



Liquefied Natural Gas Fundamentals

An Online Continuing Education Course for Engineers

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Liquefied Natural Gas Fundamentals

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1. Introduction

Liquefied natural gas (LNG) is natural gas (predominantly methane (CH₄)) that has been converted to liquid form for ease of storage or transport.

Natural gas is a major source of energy, but many towns and cities that need the energy are located far from the gas fields. Transporting gas by pipeline can be costly and impractical. LNG is formed by cooling the gas to a liquid to -160°C. LNG is a clear, colorless, non-toxic liquid that can be transported and stored more easily than natural gas because it occupies up to 600 times less space.

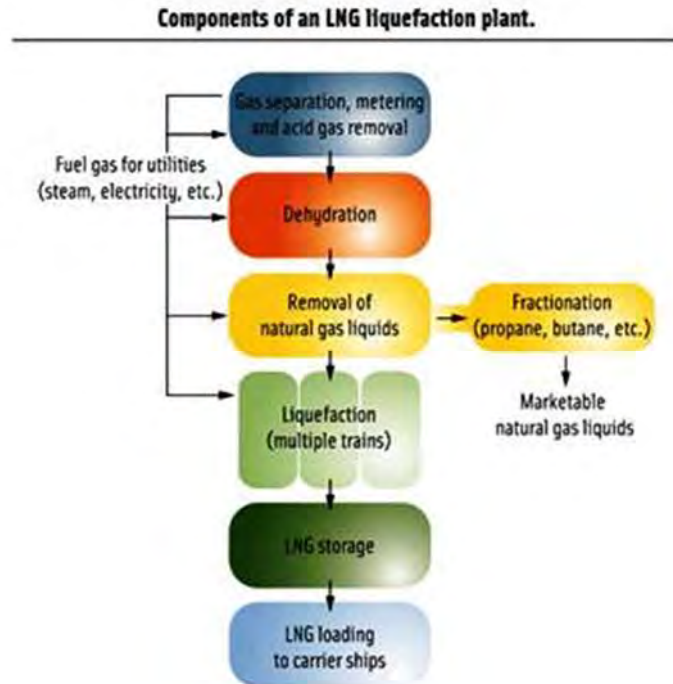
When LNG reaches its destination, it is returned to a gas at regasification facilities. It is then piped to homes, businesses and industries.

This course will cover the following aspects of LNG:

- LNG Process
- Production
- Commercial Aspect
- LNG Quality
- Liquefaction technology
- Storage
- Transportation
- Safety and Accidents
- Mechanics of Gas Explosions

2. LNG Process





In a typical LNG process, the gas is first extracted and transported to a processing plant where it is purified by removing any condensates such as water, oil, mud, and other gases such as CO₂ and H₂S. An LNG process train will also typically be designed to remove trace amounts of mercury from the gas stream to prevent mercury from amalgamizing with aluminum in the cryogenic heat exchangers. The gas is then cooled down in stages until it is liquefied. LNG is finally stored in storage tanks, and can be loaded and shipped.



The liquefaction process involves the removal of certain components such as dust, acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty downstream. The natural gas is then condensed into a liquid at close to atmospheric pressure (maximum transport pressure set at around 25 kPa (3.6 psi)) by cooling it to approximately -162°C (-260°F .)

LNG achieves a higher reduction in volume than compressed natural gas (CNG). Therefore, the energy density of LNG is 2.4 times greater than that of CNG and 60% that of diesel fuel. This makes LNG cost efficient to transport over long distances where pipelines do not exist. Specially designed cryogenic sea vessels (LNG carriers) or cryogenic road tankers are used for its transport.

The LNG Value Chain

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

LNG is principally used for transporting natural gas to markets, where it is regasified and distributed as pipeline natural gas. It can be used in natural gas vehicles, although it is more common to design vehicles to use compressed natural gas. Its relatively high cost of production and the need to store it in expensive cryogenic tanks have hindered its widespread commercial use.

Energy density and other physical properties

The heating 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. The lower heating value of LNG is 21 MJ/L or 563623 BTU/ft³. For comparison purposes, the heating value is also known as the energy density expressed in MJ/L or the gasoline gallon equivalent expressed in BTU/ft³. The energy density of LNG is comparable to propane and ethanol, but is only 60% that of diesel and 70% of that of gasoline.

The density of LNG is roughly 0.41 kg/L to 0.5 kg/L, depending on temperature, pressure, and composition, compared to water at 1.0 kg/L.

3. Production

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 that will be destructive to the liquefaction facility. LNG typically contains more than 90% methane. It also contains small amounts of ethane, propane, butane, some heavier alkanes, and nitrogen. The purification process can be designed to produce almost 100% methane. One of the risks of LNG is a rapid phase transition explosion (RPT), which occurs when cold LNG comes into contact with water.

The most important infrastructure needed for LNG production and transportation is an LNG plant consisting of one or more LNG trains, each of which is an independent unit for gas liquefaction. LNG is loaded onto ships and delivered to a regasification terminal, where the LNG is allowed to expand and reconvert 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.)

World Total Production of LNG

Year	Capacity (Mtpa*)
1990	50
2002	130
2007	160

*Mtpa = Million Tons Per Annum

In the early 2000s, as more players invested both in liquefaction and regasification and with new

technologies, the prices for construction of LNG plants, receiving terminals and vessels have fallen, making LNG a more competitive means of energy distribution. However, increasing material costs and demand for construction contractors have driven up prices in the last few years. The standard price for a 125,000 cubic meter LNG vessel built in European and Japanese shipyards used to be \$250 million USD. When Korean and Chinese shipyards entered the race, increased competition reduced profit margins and improved efficiency, and costs were reduced by 60%. Costs in US dollar terms also declined due to the devaluation of the currencies of the world's largest shipbuilders, and the Japanese yen and Korean won. Since 2004, ship costs have increased due to a large number of orders, which has increased the demand for shipyard slots. The per-ton construction cost of an LNG liquefaction plant fell steadily from the 1970s through the 1990s. As a result, costs decreased by approximately 35%. However, due to recent materials costs, lack of skilled labor, shortage of professional engineers, designers, managers and other white-collar professionals, the cost of building liquefaction and receiving terminals has doubled.

The commercial development of LNG means LNG suppliers first confirm sales contracts with strict terms and structures for greenfield projects. The development of a greenfield project involves significant investment in their development and infrastructure. It is a game of the rich, with major players involved. Major international players include BG Group, Chevron and Exxon.

The Basics of Natural Gas Exploration

Exploring for natural gas can cost tens of millions of dollars before a firm or group of firms then develops a prospect. The firm then develops a prospect target zone with a high

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