# Liquefied natural gas

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(Redirected from LNG)

**Liquefied natural gas** or **LNG** is natural gas that has been converted to liquid form for ease of storage or transport.

The liquefaction process involves removal of certain components (such as dust, helium, or impurities that could cause difficulty downstream, e.g. water, and heavy hydrocarbons) and then condensed into a liquid at close to atmospheric pressure (Maximum Transport Pressure set around 25 kPa (3.6psi)) by cooling it to approximately -163 degrees Celsius. LNG is transported in specially designed cryogenic sea vessels or cryogenic road tankers; and stored in specially designed tanks. LNG is about 1/614th the volume of natural gas at standard temperature and pressure (STP), making it much more cost-efficient to transport over long distances where pipelines do not exist. Where moving natural gas by pipelines is not possible or economical, it can be transported by LNG vessels. The most common tank types are membrane (TGZ Mark III and GT96) and Moss Rosenberg (spheres) or Self-Supporting Prismatic Type.

## Contents



## Basic facts on LNG

LNG offers an energy density comparable to petrol and diesel fuels and produces less pollution, but its relatively high cost of production and the need to store it in expensive cryogenic tanks have prevented its widespread use in commercial applications. It can be used in natural gas vehicles, although these are more commonly designed to use compressed natural gas.

Conditions required to condense natural gas depend on its precise composition, the market that it will be sold to and the process being used, but typically involve temperatures between −120 and −170 degrees Celsius (pure methane liquefies at −161.6 °C) and pressures of between 101 and 6000 kPa (14.7 and 870 lbf/in² [approx 1-60 atm]). High pressure natural gas that is condensed is then reduced in pressure for storage and shipping.

The density of LNG is roughly 0.41 to 0.5 kg/L, depending on temperature, pressure and composition. In comparison water has a density of 1.0 kg/L.

LNG does not have a specific heat value as it is made from natural gas, which is a mixture of different gases. The heat value depends on the source of gas that is used and the process that is used to liquefy the gas. The higher heating value of LNG is estimated to be 24 MJ/L at −164 degrees Celsius. This corresponds to a lower heating value of 21 MJ/L.

The natural gas fed into the LNG plant will be treated to remove water, hydrogen sulfide, carbon dioxide and other components that will freeze (e.g., benzene) under the low temperatures needed for storage or be destructive to the liquefaction facility. Purified LNG typically contains more than 90% methane. It also contains small amounts of ethane, propane, butane and some heavier alkanes. The purification process can be designed to give almost 100% methane.

The most important infrastructure needed for LNG production and transportation is an LNG plant consisting of one or more **LNG train**s, each of which is an independent unit for gas liquefaction. The largest LNG train is the SEGAS Plant in Egypt with a capacity of 5 million ton per annum (mtpa). Exxon Mobil operating Qatargas stage 2, of which one train has a production ability of 5 mtpa. Other facilities needed are load-out terminals for loading the LNG onto vehicles, LNG vessels for transportation, and a receiving terminal at the destination for discharge and regasification, where the LNG is reheated and turned into gas. Regasification terminals are usually connected to a storage and pipeline distribution network to distribute natural gas to local distribution companies (LDCs) or Independent Power Plants (IPPs).

In 1964 the UK and France were the LNG buyers under the world's first LNG trade from Algeria, witnessing a new era of energy. As most LNG plants are located in "stranded" areas not served by pipelines, the costs of LNG treatment and transportation were so huge that development has been slow during the past half century. The construction of an LNG plant costs USD 1-3 billion, a receiving terminal costs USD 0.5-1 billion, and LNG vessels cost USD 0.2-0.3 billion. Compared with the crude oil, the natural gas market is small but mature. The commercial development of LNG is a style called value chain, which means LNG suppliers first confirm the downstream buyers and then sign 20-25 year contracts with strict terms and structures for gas pricing. Only when the customers were confirmed and the development of a greenfield project deemed economically feasible could the sponsors of an LNG project invest in their development and operation. Thus, the LNG business has been regarded as a game of the rich, where only players with strong financial and political resources could get involved. Major international oil companies (IOCs) such as BP, ExxonMobil, Royal Dutch Shell; and national oil companies (NOCs) such as Pertamina, Petronas are active players. Japan, South Korea and Taiwan import large sums of LNG due to their shortage of energy. In 2002 Japan imported 54 million tons of LNG, representing 48% of the LNG trade around the world that year. Also in 2002, South Korea imported 17.7 million tons and Taiwan 5.33 million tons. These three major buyers purchase approximately 70% of the world's LNG demand.

In recent years, as more players take part in investment, both in downstream and upstream, and new technologies are adopted, the prices for construction of LNG plants, receiving terminals and vessels have fallen, making LNG a more competitive means of energy distribution. The standard price for a 125,000-cubic-meter LNG vessel built in European and Japanese shipyards used to be USD 250 million. When Korean and Chinese shipyards entered the race, increased competition reduced profit margins and improved efficiency, reducing costs 60%. Costs in US dollar terms also declined due to the devaluation of the currencies of the world's largest shipbuilders, Japan and Korean. Since 2004, ship costs have increased due to a large number of orders increasing demand for shipyard slots. The per-ton construction cost of a LNG liquefaction plant fell steadily from the 1970s through the 1990s, with the cost reduced approximately 35%.

Due to energy shortage concerns, many new LNG terminals are being contemplated in the United States. Concerns over the safety of such facilities has created extensive controversy in the regions where plans have been created to build such facilities. One such location is in the Long Island Sound between Connecticut and Long Island. Broadwater Energy, an effort between TransCanada Corp. and Shell (A British-Dutch Corporation) wishes to build a LNG terminal in the sound on the New York side. Local politicians including the Suffolk County Executive have raised questions about the terminal. New York Senators Chuck Schumer and Hillary Clinton have both announced their opposition to the project. Several terminal proposals along the coast of Maine have also been met with high levels of resistance and questions. The Government Accountability Office (GAO) is planning to deliver its report to Congress on LNG in the spring of 2006.

## Trade in LNG

LNG is shipped around the world in specially constructed seagoing vessels. The trade of LNG is completed by signing a sale and purchase agreement (SPA) between a supplier and receiving terminal, and by signing a gas sale agreement (GSA) between a receiving terminal and end-users. Most of the contract terms used to be DES or Ex Ship, which meant the seller was responsible for the transportation. But with low shipbuilding costs, and the buyer preferring to ensure reliable and stable supply, there are more and more contract terms of FOB, under which the buyer is responsible for the transportation, which is realized by the buyer owning the vessel or signing a long-term charter agreement with independent carriers.

The agreements for LNG trade used to be long-term portfolios that were relatively inflexible both in price and volume. If the annual contract quantity is confirmed, the buyer is obliged to take and pay for the product, or pay for it even if not taken, which is called the obligation of take or pay (TOP).

In contrast to LNG imported to North America, where the price is pegged to Henry Hub, most of the LNG imported to Asia is pegged to crude oil prices by a formula consisting of indexation called the Japan Crude Cocktail (JCC).

The pricing structure that has been widely used in Asian LNG SPAs is as follows: PLNG = A+B×Pcrude oil, where A refers to a term that represents various non-oil factors, but usually a constant determined by negotiation at a level that can prevent LNG prices from falling below a certain level. It thus varies regardless of oil price fluctuation. Typical figures of ex-ship contracts range from USD 0.7 to 0.9. B is a degree of indexation to oil prices; typical figures are 0.1485 or 0.1558, and Pcrude oil usually denominated in JCC. PLNG and Pcrude oil stand for price of oil in USD per million British Thermal Unit (MMBTU (in the fuel industry, M stands for 1000 and MM for 1 000 000)). With the demand of LNG moving up and down, the price of LNG moves in a "S" curve. With new demand from China, India and US increasing dramatically, and crude oil price skyrocketing, the LNG price is on the rise too.

In the mid 1990s LNG was a buyer's market. At the request of buyers, the SPAs began to adopt some flexibilities on volume and price. The buyers had more upward and downward flexibilities in TOP, and short-term SPAs less than 15 years came into effect. At the same time, alternative destinations for cargo and arbitrage were also allowed. By the turn of the 21st century, the market was again in favor of sellers. Sellers now propose rigid SPAs and would like an association similar to OPEC to be established to protect their interests. It is certain that the competition between sellers and buyers will go on.

Until 2003, LNG prices have closely followed oil prices. Since then, LNG prices to Europe and Japan, have been lower than oil prices, though the link between LNG and Oil is still strong In contrast, recent prices in the US and UK markets have skyrocketed then fallen as a result of changes in supply and storage.

Price arbitrage has not yet led to a convergence of regional prices and to a global market For the time being, the market is a seller's market (hence net-back is best estimation for prices). The balance of market risks between the buyers (taking most of the volume risks through off-take obligations) and the sellers (taking most of the value risks through indexation to crude oil and petroleum products) is changing.

Receiving terminals exist in several countries (China is expected to move onto the list by 2006), allowing gas imports from other areas.

The U.S. Department of Energy's Energy Information Administration provides estimates of LNG trade in 2002 as follows:

In 2005, Egyptian NG production outpaced consumption and it joined the LNG exporting countries.

Global LNG demand is expected to reach 500 bcm/year by 2015 and 635 bcm/year in 2020. The International Energy Agency estimates that European imports of gas from Africa and the Middle East (mainly in the form of LNG) will quadruple by 2030 (source: Economist, 14/4/07, p39).

## LNG environmental concerns

Natural gas can be considered as the most environmentally friendly of the fossil fuels, because it has the lowest CO2 emissions per unit of energy and because it is suitable for use in high efficiency combined cycle power stations. Because of the energy required to liquefy and to transport it, the environmental performance of LNG is inferior to that of natural gas, although in most cases LNG is still superior to alternatives such as fuel oil or coal. This is particularly so in the case where the source gas would otherwise be flared.

Some environmental groups argue strongly against the use of LNG. One (unspecified) study concluded that a proposed LNG terminal proposed near Oxnard, California will emit 25 million tons of greenhouse gases per year. On the West Coast of the United States where up to five new LNG importation terminals have been proposed, environmental groups, such as Pacific Environment, Ratepayers for Affordable Clean Energy (RACE), and Rising Tide have moved to oppose them.[1] Whilst natural gas power plants emit approximately half the carbon dioxide of an equivalent coal power plant, the natural gas combustion required to produce and transport LNG to the plants adds 20 to 40 percent more carbon dioxide than burning natural gas alone.[2] With the extraction, processing, chilling transportation and conversion back to a usable form is taken into account LNG is a major source of greenhouse gases. In addition to this many of the sites where LNG is being extracted, such as Sakhalin 2 have suffered fairly serious environmental destruction.

## LNG safety and accidents

In its liquid state, LNG is not explosive. For an explosion to occur with LNG, it must first vaporize, then mix with air in the proper proportions (the flammable range is 5% to 15%), and then be ignited. Serious accidents involving LNG to date are listed below:

- 1944, 20 October. The East Ohio Natural Gas Company experienced a failure of an LNG tank in Cleveland, Ohio.[3] 128 people perished in the explosion and fire. The tank did not have a dike retaining wall, and it was made during World War II, when metal rationing was very strict. The steel of the tank was made with an extremely low amount of nickel, which made the tank brittle when exposed to the extreme cold of LNG, and the tank ruptured, spilling LNG into the city sewer system.

- 1973, February, Staten Island, New York. While repairing the interior of an empty storage tank, a fire started.[3] The pressure increased inside the tank so fast the concrete dome on the tank lifted and then collapsed falling inside the tank and killing the 37 construction workers below. No LNG was involved in this incident.

- 1979, October, Lusby, Maryland, at the Cove Point LNG facility a pump seal failed, releasing gas vapors, which entered and settled in an electrical conduit.[3] A worker switched off a circuit breaker, igniting the gas vapors, killing a worker and causing heavy damage to the building. National fire codes were changed as a result of the accident.

- 2004, 19 January, Skikda, Algeria. Explosion at Sonatrach LNG liquefaction facility.[3] 27 killed, 80 injured, three LNG trains destroyed, 2004 production was down 76% for the year. A cold hydrocarbon leak occurred and hydrocarbon gases were drawn into the combustion air for a high-pressure steam boiler. The explosion inside the boiler fire box precipitated a larger explosion of vapors outside the box.

Seaborne LNG transport tankers (including their loading terminals) have not had a major [4] accident in over 47,000 voyages [5] since maritime inception in 1959. There have, however, been several significant incidents with LNG ships, but with only minor spills. In addition to accidents, terrorism experts are concerned that intentional sabotage could lead to unprecedented releases, resulting in massive fires and other damaging effects. The latter may include detonations (producing large blast waves) and deflagration-to-detonation transition phenomena. As the Department of Energy notes in its December 2004 report (Sandia National Labs, SAND2004-6258), the available testing data on LNG spills are based on releases of very small size in comparison to releases expected from intentional attacks. The Sandia report assumes that a ship's tank with a hole in it (up to several square meters in area) from any cause will drain by gravity while a fire burns outside the ship. This may not be a valid assumption for holes in tanks below the waterline of a vessel, or at the waterline. If the hole is below the waterline, the LNG in contact with water may vaporize violently in a rapid-phase transition, possibly pressurizing the tank and forcing LNG and gas to exit the hole under the water. The Sandia report notes the experimentally observed phenomena of RPT causing extensive damage to a marine structure, and gives a corresponding yield of high explosive for a relatively small LNG spill into water. The extent of damage to an LNG tank from RPT phenomena that could lead to a cascading failure of all tanks on an LNG ship remains to be determined. For a hole at the waterline in the presence of a pool fire, the contact of water with the LNG may also cause RPT at the hole, and might cause a dynamic pressure condition within the holed tank, leading to a higher rate of LNG release than from gravity alone. For a hole above the waterline in the presence of fire, the volume of LNG released from an unvented rigid tank must be replaced by an equal volume of some mass entering the tank. In the context of the Sandia report analysis, the available mass to enter the tank above the waterline consists of one or more of the following components: LNG vapor, air, flame, and combustion products. If the tank is rigid and vented while holed, the same components are presumably present to enter the holed tank. This import of mass and corresponding heat energy might be expected to vaporize the LNG in the tank, and may create the conditions needed for a detonation inside the tank. The recent GAO report of February 2007 (GAO-07-316) surveyed experts who were not unanimous in confirming the findings of the original Sandia report. The expert GAO panel concluded that additional research was needed to understand the potential effects of LNG ship accidents and malevents. The Department of Energy has funded Sandia to continue research, but not all of the topics identified by the GAO study are included in the current Sandia research agenda. While natural gas explosions are common in confined spaces such as houses, claims that outdoor releases of natural gas are at low risk of explosion must consider adjacent structures as enclosed spaces. If an LNG ship release occurs, any buildings, vehicles, or escort vessels close to the release constitute enclosed spaces where natural gas explosions may occur. Despite intense local opposition, the Federal Energy Regulatory Commission has approved a site permit for an LNG terminal in Fall River, Massachusetts in a densely populated harbor area.

# LNG storage


LNG storage tank at EG LNG

LNG above-ground tanks are mainly of double-wall, high-nickel steel construction with extremely efficient insulation between the walls. Large tanks are low aspect ratio (height to width) and cylindrical in design with a domed roof. Storage pressures in these tanks are very low, less than 5 psig. Sometimes more expensive frozen-earth, underground storage is used. Pre-stressed concrete backed up with suitable thermal insulation, are designed to be both under and above ground to suit sites conditions and local safety regulations and requirements. Smaller quantities, 190,000 US gallons (700 m³) and less, are stored in horizontal or vertical, vacuum-jacketed, pressure vessels. These tanks may be at pressures anywhere from less than 5 psig to over 250 psig (35 to 1700 kPa gauge pressure).

LNG must be maintained cold (at least below −117 °F or −83 °C) to remain a liquid, **independent of pressure**. There will inevitably be some degree of boil-off as a result of heat gained from the outside ambient atmosphere. This gas may be returned to storage by recompression and reliquefaction, or used in the liquefaction process. When gas is cooled to -160°C (-260°F), NG becomes liquid and is much more compact-occupying 1/600 of its gas volume. Where long overseas distances are involved, transporting NG in its liquid state is more economical. The LNG industry is set for a large and sustained expansion as improved technology has reduced transportation costs of formerly stranded NG reserves as a liquid to consumer markets.

# LNG Transportation

Transportation and supply is an important aspect of the gas business, since LNG reserves are normally quite distant from consumer markets. LNG has far more mass than oil to transport, and most gas is transported by pipelines. There is a pipeline network in the former USSR, Europe and North America. LNG, when in its gaseous state is rather bulky. Gas travels much faster than oil though a high-pressure pipeline can transmit only about a fifth of the amount of energy per day. As well as pipelines, LNG is transported using both road/rail truck and ship. LNG will be sometimes taken to cryogenic temperatures to reduce the mass. Recently ship-to-ship transfer (STS) transfers have been carried out by Exmar the Belgian gas tanker owner in the Gulf Of Mexico which involved the transfer of LNG from the LNG regasification vessel (LNGRV) to a conventional LNG carrier. Prior to this commercial exercise LNG had only ever been transferred between ships on a handful of occasions as a necessity following an incident.

# LNG refrigeration

The insulation, as efficient as it is, will not keep the temperature of LNG cold by itself. LNG is stored as a "boiling cryogen", that is, it is a very cold liquid at its boiling point for the pressure it is being stored. Stored LNG is analogous to boiling water, only 470 °F (260 °C) colder. The temperature of boiling water (212 °F or 100 °C) does not change, even with increased heat, as it is cooled by evaporation (steam generation). In much the same way, LNG will stay at near constant temperature if kept at constant pressure. This phenomenon is called "**autorefrigeration**". As long as the steam (LNG vapor boil off) is allowed to leave the tea kettle (tank), the temperature will remain constant.

If the vapor is not drawn off, then the pressure and temperature inside the vessel will rise. However, even at 1000 psig (7 MPa), the LNG temperature will still be only about −200 °F (−130 °C).

# LNG, LPG, and CNG

## Liquefied natural gas (LNG)

When natural gas is cooled to a temperature of approximately −260 °F (−160 °C) at atmospheric pressure it condenses to a liquid called liquefied natural gas (LNG). One volume of this liquid takes up about 1/600th the volume of natural gas at a stove burner tip. LNG is only about 45% the density of water. LNG is odorless, colorless, non-corrosive, and non-toxic. When vaporized it burns only in concentrations of 5% to 15% when mixed with air. Neither LNG, nor its vapor, can explode in an unconfined environment.

Natural gas is composed primarily of methane (typically, at least 90%), but may also contain ethane, propane and heavier hydrocarbons. Small quantities of nitrogen, oxygen, carbon dioxide, sulfur compounds, and water may also be found in "pipeline" natural gas. The liquefaction process removes the oxygen, carbon dioxide, sulfur compounds, and water. The process can also be designed to purify the LNG to almost 100% methane.

## Compressed natural gas (CNG)

Compressed natural gas (CNG) is natural gas pressurized and stored in welding bottle-like tanks at pressures up to 3,600 psig (25 MPa). Typically, it is same composition of the local "pipeline" gas, with some of the water removed. CNG and LNG are both delivered to gas engines as low pressure vapor (ozf/in² to 300 psig, up to 2.1 MPa). CNG is often misrepresented as the only form natural gas can be used as vehicle fuel. LNG can be used to make CNG. This process requires much less capital intensive equipment and about 15% of the operating and maintenance costs.

## Liquid petroleum gas (LPG)

Liquid petroleum gas (LPG, and sometimes called propane) is often confused with LNG and vice versa. They are not the same and the differences are significant. Varieties of LPG bought and sold include mixes that are primarily propane, mixes that are primarily butane, and mixes including propane, propylene, n-butane, butylene and iso-butane. Depending on the season—in winter more propane, in summer more butane. Vapor pressures, at 30 °C, are for commercial propane in the range 10-12 barg (1 to 1.2 MPa), for commercial butane, 2-4 barg (0.2 to 0.4 MPa). In some countries LPG is composed primarily of propane (upwards to 95%) and smaller quantities of butane. The vapor pressure of commercial butane is generally too low to release it from the top vapor space. Pumps and (hot water, steam, electricity or direct-fired) vaporizers are frequently used. An alternative to using neat butane vapor which overcomes the need for pipework heating, is to use a gas-air mixture (well outside flammability limits). Air depresses the vapor dew-point temperature. Another advantage is that the mixture can be made to "simulate" natural gas or town gas to produce the same heat release through a burner under equal supply pressures, characterized by a term known as Wobbe number or Wobbe index.

LPG compared to natural gas has a significantly higher heating value and requires a different air-to-gas mixture (propane: 24:1, butane: 30:1) for good combustion.

LPG can be stored as a liquid in tanks by applying pressure alone. While the distribution of LNG requires heavy infrastructure investments (pipelines, etc.), LPG is portable. This fact makes LPG very interesting for developing countries and rural areas. LPG (sometimes called autogas) has also been used as fuel in light duty vehicles for many years. An increasing number of petrol stations around the world offers LPG pumps as well. A final example that should not be forgotten is that the "bottled gas" can often be found under barbecue grills.

## References


1. ^ http://www.pacificenvironment.org/article.php?list=type&type=21
2. ^ http://www.lngwatch.com/race/truth.htm
3. ^ *a b c d* Safe History of International LNG Operations, CH-IV December 2006
4. ^ No significant loss of cargo, no loss of life, no loss of vessel
5. ^ LNG World Shipping (2006-12-22). LNG World Shipping. (http://www.lngworldshipping.com/content/news/compNews224.htm) . Retrieved on 2007-05-19.


## See also

- List of LNG terminals
- Natural gas processing
- CNG: Compressed natural gas
- LPG: Liquified petroleum gas
- Natural gas storage

***Energy Portal***

## External links

- What is LNG? (http://www.gorgon.com.au/06-news/factsheets/Gorgon%20Fact%20Sheet%20-%20What%20is%20LNG.pdf) PDF (209 KiB)
- The Global Liquefied Natural Gas Market: Status and Outlook (http://www.eia.doe.gov/oiaf/analysispaper/global/index.html) EIA website
- Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water (http://www.fossil.energy.gov/programs/oilgas/storage/lng/sandia_lng_1204.pdf) PDF (1.62 MiB) Sandia National Laboratories Report SAND2004-6258
- Liquefied Natural Gas in the US: Federal Energy Regulatory Commission (FERC) (http://www.ferc.gov/industries/lng.asp)
- LNG safety (http://www.our-energy.com/liquefied-natural-gas-lng_en.html)
- Alternative Fuel Vehicle Training (http://www.naftc.wvu.edu) From the National Alternative Fuels Training Consortium