explosive. LNG vapor will only explode if in an enclosed space. LNG vapor is only explosive if within the flammable range of 5%-15% when mixed with air.

### **What is a Rapid Phase Transition?**

When enough LNG is spilled on water at a very fast rate, a Rapid Phase Transition, or RPT, occurs. Heat is transferred from the water to the LNG, causing the LNG to instantly convert from its liquid phase to its gaseous phase. A large amount of energy is released during this rapid transition between phases and a physical explosion can occur. While there is no combustion, this physical explosion can be hazardous to any nearby person or buildings.



Photo courtesy of CH-IV International  
<http://www.ch-iv.com>

### **What about security?**

All LNG ships must comply with all pertinent local and international regulatory requirements, which include regulations and codes set forth by the International Maritime Organization (IMO), the U.S. Maritime Administration (MARAD), the U.S.

Coast Guard (USCG), and the U.S. Department of Transportation (DOT), as well as the hosting Port Authority.

DOT regulations must be followed at onshore LNG facilities and marine terminals. The Research and Special Programs Administration, DOT, regulations include 49 CFR Part 193 - Liquefied Natural Gas Facilities: Federal Safety Standards. These standards specify siting, design, construction, equipment, and fire protection requirements that apply to new LNG facilities and to existing facilities that have been replaced, relocated, or significantly altered.

Offshore marine terminals must follow regulations set by the USCG. The USCG monitors the safety of coastal waters around the U.S. and ensures the safety of ships while in U.S. waters and in port by preventing other ships from getting near LNG tankers. The USCG works with local harbor authorities and LNG facility personnel to ensure that proper procedures are followed. The USCG and MARAD are the federal agencies responsible for siting off-shore LNG facilities and are currently developing regulations.

### **What is a "peak-shaving" facility?**

LNG peak-shaving facilities are used for storing surplus natural gas that is to be used to meet the requirements of peak consumption later during winter or summer. Each peak-shaving facility has a regasification unit attached but may or may not have a liquefaction unit. These facilities without a liquefaction unit depend upon tank trucks to bring LNG from other nearby sources to them. Of the approximate 113 active LNG facilities in the United States, 57 are peak-shaving facilities. The other LNG facilities include marine terminals, storage facilities, and operations involved in niche markets such as LNG vehicular fuel. (Source: University of Houston IELE, *Introduction to LNG*.) Please see map of U.S. facilities.

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Liquefied natural gas (LNG) is the liquid form of the same natural gas millions of people use in their homes for heating, cooking and for generating electricity from gas-fired power stations. Natural gas is primarily methane, nature's simplest and most abundant hydrocarbon fuel.



## Environmental Benefits of LNG

Growing gas demand around the world is being driven by the need for cleaner burning fuels. Consumers expect cheaper, more efficient and environmentally friendly sources of energy, which LNG provides. BP is an industry leader in global environmental stewardship, and this commitment is demonstrated through BP's focus on natural gas and LNG.

## LNG General Facts

- Colorless, odorless and non-toxic
- Less than half the density of water
- Liquefies at -256° F (-160° C)
- LNG has first class safety record since commercial shipments began in 1964
- No contaminants
- Transported and handled similar to other liquid gases such as oxygen and nitrogen

## Why liquify gas?

Natural gas can be moved using pipelines, but over long distances it becomes more economic to move it by ship. In order to ship natural gas, it must first be liquefied because as a gas it occupies a considerable amount of space at atmospheric pressure. The liquefaction process shrinks natural gas to 600 times its original volume.



About half of the world's remaining hydrocarbon resources are in the form of natural gas. These are often located in areas of lower gas demand, however, by liquefying the gas it can be safely transported by ship to where it is needed, just like crude oil.

## Natural Gas Facts

- World natural gas consumption is rising
- In 2002, the United States consumed over 22 trillion cubic feet (Tcf) of natural gas - more than any other country and a quarter of the world's production
- The global natural gas and power economy is nearly twice the size of the global oil economy
- U.S. domestic production is not keeping up with growth in demand. In 2010, demand will outstrip supply by 3 Tcf
- World gas demand is expected to double by 2010
- The country needs to supplement more of its natural gas supplies from other parts of the world

## History of LNG

Natural gas liquefaction dates back to the 19th century.



### The History

- The first LNG plant built in West Virginia in 1912. It began operation in 1917
- The first commercial liquefaction plant was built in Cleveland, Ohio, in 1941
- In 1959, the world's first LNG cargo transported from Lake Charles, Louisiana to United Kingdom
- Subsequently liquefaction plants and import terminals constructed in both the Atlantic and Pacific regions
- Four marine receiving terminals were built in the United States between 1971-1980 -Lake Charles Louisiana, Everett, Massachusetts, Elba Island Georgia and Cove Point, Maryland
- After a natural gas surplus developed in North America Elba Island and Cove Point receiving terminals were mothballed in 1980
- First exports of LNG from U.S. to Asia in 1969 when Alaskan LNG sent to Japan
- The LNG market in both Europe and Asia continued to grow rapidly from that point on
- In 1999, first Atlantic Basin LNG liquefaction plant in the western hemisphere began production in Trinidad

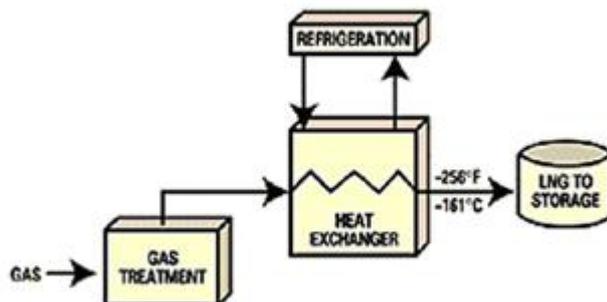
- Growing demand for natural gas in the U.S., particularly for power generation, results in renewed interest in LNG in US
- The two mothballed LNG receiving terminals are reactivated - Elba Island, 2001; Cove Point 2003

## How is Natural Gas Liquefied?

When natural gas is extracted from underground reservoirs, it often contains other materials and components, such as those listed below, that must be removed before the gas can be liquefied and used by the consumer.



- Sulfur, carbon dioxide and mercury, which are corrosive to equipment
- Water, which would naturally freeze and cause equipment blockage if not removed as the gas is cooled
- Heavier hydrocarbons and carbon dioxide which can freeze (like water) and cause equipment blockage and gas ignition problems



## Natural Gas Liquefaction Process

### Cooling Process

To convert the natural gas to a liquid, it is cooled to the temperature at which the main component, methane, will form a liquid (approximately  $-256^{\circ}\text{F}$  or  $-160^{\circ}\text{C}$ ). The liquefaction process works much like a typical refrigerator: cold liquid refrigerants such as propane and ethylene are reduced in pressure and evaporated as heat is exchanged with the natural gas steam. As this happens, it cools the natural gas to

the point where it turns into a liquid. Once the gas has been liquefied, it is sent to storage to await shipping.



## The Global Liquefied Natural Gas Market: Status and Outlook

Report #: DOE/EIA-0637  
Release Date: December 2003  
Next Release Date: One-time

### LNG Exporters

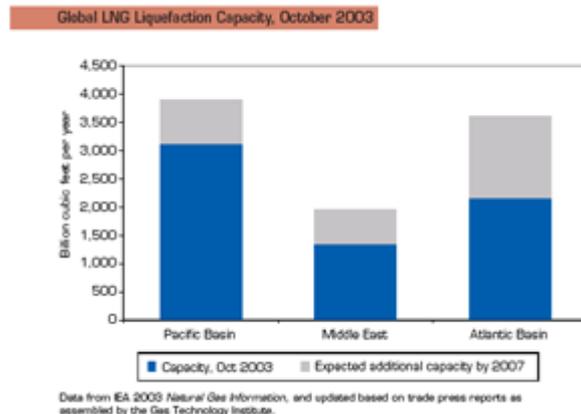
- In 2002, 12 countries exported 5.4 Tcf (113 million tons) of natural gas as LNG, up from 9 countries and almost 4 Tcf (84 million tons) in 1997.

- Indonesia is the world's largest LNG producer, exporting about one-fifth of the world's total volume in 2002.

- The Pacific Basin<sup>4</sup> is the largest LNG-producing region in the world, supplying nearly half (49%) of all global exports in 2002. Indonesia alone

supplied 21 percent. Countries in the Middle East, led by Qatar, exported 23 percent, while countries in the Atlantic Basin, led by Algeria, exported about 29 percent that year.

- In the first nine months of 2003, two new LNG trains began operating in Trinidad and Tobago and in Malaysia, increasing world annual liquefaction capacity<sup>5</sup> by around 6 percent to 6.6 Tcf (135 million tons).
- New projects under construction in Australia, Russia, Norway, and Egypt, together with expansions of existing facilities throughout the world, will increase annual liquefaction capacity by 2.8 Tcf (58 million tons) by 2007, increasing global capacity to 9.4 Tcf (197 million tons) per year, which represents 10 percent of 2002 global natural gas consumption.
- Potential new exporters such as Iran, Yemen, Equatorial Guinea, Angola, Venezuela, Bolivia (via Peru or Chile), and Peru are looking to LNG exports as a way of monetizing their natural gas resources.



## Pacific Basin Exporters

Pacific Basin LNG exporters produced 2.6 Tcf (55 million tons) in 2002, about 49 percent of total world LNG production. As of late 2003, five Pacific Basin exporters had 3.1 Tcf (63 million tons) of annual liquefaction capacity. Liquefaction capacity in the Pacific Basin is expected to increase by 780 billion cubic feet (Bcf) or 16 million tons of annual capacity over the next few years to more than 3.8 Tcf (80 million tons) per year by 2007.

- **Indonesia** is the world's largest LNG producer and exporter. In 2002, Indonesia exported 1.1 Tcf (23 million tons) of LNG or 21 percent of the world's total LNG exports. Most of Indonesia's LNG is imported by Japan with smaller volumes going to Taiwan and South Korea. Indonesia's annual liquefaction capacity is 1.4 Tcf (30 million tons) from the two exporting complexes at Bontang and Arun. An additional train at Bontang is under consideration but has yet to contract for the capacity. BP is leading development of a two-train, 341-Bcf-per-year (7.0-million-tpy) project at Tangguh scheduled to start up in 2007. The Tangguh LNG is destined for China, other Asian markets, and potentially the United States.
- **Malaysia**, the world's third largest LNG exporter after Indonesia and Algeria, exported 741 Bcf (15.6 million tons) in 2002. These exports went primarily to Japan, with smaller volumes to Taiwan and South Korea. Three liquefaction terminals have been developed at the Bintulu LNG complex in Sarawak, Malaysia Satu, Dua, and Malaysia Tiga, the first train of which went on-stream in mid-2003. A second train will come online in November 2003, raising the total capacity of the Bintulu complex to an annual 1.1 Tcf (22.7 million tons).
- **Australia** exported 367 Bcf (7.7 million tons) of LNG from the Northwest Shelf project in 2002, primarily to Japanese utilities. The project owners have started construction on an additional 205-Bcf-per-year (4.2-million-tpy) train scheduled to come online in 2004. An additional train is under consideration. Three new projects are also in various stages of development. ConocoPhillips has begun construction on a 175-Bcf-per-year (3.6-million-tpy) Darwin LNG project, to monetize reserves in the Timor Sea shared by Australia and East Timor. ConocoPhillips is also working with Shell, Osaka Gas, and Woodside Petroleum to develop the 258-Bcf-per-year (5.3-million-tpy) Greater Sunrise project via a floating LNG facility. ChevronTexaco, in partnership with ExxonMobil and Shell, is spearheading a two-train Gorgon project with an annual capacity of 487 Bcf (10.0 million tons) to monetize reserves discovered offshore Northwest Australia.
- **Brunei Darussalam** has a two-train liquefaction terminal at Lumut with an

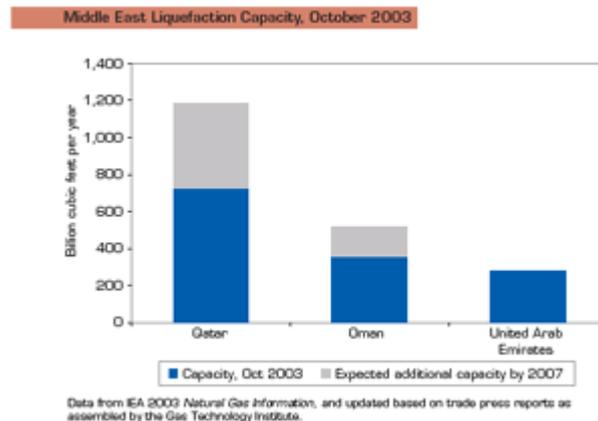


annual capacity of 351 Bcf (7.2 million tons). About 90 percent of its output goes to customers in Japan and the remaining 10 percent to South Korea.

- The **United States** has a 68-Bcf-per-year (1.4-million-tpy) liquefaction terminal at Kenai, Alaska, that has been exporting LNG to Japan for more than 30 years. There are currently no plans to expand this facility.
- **Russia's** first LNG plant is under construction on Sakhalin Island off Russia's east coast. The two-train facility will have an annual capacity of 466 Bcf (9.6 million tons), with exports of 234 Bcf (4.8 million tons) per year from the first train scheduled to begin in 2007. The partners have already secured sales contracts with three Japanese utilities for 136 Bcf (2.8 million tons) per year over 20 years. There are reports that Russian officials have also expressed interest in exporting LNG from the giant Shtokman field in the Barents Sea to the United States and elsewhere.

## Middle East Exporters

Exporters from the Middle East produced 1.2 Tcf (25 million tons) in 2002, about 23 percent of total world LNG production. As of late 2003, the three Middle Eastern exporters had 1.4 Tcf (29 million tons) of annual capacity. Expansions to facilities in Qatar and Oman will add 619 Bcf (13 million tons) of annual liquefaction capacity, increasing Middle East capacity to 2.0 Tcf (42 million tons) per year by 2007.

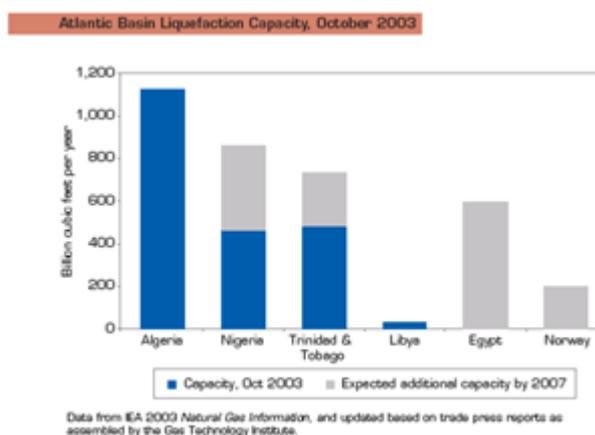


- **Qatar** ranks fourth in world LNG exports and has an annual capacity of 726 Bcf (14.9 million tons) from two liquefaction plants owned by the Qatargas and Ras Laffan LNG (RasGas) consortia. The Qatargas plant is being debottlenecked, and two more trains are being added to the RasGas facility, which would add 458 Bcf (9.4 million tons) of annual capacity by 2005. Most of Qatar's exports go to customers in Japan and South Korea, but short-term cargoes have also been shipped to the United States and Europe. Its enormous natural gas reserves and low upstream production costs give Qatar the potential to significantly expand its LNG exports to a targeted annual capacity of 2.9 Tcf (60 million tons) by 2015.
- **Oman** has one LNG export terminal, which began operation in 2000 with two liquefaction trains and an annual capacity of 356 Bcf (7.3 million tons). Most of the LNG is sold to South Korea's Kogas. Smaller volumes are shipped to customers in Japan, the United States, and Europe. A planned third train would add 161 Bcf (3.3 million tons) per year in 2006. Further expansion potential for LNG exports from Oman is limited by the modest size of the country's reserves.
- The **United Arab Emirates (UAE)** has the world's fifth largest natural gas reserves and ranks ninth in LNG exports. Abu Dhabi Gas Liquefaction Co.

operates the nation's only export facility with a capacity of 278 Bcf (5.7 million tons). Roughly 90 percent of UAE LNG production is exported to Japan. Despite its large reserves, the UAE is unlikely to expand its production of LNG since it uses much of the gas for domestic purposes.

## Atlantic Basin Exporters

Atlantic Basin exporters produced 1.5 Tcf (32 million tons) in 2002, about 29 percent of total world LNG production. As of late 2003, Atlantic Basin LNG producers had 2.1 Tcf (43 million tons) of annual capacity. Expansions in Nigeria and Trinidad and Tobago, as well as new facilities in Egypt and Norway, would increase annual Atlantic Basin liquefaction capacity to 3.3 Tcf (73 million tons) by 2007.



- **Algeria** was the second largest LNG exporter in 2002, shipping 935 Bcf (19.6 million tons) mainly to Europe (France, Belgium, Spain, and Turkey) and the United States. A major renovation in 1999 raised the country's LNG production capacity to more than 1.1 Tcf (23.1 million tons) per year. Algeria also exports more than 1.0 Tcf of natural gas per year to Europe by pipeline. The Algerian State-owned oil and gas company Sonatrach owns and operates four liquefaction complexes, the first of which started up in 1964, making Algeria the world's first LNG exporter. Algeria has no new liquefaction capacity planned before 2008 but in the long term is planning to add another train.
- **Nigeria** exported 394 Bcf (8.2 million tons) of LNG in 2002, mainly to Turkey, Italy, France, Portugal, and Spain. Nigeria has also delivered more than 20 cargoes under short-term contracts to the United States over the past three years. The total annual capacity of Nigeria's Bonny Island LNG plant is 463 Bcf (9.5 million tons), and Nigeria LNG has begun construction of two additional 200-Bcf-per-year (4.1-million-tpy) trains that are scheduled to begin operation in 2005. Additional trains are under discussion as are three new projects that have been considered in the West Niger Delta (by ExxonMobil, ChevronTexaco, and ConocoPhillips), Brass River (by the Italian company ENI and ConocoPhillips), and a floating offshore project (by Statoil and Total).
- **Trinidad and Tobago** exported 189 Bcf (4.0 million tons) of LNG in 2002. Trinidad and Tobago's LNG facility at Point Fortin has three trains and an annual capacity of 482 Bcf (9.9 million tons). In June 2003, the Government of Trinidad and Tobago approved the construction of a fourth train that could produce an additional 253 Bcf (5.2 million tons) per year. Trinidad and Tobago exports LNG to the continental United States, Puerto Rico, Spain, and the Dominican Republic.

- **Libya** exported 21 Bcf (0.4 million tons) of LNG in 2002. The plant at Marsa El Brega has an annual capacity of about 131 Bcf (2.7 million tons). Only about 25 percent of the total capacity, or 29 Bcf (0.6 million tons) per year, is available for export due to maintenance issues.
- Two LNG export projects are being built in **Egypt**: a one-train liquefaction facility at Damietta, which will start operations in 2004 with an annual capacity of 244 Bcf (5.0 million tons), and a two-train project at Idku with a 2005 startup date and a projected annual capacity of 175 Bcf (3.6 million tons). All of the Idku LNG is contracted to Gaz de France. Commitment to a second 175-Bcf-per-year (3.6-million-tpy) train was announced in September 2003. British Gas (BG) has agreed to buy the entire output for U.S. and Italian markets.
- Beginning in 2006, **Norway** plans to export LNG from a 200-Bcf-per-year (4.1-million-tpy) liquefaction terminal now being built on Melkøye Island in the Norwegian Sea. Exports are targeting markets in Spain, France, and the United States.

### Potential New LNG Exporters

At least seven additional countries are exploring their potential as LNG exporters.

#### Pacific Basin

- A project is proposed for exporting natural gas from **Peru's** Camisea field to a terminal in Mexico.
- Several European and U.S. companies are proposing a project to pipe gas from Bolivia to either Peru or Chile on the Pacific Coast where it could be liquefied and shipped to a terminal on the West Coast of North America.

#### Middle East

- With the world's second largest proved gas reserves, **Iran** has great potential to export gas to markets in Europe, Asia, and India by pipeline and as LNG. The Iranian government is considering at least four projects, each of 390 to 490 Bcf (8 to 10 million tons) per year, to process reserves in the South Pars-North field in partnership with companies in Europe and Asia.
- An LNG project has been proposed in **Yemen** for more than a decade but to date has not made significant progress.

#### Atlantic Basin

- In **Venezuela**, an LNG project has been discussed since the early 1970s. Shell and Mitsubishi have signed preliminary agreements to develop a 229-Bcf-per-year (4.7-million-tpy) project called Marisal Sucre based on offshore reserves. Discussions have been held with neighboring Trinidad and Tobago to bring Venezuelan gas to their Atlantic LNG plant for processing until a Venezuelan LNG plant can be built.

- In **Angola**, ChevronTexaco, ExxonMobil, BP, Total, and Sonangol are proposing to build a plant based on offshore associated gas for export to North American and European markets. The plant would initially have a single 195-Bcf-per-year (4.0-million-tpy) train with the option for development of additional trains later.
  - **Equatorial Guinea** is looking to export LNG from its offshore Alba field. In May 2003, U.S.-based firm Marathon Oil signed a 17-year draft agreement to supply British Gas with 166 Bcf (3.4 million tons) per year of LNG to be delivered to the Lake Charles regasification facility in the United States. The project is currently undergoing advanced engineering feasibility studies, and a final investment decision is due in the first quarter of 2004.
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## Liquefied Natural Gas Worldwide

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Note to readers:

The information below uses formal western and eastern names of each country, when possible, in order to assist our readers around the world. For example, the United Arab Emirates is also known as Al Imarat al-Arabiyyah al-Muttahidah. Formal country names typically convey the political structure of each nation, and the political level (federal, state or provincial) decisions pertaining to implementing or managing energy infrastructure are occurring.

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Natural gas, in the form of liquefied natural gas or LNG, has the potential to be exported from countries with large, proven natural gas reserves and relatively high reserves-to-production ratios. Some countries meeting this criterion include the Republic of Peru, Republic of Venezuela, Azerbaijan Republic, Republic of Kazakhstan, Islamic Republic of Iran, Republic of Iraq, State of Kuwait, State of Qatar, United Arab Emirates (also known as Al Imarat al-Arabiyyah al-Muttahidah), Republic of Yemen, Federal Republic of Nigeria, and Independent State of Papua New Guinea.

However, not all of these countries are exporters of natural gas as LNG due to domestic need, inaccessibility to international natural gas trade and infrastructure, geopolitics, and lack of capital or technological investment. As largely populated countries such as the People's Republic of China and the Republic of India enter the international LNG market, the need to overcome these particular barriers, in

addition to further exploration and discovery of accessible, proven natural gas reserves, is evident.

As traditional, economically viable oil and gas fields deplete, exploration and discovery have reached out to the furthest ends of the earth. The Arctic Ocean, long regarded as international territory, has experienced a recent rush for claims by not only Russia, but Denmark (via territory Greenland), Norway, the United States and Canada. In addition to oil and natural gas, the Arctic holds valuable mineral deposits, and non-mineral resources, such as fish and trade routes through the North East and West Passages.

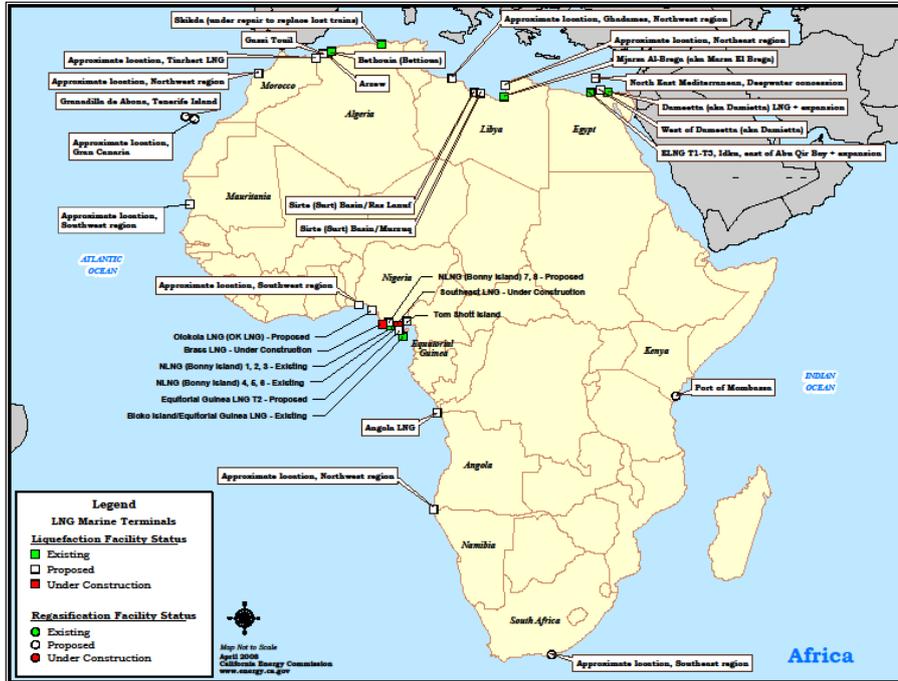
The Antarctic landmass, traditionally used for research, has also seen a recent surge of land and maritime claims, most recently by the United Kingdom. Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom all claim portions of the great landmass, although the United States does not recognize any of these claims. Along with Russia, the United States has reserved the right to make claims in the future on the southern most continent.

Ongoing territorial disputes over hydrocarbon rich land and maritime regions have occurred in several areas of the world, including:

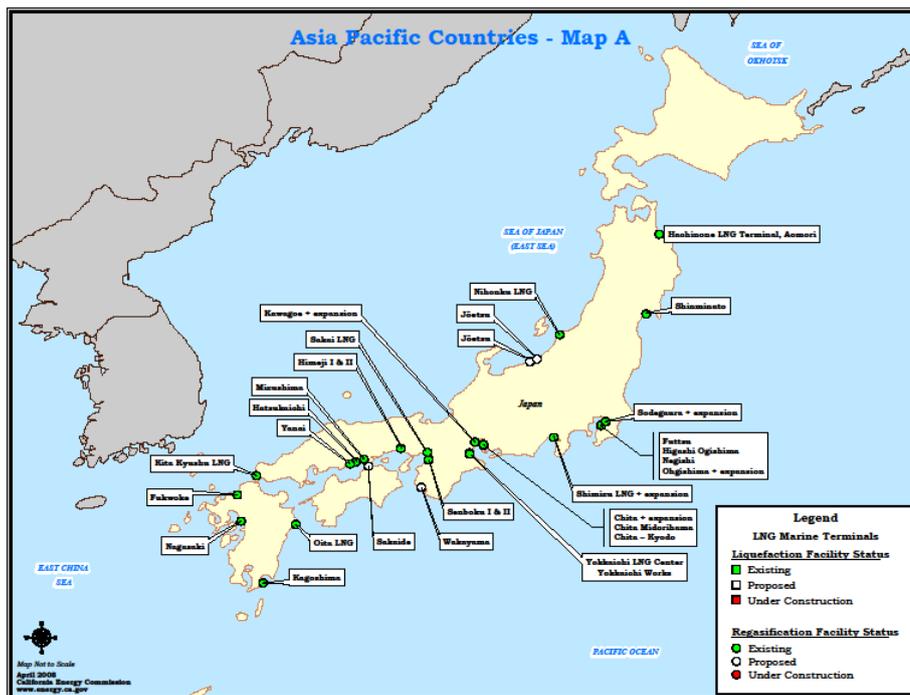
- Senkaku Islands (or Diaoyutai Islands), located in the East China Sea, (Japan, the People's Republic of China and Taiwan);
- Western Sahara, a northwestern African country (Morocco and Western Sahara);
- Rockall, an islet located in the North Atlantic (United Kingdom, Denmark (representing the Faroe Islands), the Republic of Ireland and Iceland);
- San Andres and Providencia island region, in the Caribbean Sea (Columbia, Nicaragua);
- the Atacama Corridor for maritime access for Bolivian natural gas (Bolivia, Chile);
- and the Beaufort Sea (Canada, United States).

# Maps of LNG Facilities Worldwide

- Africa



- Asia Pacific (includes Japan, China, India, Malaysia, Philippines, South Korea)





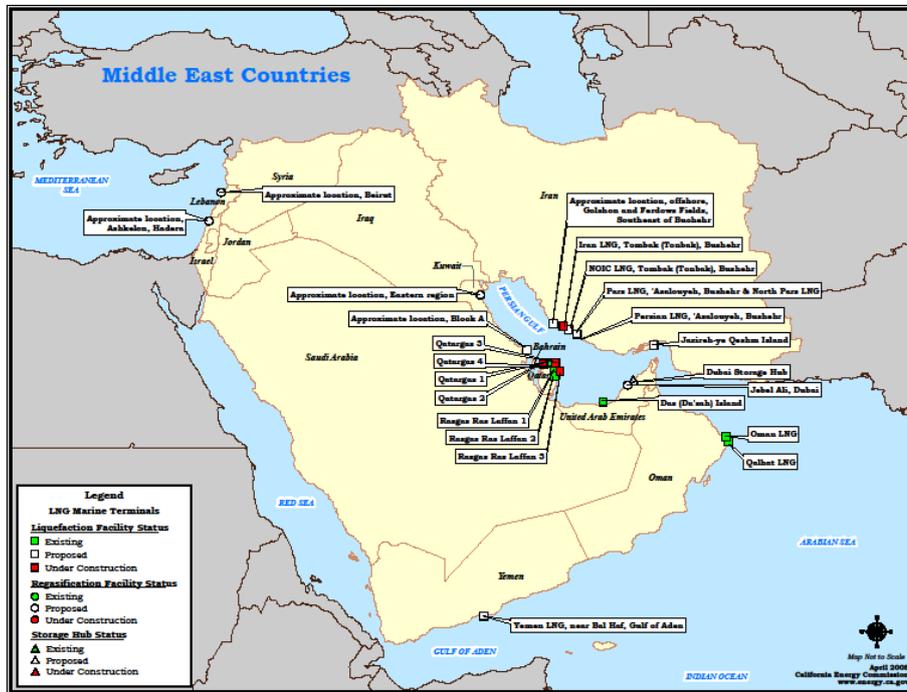
- Canada



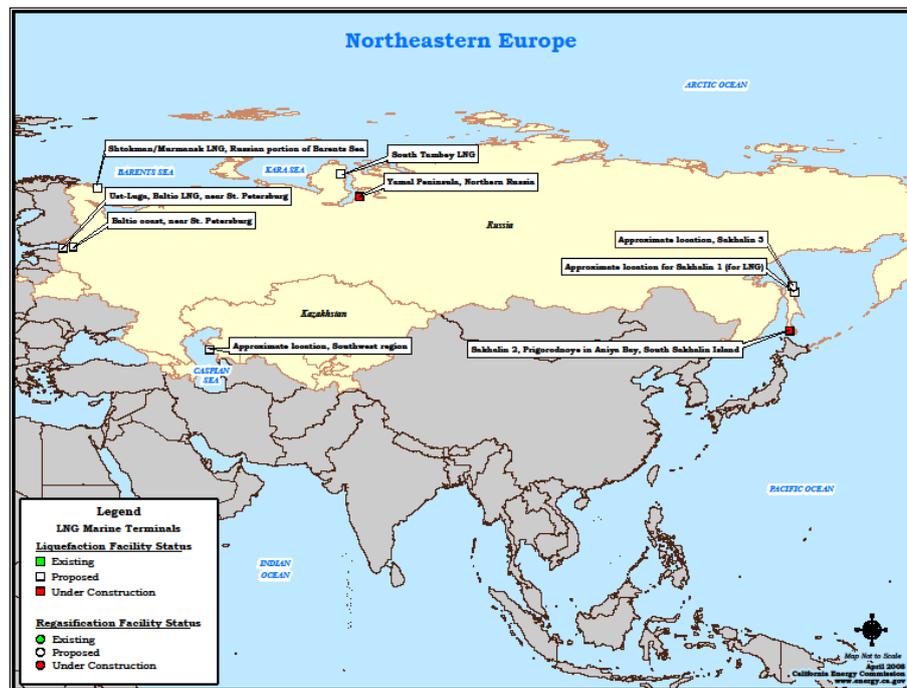
- Mexico



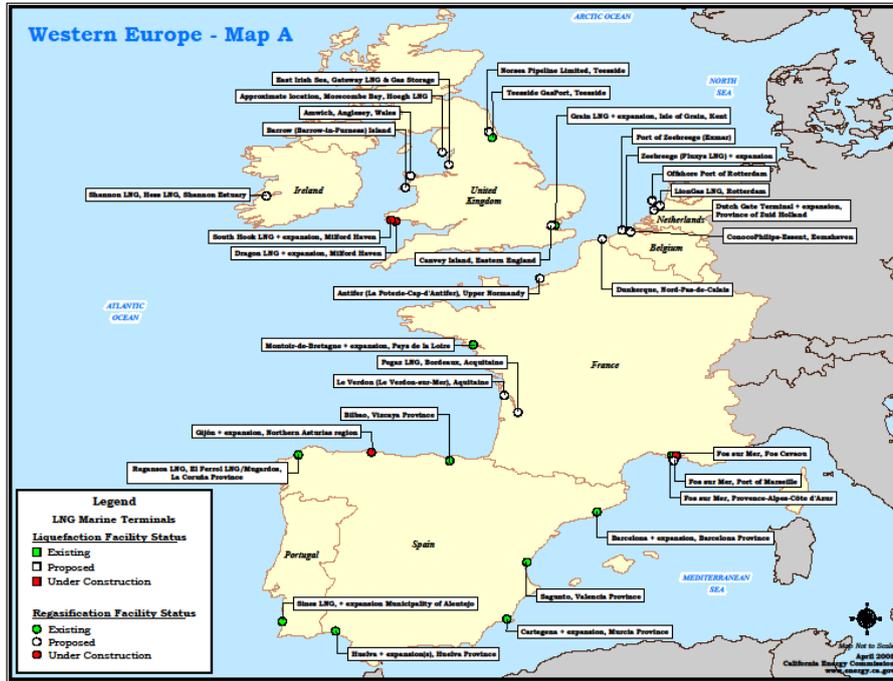
- Middle East



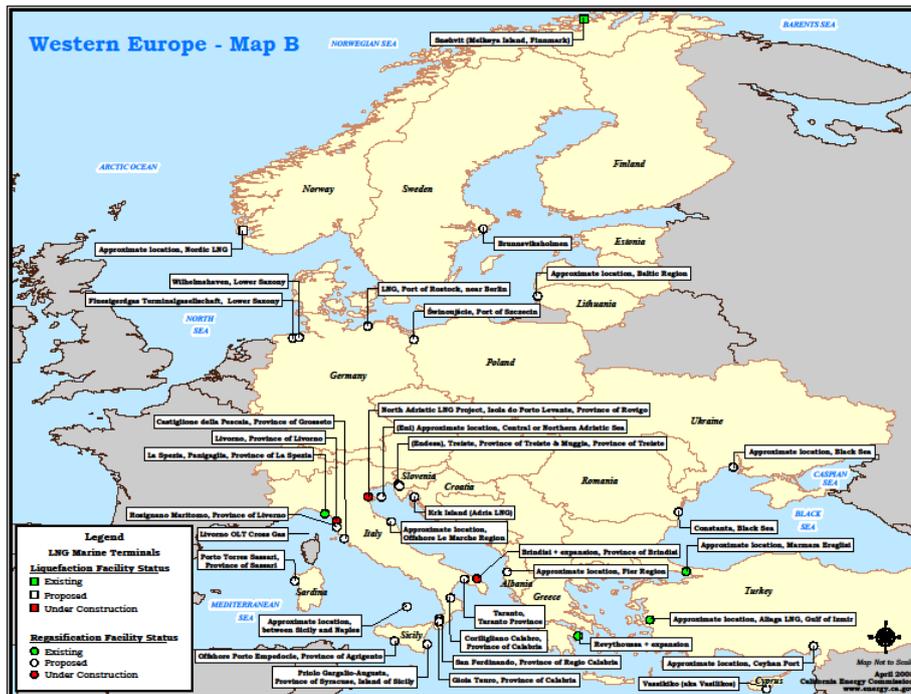
- Europe – North East (includes Russia)



- Europe - West



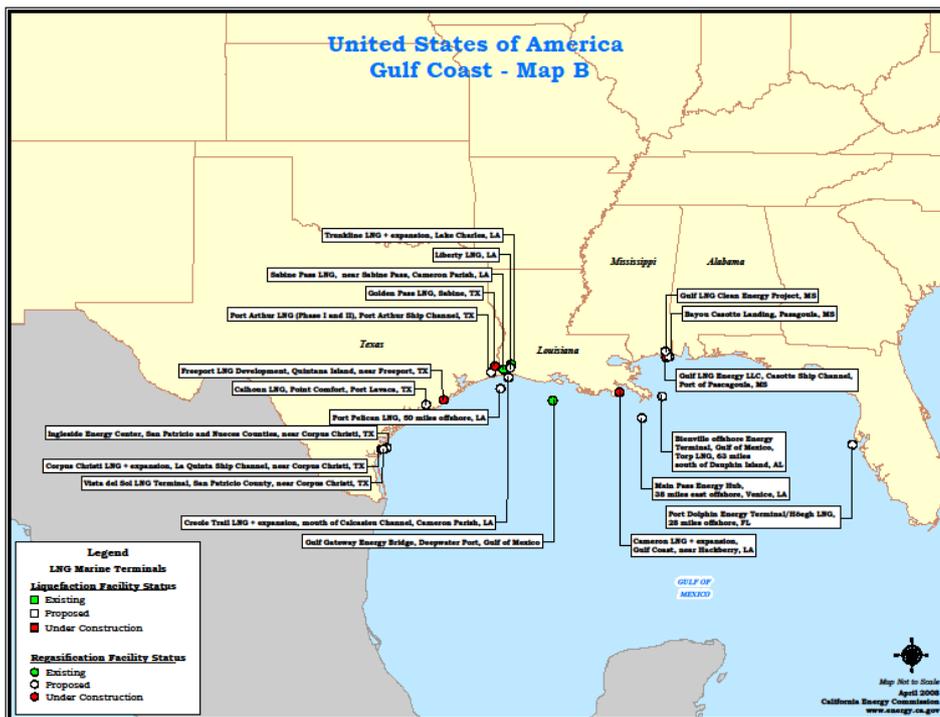
- Europe - Central



- United States – East Coast



- United States – Gulf Coast



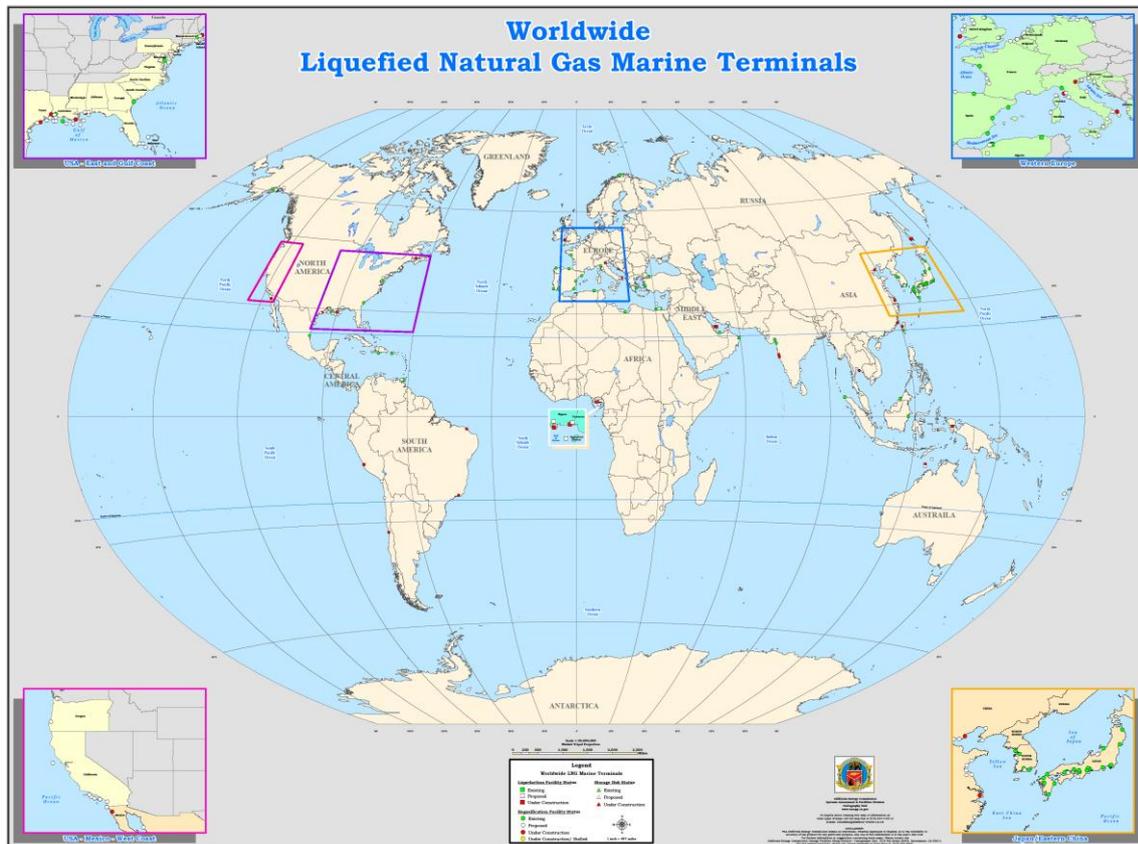
- United States – West Coast



- Caribbean, South and Central America



- Worldwide LNG Facilities



## What Countries Export LNG? What Countries Import LNG?

Worldwide, there are 26 existing export, or liquefaction, marine terminals, located on or off shore, in 15 countries. In contrast, there are 60 existing import, or regasification, marine terminals, on or off shore, spread across 18 different countries. In addition to these existing terminals, there are approximately 65 liquefaction marine terminal projects and approximately 181 regasification terminal projects that have been either proposed or are under construction all around the world. It is not expected that all of the proposed terminals will be constructed.

## Countries that Export LNG

(start up date of earliest liquefaction terminal is in parentheses)

- Algeria, Republic of (1971)
- Australia, Commonwealth of (1989)

Brunei (Darussalam), State of (1972)  
Equatorial Guinea, Republic of (2007)  
Egypt, Arab Republic of (2004)  
Indonesia, Republic of (1977)  
Libya (also known as the Socialist People's Libyan Arab Jamahiriya) (1970)  
Malaysia (also known as Persekutuan Tanah Malaysia) (1983)  
Nigeria, Federal Republic of (1999)  
Norway, Kingdom of (2007)  
Oman, Sultanate of (also known as Saltanat Uman) (2000)  
Qatar, State of (also known as Dawlat Qatar) (1997)  
Trinidad and Tobago, Republic of (1999)  
United Arab Emirates (also known as Al Imarat al-Arabiyah Al-Muttahidah) (1977)  
United States of America (1969)

## **Countries that Import LNG**

(start up date of earliest regasification terminal is in parentheses)

Belgium, Kingdom of (1987)  
China, People's Republic of (2006)  
Dominican Republic (2003)  
France (also known as the French Republic) (1972)  
Greece (also known as the Hellenic Republic) (2000)  
India, Republic of (2004)  
Italy (also known as the Italian Republic) (1971)  
Japan (also known as Nihon, Nippon, Nihon Koku) (1969)  
Mexico (also known as the United Mexican States) (2006)  
Portugal (also known as the Portuguese Republic) (2003)  
Puerto Rico, Commonwealth of (U.S. Outlying Territory) (2000)  
South Korea, Republic of (1986)  
Spain, Kingdom of (1969)  
Taiwan (Republic of China) (1990)  
Turkey, Republic of (1992)  
United Kingdom (2005)  
United States of America (1971)

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# Liquefied Natural Gas Safety

LNG is natural gas that has been refrigerated into a cryogenic liquid so that it can be shipped long distances in carriers. Once an LNG carrier reaches a receiving terminal, the LNG is unloaded and stored in large tanks until it is revaporized and piped into the natural gas distribution network. LNG is a hazardous liquid, because it is cryogenic and, as natural gas, it is combustible.

LNG hazards result from three of its properties: cryogenic temperatures, dispersion characteristics, and flammability characteristics. The extremely cold LNG can directly cause injury or damage. A vapor cloud, formed by an LNG spill, could drift downwind into populated areas. It can ignite if the concentration of natural gas is between five and 15 percent in air and it encounters an ignition source. An LNG fire gives off a tremendous amount of heat.

A large array of laws, regulations, standards, and guidelines are currently in place to prevent and lessen the consequences of LNG releases. These requirements affect LNG facilities' design, construction, operation, and maintenance.

To address terrorist risk, the Ship and Port Facility Security Code was adopted in 2003 by the member countries of the International Maritime Organization (IMO), an agency of the United Nations responsible for maritime matters concerning ship safety. This code requires both ships and ports to conduct vulnerability assessments and to develop security plans. To heighten security of LNG facilities at American seaports, Congress passed the U.S. Maritime Transportation Security Act of 2002, which requires all ports to have federally-approved security plans. Detailed security assessments of LNG facilities and vessels are also required.

The Department of Transportation (DOT), Research and Special Programs Administration, issues and enforces federal safety standards for land-based LNG facilities, although the Federal Energy Regulatory Commission (FERC) can impose more stringent safety requirements than DOT's when warranted. The U.S. Coast Guard (USCG) issues and enforces regulations for waterfront facilities handling LNG.

All of these federal agencies oversee all land and sea-based LNG operations, with some overlapping authorities and some new responsibilities. The recent reactivation of LNG facilities on the East Coast and in the Gulf Coast and permitting of new facilities, have resulted in new methodologies (risk-based decision making) and processes (security workshops, scoping meetings) to assess and communicate safety risk to the public.

## Accidents

### Explosions and Fires

- **October 1944, Cleveland, Ohio** - At the Cleveland peak-shaving plant a tank failed and spilled its contents into the street and storm sewer system. The resulting explosion and fire killed 128 people. The tank was built with a steel alloy that had low-nickel content, which made the alloy brittle when exposed to the extreme cold of LNG.

- **1964 and 1965 Methane Progress.**- While loading LNG in Arzew, Algeria, lightning struck the forward vent riser of the Methane Progress and ignited vapor which was being routinely vented through the ship venting system. A similar event happened early in 1965 while the vessel was at sea shortly after leaving Arzew. In both cases, the flame was quickly extinguished by purging with nitrogen through a connection to the riser.
- **1969, Portland, Oregon** - An explosion occurred in an LNG tank under construction. No LNG had ever been introduced into the tank. The cause of the accident was attributed to the accidental removal of blinds from natural gas pipelines which were connected to the tank. This led to the flow of natural gas into the tank while it was being constructed.
- **January 1972, Montreal East, Quebec, Canada** - A back flow of natural gas from the compressor to the nitrogen line occurred during defrosting operations at an LNG liquefaction and peak shaving plant. The valves on the nitrogen were not closed after completing the operation. This caused over-pressurization of the compressor and the natural gas entered the control room (where operators were allowed to smoke) through the nitrogen header. An explosion occurred when an operator tried to light a cigarette.
- **February 1973, Staten Island, New York**- While repairing the interior of an empty storage tank, a fire started. The resulting increase in pressure inside the tank was so fast that the concrete dome on the tank lifted and then collapsed down inside the tank killing the 37 construction workers inside.
- **October 1979, Cove Point, Maryland** - A natural gas leak caused an explosion killing one plant employee and seriously injuring another and causing about \$3 million in damages.
- **April 1983, Bontang, Indonesia** - A rupture in an LNG plant occurred as a result of overpressurization of the heat exchanger caused by a closed valve on a blowdown line. The exchanger was designed to operate at 25.5 psig. When the gas pressure reached 500 psig, the exchanger failed and the explosion occurred.
- **August 1987, Nevada Test Site, Mercury, Nevada** - An accidental ignition of an LNG vapor cloud occurred at the U.S. Department of Energy Test Site during large-scale tests involving spills of LNG. The cloud was accidentally ignited and damaged and propelled polyurethane pipe insulation outside the fence.
- **June 2004, Trinidad, Tobago** - Workers were evacuated after a gas turbine at Atlantic LNG's Train 3 facility exploded.
- **July 2004, Ghislenghien, Belgium** - A pipeline carrying natural gas from the Belgian port of Zeebrugge to northern France exploded, resulting in 23 known fatalities. The cause of the incident is still under investigation but it appears that a contractor accidentally damaged the pipe.
- **March 2005, District Heights, Maryland** - A Washington Gas company-sponsored study released in July 2005 pointed to subtle molecular differences in the imported liquefied natural gas the utility began using in August 2003 as the cause of a house explosion.

## Spills and Leaks

- **Early 1965, Methane Princess Spill** - LNG discharging arms were disconnected prematurely before the lines had been completely drained, causing LNG liquid to pass through a partially opened valve and onto a stainless steel drip pan placed

underneath the arms. This caused a star-shaped fracture to appear in the deck plating in spite of the application of seawater.

- **May 1965, Jules Verne Spill** - LNG liquid spill at Arzew, Algeria, caused by overflowing of a cargo tank that resulted in the fracture of the cover plating of the tank and adjacent deck plating.
- **1971, La Spezia, Italy** - This accident was caused by "rollover" where two layers of LNG with different densities and heat content form. The sudden mixing of these two layers results in the release of large volumes of vapor. In this case, about 2,000 tons of LNG vapor discharged from the tank safety valves and vents over a period of a few hours, damaging the roof of the tank.
- **July 1974, Massachusetts Barge Spill** - After a power failure and the automatic closure of the main liquid line valves, 40 gallons of LNG leaked as it was being loaded on a barge. The LNG leaked from a one-inch nitrogen-purge globe valve on the vessel's liquid header. This leak caused several fractures to the deck plates.
- **September 1977, Aquarius Spill** - During the filling of a cargo tank at Bontang, LNG overflowed through the vent mast serving that tank. The incident may have been caused by difficulties in the liquid level gauge system. The high-level alarm had been placed in the override mode to eliminate nuisance alarms.
- **March 1978, Das Island, United Arab Emirates** - An accident occurred due to the failure of a bottom pipe connection of an LNG tank. The tank had a double wall (a nine-percent nickel steel inner wall and a carbon steel outer wall). Vapor from the outer shell of the tank formed a large heavier-than-air cloud which did not ignite.
- **April 1979, Mostafa Ben Bouliad Spill** - While discharging cargo at Cove Point, Maryland, a check valve in the piping system of the vessel failed releasing a small quantity of LNG. This resulted in minor fractures of the deck plating.
- **April 1979, Pollenger Spill** - While the vessel was discharging LNG at a terminal in Everett, Massachusetts, LNG leaking from a valve gland apparently fractured one of the tank's cover plating.

## Safety Studies

- [Breach and Safety Analysis of Spills Over Water from Large Liquefied Natural Gas Carriers](#), prepared by Sandia National Laboratories, SAND2008-3153, May 2008. (PDF file, 34 pages, 386 KB)
- [International and National Efforts to Address the Safety And Security Risks of Importing Liquefied Natural Gas: A Compendium](#), prepared for the California Energy Commission by Aspen Environmental Group, January 2005. (Acrobat PDF file, 84 pages, 588 kilobytes).
- [Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas \(LNG\) Spill Over Water](#), prepared by Sandia National Laboratories, SAND2004-6258, December 2004. (PDF file, 167 pages, **1.7 megabytes - note file size**)
- ["Consequences of LNG Marine Incidents"](#), R M Pitblado, J Baik, G J Hughes, C Ferro, S J Shaw, Det Norske Veritas (USA) Inc. Presented at a conference held by the Center for Chemical Process Safety (CCPS) in Orlando, Florida June, 2004. (Acrobat PDF file, 20 pgs, 948 kb)
- [Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers](#); prepared by ABSG Consulting Inc. for the Federal Energy Regulatory

Commission under contract number FERC04C40196; May 13, 2004. (PDF file, 128 pages, 811 kilobytes).

- ["LNG Safety and Security."](#) Center for Energy Economics at the Bureau of Economic Geology, the University of Texas at Austin. October 2003. (PDF file, 81 pgs, **1 megabyte - note file size**)
  - ["Liquefied Natural Gas \(LNG\) Infrastructure Security: Background and Issues for Congress."](#) Congressional Research Service - Library of Congress. September 9, 2003. (Acrobat PDF file, 25 pgs, 228 kb)
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