Let me explain issues related to LNG in question and answer form

NATURAL GAS

- **What is Natural Gas?**

A naturally occurring mixture of Hydrocarbon and Non-hydrocarbon gases found in porous geological formations beneath the earth's surface, often in association with oil. The principal constituent is Methane (CH_4).

- **Where is Natural Gas available?**

Natural Gas is formed from the buried remains of tiny plants and sea animals that died more than 200 million years ago in mother earth. Under the heat and pressure inside the earth, these energy rich organic material slowly decayed, then changed form until all that was left were concentrations of Natural Gas in layers of rocks.

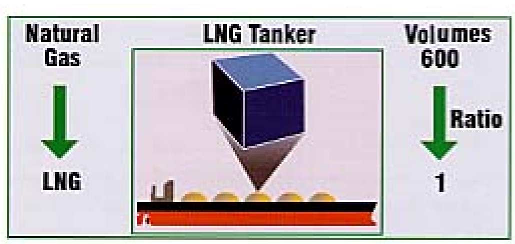
Natural Gas is removed from the earth by drilling wells into the rock, then using pipes to bring gas to the surface. In most wells, the pressure of the gas is enough to force it to the surface and then to the central collection points. When Natural Gas comes out along with crude oil, it is known as Associated Gas, as in case of Bombay High.

- **Where is Natural Gas found in India?**

Natural Gas is found onshore in the North East, Rajasthan and Gujarat and Off-shore in Bombay High. Recently, gas find has been reported by Reliance Industries in the Krishna Godavari Basin.

- **What Is LNG?**

Liquefied Natural Gas (LNG) is Natural Gas that has been cooled to the point that it condenses to a liquid, which occurs at a temperature of approximately -256 ° F (-161 ºC) and at atmospheric pressure. Liquefaction reduces the volume by approximately 600 times thus making it more economical to transport between continents.



Transportation of LNG is done in specially designed ocean vessels. Ocean transportation is undertaken wherever traditional pipeline transportation systems would be less economically attractive and could be technically or politically infeasible. Thus, LNG technology makes Natural Gas available throughout the world.

- ## What is the distinction between CNG / PNG / LCNG?

CNG is Natural Gas that is compressed to a pressure of 200-250 Kg/cm^2 (g) (due to its low density) to enhance the vehicle on-board storage capacity. Thus, this compressed form of Natural Gas is used as a fuel for transportation purposes.

PNG is nothing but Piped Natural Gas i.e. processed natural gas piped to the homes and establishments for the kitchen and home heating like geysers etc. PNG installation inside the premises contains only a limited quantity of Natural Gas at low pressure at around 21 milibar (mbar) and is much safer compared to LPG which is stored in a liquefied form in a cylinder.

For markets that are not serviced by gas pipelines, CNG can be produced from an LNG storage system. These facilities are called **LCNG**. LNG contains no water. This eliminates the concerns of corrosion, plugging of fuel lines, and the formation of hydrates or exceeds all of the requirements relative to pressure water-dew point temperatures.

LNG does not contain any other impurities, such as, oil, particulate, hydrogen sulfide, or oxygen. LNG is not subject to compositional changes driven by the time of year, pipeline demand, or pipeline system. Often, LNG can be delivered as nearly pure methane, the most desirable component of Natural Gas for vehicular fuel. This eliminates any concern over propane-air. The composition of LNG is always acceptable for use as a gasoline replacement. In the Indian market, LCNG is yet to come.

- ## What are the units of measurement?

Natural Gas is measured in volume units, i.e. in cubic feet or cubic meters. Gas production from wells and supplies to Power plants is measured in Thousands or Millions cubic feet (Mcf or MMcf) / cubic meter (MSCM or MMSCM). Resources and reserves are calculated in Trillions of cubic feet (Tcf). For instance, a gas field containing 3.65 TCF is equivalent to around 12 MMSCMD gas for 25 years. A rough way of visualizing a trillion cubic feet of gas would be to imagine enough of product to fill a cube with its sides two miles long.

Another way of measuring the gas is in terms of Energy Values. The amount of energy that is obtained from the burning of a unit volume of Natural Gas is measured in British Thermal Unit (BTU). At sea level, it takes about 75 BTU to make a jolly good cup of tea. A cubic feet of natural gas on an average gives off 1000 BTU, but the range of values is 500 to 1500 BTU depending on the quality of gas. Therefore, one cubic feet of some Natural Gas may make 7 cups of tea, while another makes as many as 20 cups of tea.

The various conversion factors used in measurement of gas are:

GENERALLY USED CONVERSION FACTORS OF LNG

1Cubic meter liquid	CuM	600	Cubic meter of gas
1 Million Metric Ton/ annum	MMTPA	4	MMSCMD
1 Metric ton LNG	MT	1420	Cubic meter of gas
1 Metric ton LNG	MT	52	MMBTU
1000 Cubic meter of Gas	MCM	40	MMBTU
1British Thermal Unit	BTU	252	Calories

MMSCMD stands for Million Standard Cubic Meter per Day.

MMBTU stands for Million British Thermal Unit.

MT stands for Metric Ton

MMTPA means Million Metric Ton Per Annum.

These are the thumb rules of conversion of gas, while the actual factors would vary based on the quality of gas.

- ## Who are the users of LNG?

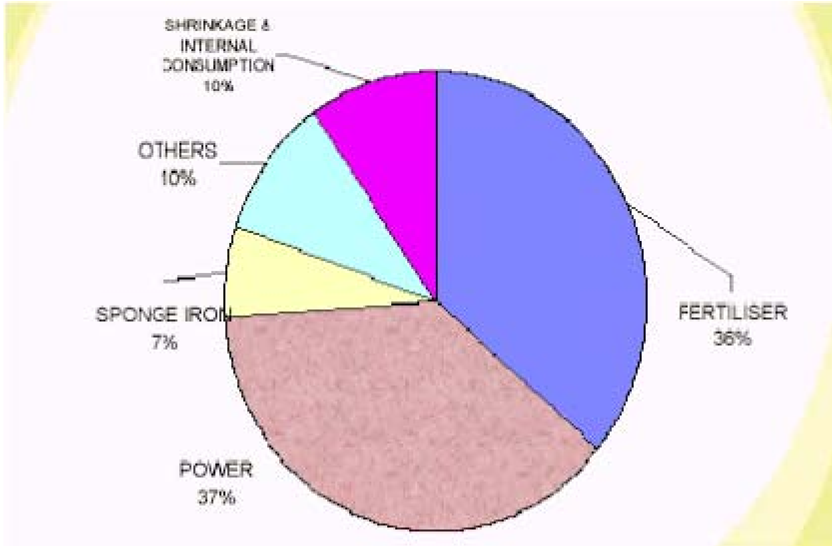
World over, LNG is used for established as well as emerging applications:

The largest application for LNG is world trade where Natural Gas is liquefied and transported by large ocean tankers from remote reserves to markets in Asia, Europe and North America. Most LNG that is traded internationally is used to fuel electric power plants. Growing needs for electricity in Asia have increased demand for LNG by nearly 8 per cent per year since 1980, making it one of the fastest growing energy sectors.

Another established application for LNG is seasonal gas storage. Roughly, 100 LNG plants have been constructed world-wide to liquefy and store natural gas during warmer months for vaporisation and injection into local pipelines during cold weather.

LNG is also emerging as an alternative motor fuel to diesel. In some regions, natural gas suppliers truck LNG to communities and industrial plants, if those are remote from gas pipelines. Once delivered, LNG is stored in insulated tanks so that it can be vaporised and distributed as natural gas to the customers.

However in case of India, Natural gas is used mostly by the power & Fertiliser industry. About 37% of the gas is used by the Power sector and 36% is used by the Fertiliser sector.



CURRENT USAGE PATTERN OF GAS IN INDIA

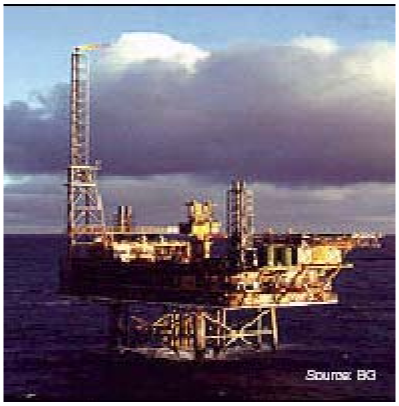
- **How much of Natural Gas would a Power plant and a Fertilizer plant consume?**

A Power plant of 100 MW consumes approximately 0.5 MMSCMD of gas. Similarly a Fertilizer plant of capacity of 5 lakh tonnes per annum of Urea would require approximately 0.9 MMSCMD of gas. However depending on the efficiency of the plant and the quality of the gas, the requirement may vary.

- ## What is a LNG value chain?

To make LNG available for use in a country, energy companies must invest in a number of different operations that are highly linked and dependent upon one another. The major stages of the **LNG value chain**, excluding pipeline operations between the stages, consist of the following.

PRODUCTION



The production stage involves the supply of gas and condensate from the wells in the offshore/on-shore facilities, through a pipeline into the processing facilities.

LIQUEFACTION

Raw Natural Gas and unstabilized condensate obtained offshore is seldom pure, as it generally contains numerous types of contaminants. Therefore the gas and condensate must be purified for reasons of safety, compliance with environmental regulations, and product specification.

The process of condensate stabilization, gas treatment and liquefaction is achieved in the LNG plant. The main units/facilities of an onshore LNG plant are:

Process units

- Storage and loading facilities.
- Utility and offsite systems and infrastructure.

Over view of a Liquefaction Plant

The process unit includes inlet gas reception unit, condensate stabilization unit, gas treatment & sweetening facilities gas liquefaction unit, sulfur recovery unit. An LNG train is a set of process units consisting of all process equipment necessary to produce LNG from a natural feed stock and having a pre-determined design.

In the liquefaction stage the condensate is stabilized and the gas is treated to remove all impurities and liquefied. The liquefaction of gas to LNG is achieved in six different steps:

The first step involves the receipt of untreated sour gas and unstabilized condensate from the offshore facilities to the inlet gas reception unit.

This is followed by stabilization of condensate and treatment of the sour gas for removal of Mercury.

The third step involves the gas sweetening step resulting in removal of contaminants mainly sulfur compounds and carbon dioxide to meet required product specification.

The fourth step involves dehydration or drying for removal of water to prevent hydrate formation, which would otherwise freeze, and block the system, resulting in operational malfunction.

Next, a stripping step involving separation of lighter hydrocarbon used to produce LNG from the heavier hydrocarbons, which would freeze at LNG temperature. The heavier hydrocarbons are further treated in fractionation unit to produce plant condensate.

The sixth step is the cooling cycle, which is the crux of the LNG plant. Here the liquefaction takes place in a specially constructed heat exchanger termed “Cryogenic heat exchanger” because of the low temperatures. The equipment employs mixed refrigerant (MR) consisting of nitrogen, methane, ethane, propane, and butane that provides the refrigeration for liquefying the natural gas. The fractionation unit provides the ethane, propane make-up for the refrigeration cycle and MR is pre-cooled by a propane refrigeration system.

The LNG, now at -160 C and atmospheric pressure and reduced to 1/600 th of its gaseous volume is stored in insulated tanks. These **storage tanks** are large, typically between 60,000 and 140,000-m3 capacity each. The tanks incorporate special cryogenic features, such as an insulation layer between double contaminant walls, an inner shell made of exotic alloy, such as nickel stainless steel to withstand the low temperatures, and an outer shell of carbon steel.

The Field and Plant Condensate are stored in atmospheric floating roof tanks. LNG and Condensate are transferred onto ships through their respective loading systems.

SHIPPING

LNG is transferred onto ships through a **loading system**. The present state of the art in **LNG ships** has contributed to cost effectiveness by increases in size from 40,000 to 135,000 m3 capacity. Unlike an oil tanker, an LNG carrier is designed to handle extremely low temperatures. LNG is carried in insulated metallic tanks constructed of exotic alloy, such as nickel stainless steel, or other suitable materials to withstand the low temperatures. The insulation system maintains the LNG temperature to prevent heat inflow from the surrounding which would otherwise evaporate the liquid.

Nevertheless, during voyage some of the LNG evaporates, forming so called "**boil off" vapor**. LNG carrier for fuel uses this boil-off vapor. At the receiving terminal, the cargo is not emptied completely; as a small proportion called "cargo heel" is retained to keep the tanks cold till the next cargo is loaded. This cargo heel provides fuel for the return voyage.

<u>The highest safety standards</u> are employed in the design and operation of LNG vessels.

REGASIFICATION

An **LNG receiving terminal** consists of pipelines; ship berthing facilities, unloading facilities, storage tanks, vaporization system, units for handling boil-off from the tanks, metering station and ancillaries. The storage tanks are of similar design to those in liquefaction plants.

At the receiving terminal, the LNG is re-gasified before distribution into pipelines for customers. The main uses of the re-gasified LNG include fuel source for boilers in the electrical power generation plants, and other industrial processes, petrochemical feed stocks, as in methanol or fertilizer production, and heating for domestic appliances, typically cooking stoves.

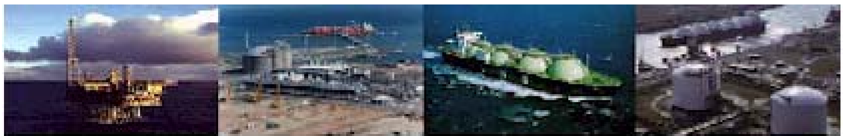
LNG IMPORT TERMINAL AT LAKE CHARLES

LNG TANKS AT PLL SITE AT DAHEJ, INDIA

An LNG project is a highly complex, capital intensive, large-scale and time-consuming venture. It involves extensive interaction between buyers and sellers, financial institutions, governments, shipping companies, and EPC Contractors for engineering, procurement, construction, and implementation.

- **How Much Does LNG Cost?**

A thumb rule estimate of the cost involved in the LNG Chain varies between USD 2.5 to USD 3.5 per MMBTU depending largely on the shipping cost



EXPLORATION & PRODUCTION $0.5-$1.0/MMBtu	LIQUEFACTION $0.8 - $1.20/MMBtu	SHIPPING $0.4 - $1.0/MMBtu	REGASIFICATION & STORAGE $0.3-$0.5/MMBtu

Sources: BG, ALNG, CMS

Exploration and production costs have been declining due to improved technologies such as 3-D (three-dimensional) seismic; drilling and completion of complex well architectures; and improved sub-sea facilities. 3-D seismic allows detailed complex imaging of rocks below the earth's surface, enabling exploration earth scientists to predict better where accumulations of natural gas might exist. Drilling and completion of complex well architectures allow petroleum engineers to target more precisely these accumulations and to maximise oil and gas reservoir recovery using multi-branched well architecture and intelligent completion systems. Improved sub-sea facilities allow companies to produce natural gas from deep below the surface of the ocean.

Further along the LNG value chain, technical innovations have also reduced the costs of LNG liquefaction and shipping, allowing more LNG projects to achieve commercial viability. For example, liquefaction costs have been lowered by as much as 35 percent because of the introduction of competing technologies and economies of scale.

Design efficiencies and technology improvements have all contributed to improved project economics. BP's Trinidad LNG Train 1, completed in June 1999, set a new benchmark for LNG unit capital cost at less than $200/ton of annual plant capacity, as shown in the figure above. Trinidad Atlantic Train 2 was completed in August 2002, two months ahead of schedule and Train 3, currently under construction is scheduled to come on stream second quarter of 2003. The capital cost of Trains 2 and 3 is expected to be about $165/ton of capacity.

In-ship design, new technologies are also helping to reduce costs. New propulsion systems are aimed to replace the traditional steam turbine engines with smaller units that are more efficient which will not only reduce fuel costs but will also increase cargo carrying capacity. Enhanced tanker efficiencies – longer operating lives, improved safety technology and improved fuel efficiency – have lowered shipping costs substantially. Shipyard expansions in the Far East and increased competition among ship builders have lowered LNG tanker costs by 40 percent from their peak.

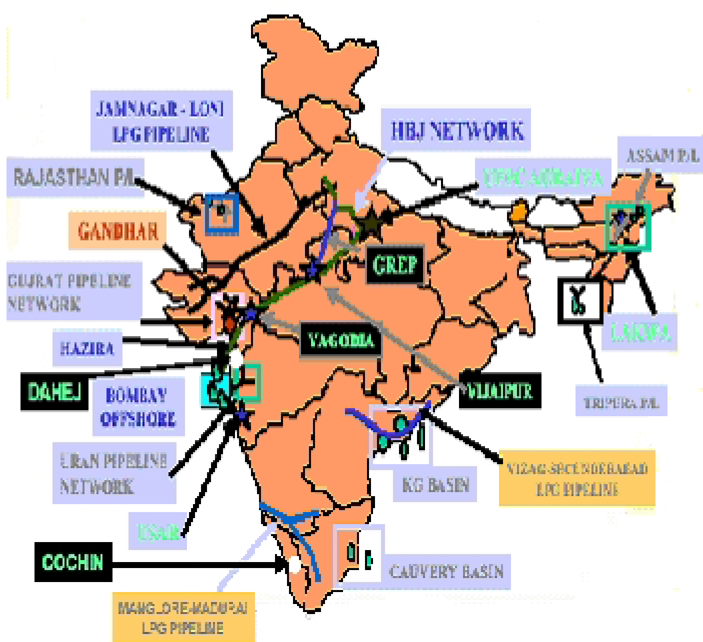
- ## Who are the players in India in LNG?

Apart from Petronet LNG, M/s Shell is also progressing with a regasification terminal at Hazira (near Surat). The other players who had earlier shown interest in developing LNG Terminals were M/s British Gas at Pipavav and Reliance at Jamnagar. British gas is yet to start any physical activity whereas Reliance is now concentrating on their Gas find at KG Basin. The Government of India is also pursuing the option of importing the transnational gas by pipeline from Bangladesh, Myanmar and Iran. Govt of India has already signed a bi lateral treaty with Govt of Iran for import of Gas and Indian Oil and Gas Authority of India will be the nodal agency for importing LNG from Iran.

- ## What is the current infrastructure in India?

The existing gas infrastructure supports production and transportation of about 90 MMSCMD of gas and transmission and distribution of about 70 MMSCMD. The Western Offshore region is the major source of gas, accounting for more than 70% of the total gas production. Adequate offshore facilities exist for the compression and evacuation of gas to shore-based facilities at Uran in Maharashtra and Hazira in Gujarat. The shore-based facilities in Uran receive gas from two offshore trunk gas pipelines, from Bombay High and the Heera Field. Similarly, the shore-based facilities at Hazira receive gas from two offshore gas trunk pipelines from the South Bassein field.

The Bombay High–Uran pipeline has a diameter of 65 cm and a capacity of about 13 MMSCMD. The two gas pipelines from South Bassein to Hazira are 90 cm and 105 cm in diameter with capacities of 22 and 30 MMSCMD, respectively. While the terminal at Uran can handle 16 MMSCMD of gas, the terminal at Hazira is being expanded to handle 41 MMSCMD. The Hazira terminal has gas sweetening facilities for treatment of sour gas from South Bassein and other offshore fields.



PIPELINE INFRASTRUCTURE IN INDIA

As regards the gas transmission and distribution network is concerned, a system of about 3800-km long pipeline trunk as well as spur (consumer) lines is presently in position. The largest pipeline system is the HBJ trunk pipeline system, which is more than 2000 km in length. The capacity of the HBJ system was expanded from 18.3 MMSCMD to 33.4 MMSCMD in July 1998. In addition, there are regional gas grids of varying sizes in Gujarat (Cambay Basin), Andhra Pradesh (Krishna–Godavari Basin), Assam (Assam–Arakan Basin), Maharashtra (Ex-Uran terminal), Rajasthan (Jaisalmer Basin), Tamil Nadu (Cauvery Basin), and Tripura (Arakan Basin).

- **Is LNG safe to handle? What happens if there is an LNG spill in the plant or onshore?**

If there is a spill, the plant has following main safety features designed to contain the material.

The first is an extensive system to detect LNG spills utilising a number of gas detectors, fire detectors, smoke or combustion product detectors, and low temperature detectors.

These sensors are equipped with automatic valve and machine shutdowns that isolate the spill and shut down equipment.

The second important containment feature is the LNG storage tank designed to prevent LNG from leaking. Each storage tanks consists of two walls. The first wall made out of high nickel steel, a material that prevents low temperature failures, and a second outer wall is made out of concrete.

- **What would happen if there were vapor leaks onshore from the plant?**

LNG is lighter than air and it rises and dissipates quickly. The facilities are designed with vapor detection systems that shut off leaks to minimise vapour loss to the environment. Without an ignition source the vapours will quickly dilute with the air and not ignite. There are extensive safety procedures in the facilities to avoid any ignition sources and therefore further minimise the likelihood of a fire.

- **Can there be an LNG fire or explosion?**

The chances of a LNG fire or explosion are extremely remote because the natural gas is lighter than air and dissipates so quickly, and because of the many safety features that is applied. In addition, a LNG fire requires first an ignition source and second, the proper concentration of fuel to oxygen ratio. For LNG, the window for the right concentration is very narrow. LNG must have a fuel/air mixture of 5% to 15%. But because LNG is light and dissipates very quickly and mixes with air to below 5%, an ignition would not likely take place. But should there be a fire, the plants are designed with fire detection sensors that would sound an alarm and immediately begin a shutdown procedure.

For a trained fire-fighter, a LNG fire is easier to extinguish than gasoline, fuel oil or propane. From an environmental standpoint there is very little smoke associated with a LNG fire.

LNG fires are easier to extinguish than gasoline, propane and butane. LNG when spilled will evaporate very quickly and form a visible "cloud" of condensing water vapour that makes it look like a fog. Because it is lighter than air it disperses quickly and is not easy to ignite. Propane and butane (LPG) when spilled will form a vapour cloud that is explosive because it is heavier than air and does not disperse. Gasoline and diesel form a flash fire and when spilled will form a flammable pool that requires an environmental cleanup. Both materials burn very hot and black. In contrast, LNG when spilled vaporises and dissipates quickly, is smokeless and leaves no residue. Fire-fighters consider LPG and gasoline fires more dangerous than an LNG fire.

▪ How pure is LNG?

LNG is a very pure form of Natural Gas and is not carcinogenic or toxic. For the Natural Gas to be liquefied all impurities are removed such as:

- Sulphur, carbon dioxide, and mercury which are corrosive to LNG equipment
- Water, which could freeze and cause equipment blockage
- Heavier hydrocarbons which could also freeze like water

The removal of these containment makes LNG, when re-gasified in an import terminal, a very clean and reliable natural gas source for cooling, heating and power.

▪ Is LNG environmentally friendly?

As a fuel, LNG is much cleaner than gasoline or diesel, reducing particle emissions to near zero and carbon dioxide (CO2) emissions by 70%. When burned for power generation, the results are even more dramatic - sulphur dioxide (SO2) emissions are virtually eliminated and CO2 emissions are reduced by 40%.

LNG has the least environmental impact of all fossil fuels.

▪ What is the typical specification of Re-gasified LNG?

The Gross Heating Value in a gaseous state is in the range of 1050 BTU's per Standard Cubic Foot (approximately equal to 9,340 kilo calories per Standard Cubic Meter) to 1170 BTU's per Standard Cubic Foot (approximately equal to 10,420 kilo calories per Standard Cubic Meter).

Component	**Specifications**
Methane (C1)	Not less than 85 Mol %
Ethane (C2)	Not more than 9.2 Mol %
Propane (C3)	Not more than 3.00 Mol %
Butanes (C4) and heavier	Not more than 2.00 Mol %
Pentanes (C5) and heavier	Not more than 0.25 Mol %
Nitrogen (N2)	Not more than 1.25 Mol %
Oxygen (O2)	Not more than 0.5 Mol %
Total Non Hydrocarbons	Not more than 2.0 Mol %
Total Sulphur including H2S	Not more than 10 ppm by weight expected H2S content not more than 4ppm by volume.

Impurities	Gas shall be reasonably free from dust (max size 5 microns), gum forming constituents and other deleterious solid and/or liquid matter, which will cause damage to or interfere with the Operations of Gas Transporter's Facilities.
Water content	not more than 112 Kg/MMSCM

- **What are the Myths about LNG?**

MYTH 1: LNG IS A BOMB! (NOT!)

The notion that LNG represents a bomb waiting to explode never fails to surface.

During the years of controlled testing by independent laboratories and hundreds of thousands of gallons of (intentionally) spilled LNG, ignition of a vapour cloud has not yet caused an explosion. In fact, some testing involved initiating the combustion of the gas cloud with high explosives. The strength of the detonation was no stronger than that delivered by the explosives. Conclusion: The ignition of LNG or LNG vapour will not cause an explosion in an unconfined environment.

Natural Gas is only combustible at a concentration of 5 to 15% when mixed with air. Furthermore, its flame speed is very slow. These facts may best be experienced by a simple demonstration often done at LNG fire schools. A large pit (e.g., 20' x 20') is filled with LNG, allowing the vapour cloud to drift with the wind. The cloud is ignited with a torch from the downwind side. Ignition typically occurs near the visible fringes of the cloud. The resulting flame front moves back toward the pit at a speed only slightly faster than a walk. The pronounced lack of detonation or over-pressure leaves a lasting impression on anyone who has witnessed the ignition of a similar size pool of gasoline or propane.

MYTH 2: LNG VAPOR CLOUDS ARE HUGE AND DEADLY! (NOT!)

Traditionally, LNG vapour dispersion studies have focused on the "worst case", catastrophic failure of enormous storage tanks (25,000,000 gallons) or guillotine failures of ship unloading lines (50,000 gpm for ten minutes). Potential vapour clouds from vehicular LNG are, on the other hand, dwarfed by these "design spills".

The size and travel of an LNG vapour cloud is a function, most of all, of the size and rate of the spill. To a lesser degree, the size and surface of the affected area, atmospheric conditions, and LNG pressure also play a role. Small spills will quickly vaporise on contact with the ground. LNG vapour becomes buoyant in air at as the gas/air mixture rises to temperatures above -160°F. Therefore, it will dissipate rapidly into the atmosphere. Spills large enough to form a dense vapour cloud will similarly dissipate due to the heat from the ground over which the cloud migrates.

Wind plays an important role as well. Conditions of little or no wind reduce movement of the cloud away from the source. The turbulence of higher winds causes rapid dispersion due to the mixing of the vapours with the ambient air.

MYTH 3: LNG IS DIFFICULT (OR COSTLY) TO KEEP COLD! (NOT!)

Stored LNG is analogous to boiling water, only 470° colder. The temperature of boiling water (212°F) 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 is a phenomenon called "auto refrigeration". As long as the steam (LNG vapour boil off) is allowed to leave the tank, the temperature will remain constant.

If the vapour is not drawn off, then the pressure and temperature inside the vessel will rise. However, even at 100 psig, the LNG temperature will still be only about -200°F. It is this pressure rise that may require venting of the on-board fuel tanks after idle periods of 7 to 14 days.

MYTH 4: LNG TECHNOLOGY IS NEW! (NOT!)

The liquefaction of natural gas dates back to early in this century. LNG has been used as vehicle fuel since the mid-60s. Let's go beyond the specific to a more generic look at the technology. LNG is a cryogenic (very low temperature) liquid.

Cryogenic liquids are a common part of life today and, as such, have been around for some time. The technology of storage and handling of all cryogenic liquids is very similar, independent of the product. Check behind any hospital and you will most likely find a vertical white tank containing liquid oxygen (-296°F). Electronics firms, food processors, and many other operations routinely store and use liquid nitrogen (-320°F).

Liquid hydrogen (-423°F), along with liquid oxygen, is used as rocket engine fuel. The low temperatures of liquid helium (-452°F) are critical in the operation of MRI medical diagnosis equipment. Trucks carrying any of these liquids, along with LNG, are common sights on the highway.

- **How does LNG compare with other fuels in terms of Energy?**

The consumption of various fuels will depend on the calorific value of the product. A typical value of various products is shown in the table below:

CALORIFIC VALUE OF DIFFERENT FUELS

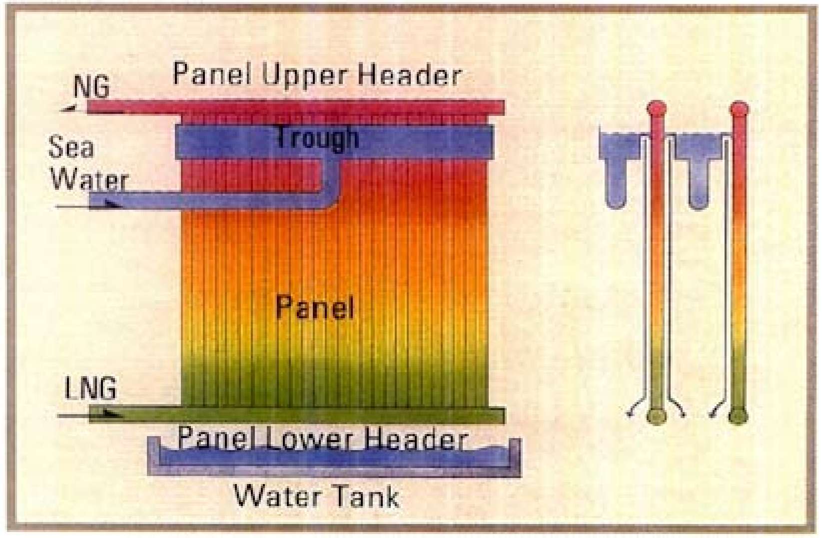
PRODUCT	SP. GRAVITY MIN.	MAX.	INDICATIVE GCV.
Naphtha	0.73	0.75	11400 Kcal/Kg
MS	0.72	0.72	11250 Kcal/Kg
SKO	0.78	0.80	11100 Kcal/Kg
HSD	0.82	0.86	10900 Kcal/Kg
LDO	0.88	0.91	10700 Kcal/Kg
FO / LSHS	0.96	0.98	10300 Kcal/Kg
LNG (Re-gasified)	0.40	0.40	9340 Kcal/SCM*
LPG (Liquid)	0.54	0.54	11200 Kcal/Kg

* THE CALORIFIC VALUE OF ALL PRODUCTS ARE IN KCal / KG EXCEPT FOR LNG WHICH IS IN KCAL / SCM.

- **How LNG is Re-gasified?**

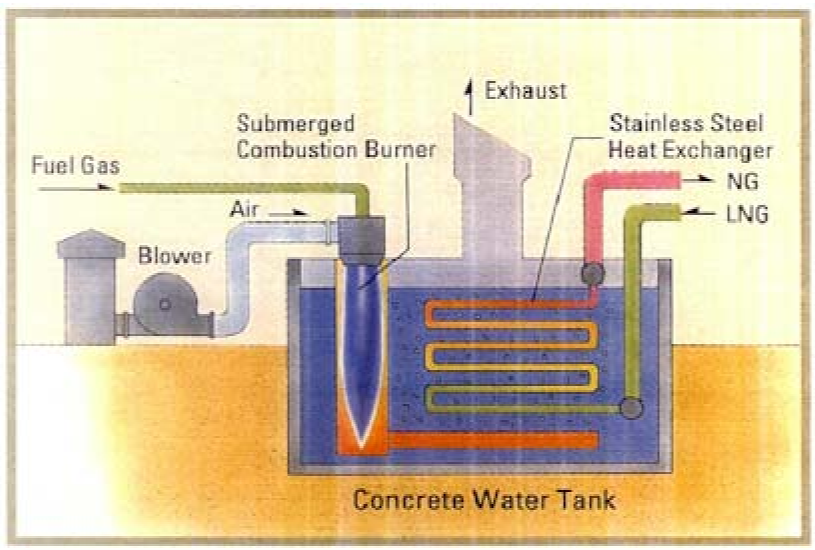
Regasification of LNG is the state that converts the Natural gas from its cryogenic liquid form to its normal gaseous state, ready for transmission by pipeline to the down stream consumer or user. Thermal energy (heat) is required to vaporise or re-gasify the LNG. For base load application the heat may be obtained either from seawater or from the combustion of a portion of the Natural Gas.

Nearly two-thirds of the base load vaporisation throughout the world is done using seawater as the heat source. The equipment used is called the Open Rack Vaporiser (ORV) which is shown below:

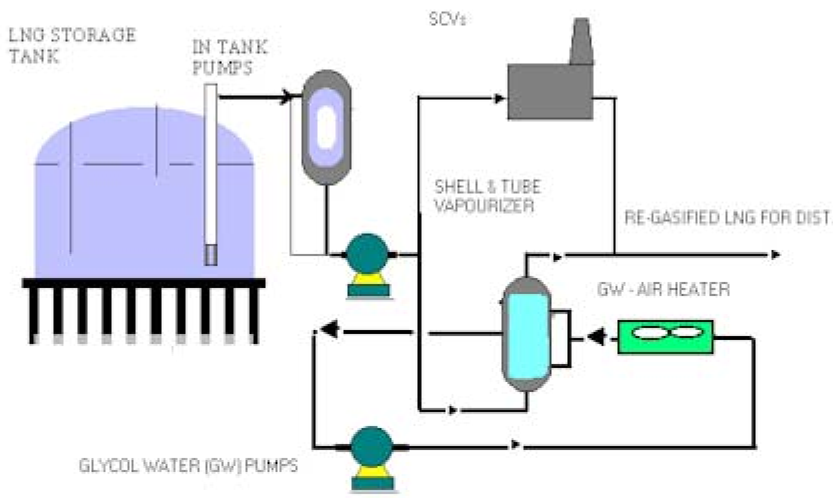


LNG Vapouriser- Basic Flow of ORV

Facilities employing Natural Gas combustion as the heat source usually use Submerged Combustion Vaporisers (SCV) to transfer the heat to the LNG as shown below:



LNG Vapouriser- Basic Flow of SCV



Schematic diagram of STV+SCV used at Dahej LNG Terminal

The shell and tube vaporisers shown above uses process fluid in the tube side and heating medium on the shell side. The heating medium chosen could be 36% Glycol-water mixture or 22% Methanol–water mixture. This heating medium has been chosen to prevent freezing inside the exchanger and to ensure high heat transfer rate. The ambient air in-turn heats the return Glycol-water mixture.

- **What are the design aspects of LNG Storage Tanks?**

Most large LNG tanks in service today, including all the large LNG tanks in the United States, are of the single-containment, double-wall type, build in accordance with API Code 620, Appendix Q.

Another standard that has influenced the design of many LNG tanks, especially outside the United States, is British Standard BS 7777 (1993). BS 7777 has its origin in the Engineering Equipment and Materials User's Association (EEMUA) Publication 147. This document pushed industry standards beyond the "single containment" concept to the "enhanced integrity" concept.

Enhanced integrity tanks include double containment and full containment tanks. The main features of the single-, double- and full containment tanks are summarised below:

1. Single Containment Tank

- Consists of a primary container and generally an outer shell
- Only the primary container is required to meet the low temperature ductility requirement for storage of the product.

- The outer shell is primarily for retention and protection of the insulation, and for containing the gas pressure.

- In the event of leakage from the primary container the outer tank is not designed to contain the refrigerated liquid

- An aboveground single containment tank is surrounded by a bund wall or dike to contain any leakage.

2. Double Containment Tank

- Both the inner self-supporting primary container and the secondary container are capable of independently containing the refrigerated liquid

- The secondary container is located at a distance of 6 meters or less, from the primary container

- The secondary container is intended to contain any leakage of the refrigerated liquid from the primary container. However, it is not intended to contain any vapour resulting from such a leakage.

3. Full Containment

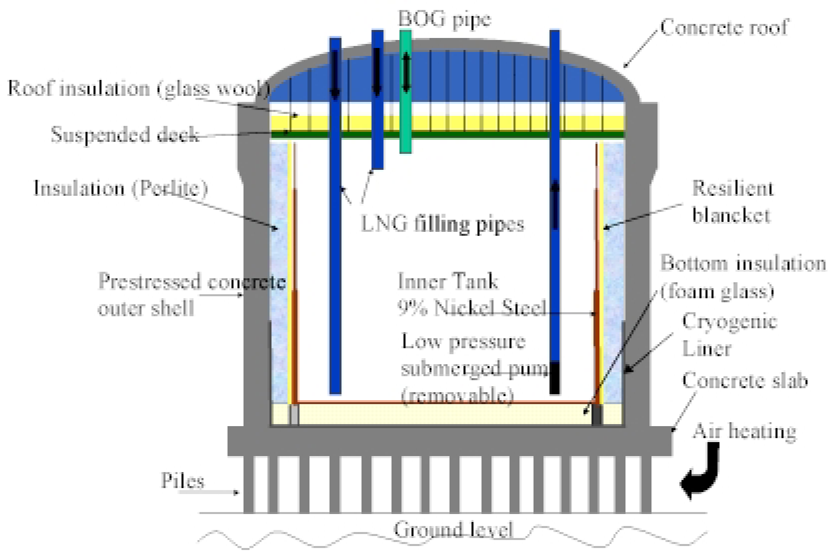
- Both the self-supporting primary container and the secondary container are capable of independently containing the refrigerated liquid

- The outer tank wall is 1 to 2 meters distant from the inner tank

- Normally the inner tank contains the refrigerated liquid

- The outer tank is capable both of containing the refrigerated liquid and of controlled venting of the vapour resulting from product leakage after a credible event

- The roof is supported by the outer tank



Full Containment above ground LNG Tank

- **What are the Codes and Standards followed to design a LNG regasification Terminal?**

LNG Re-gasification facilities

General view LNG Terminal

LNG Terminal must comply with the codes and standards prescribed by the Governmental and other regulatory bodies having jurisdiction over the facility. Examples include the United States, Japan, the United Kingdom, France and India.

The United States

In the United States the LNG industry, especially for peak shaving utility applications, has been around for well over 50 years. The use of LNG beyond the utility industry provided the impetus to adopt a standard with broader scope and led to the development of the National Fire Protection Association, 59 A – Standard for the production, storage and handling of Liquefied Natural Gas (LNG). The standard commonly referred to as NFPA 59 A, is one of the most widely referred to in the LNG industry.

The two U.S. standards applicable to the design and construction of LNG storage tanks are API 620. Design and Construction of Large, Welded Low Pressure Storage Tanks, and NFPA 59, Standard for Storage of Liquefied Petroleum Gases and Utility Gas Plants.

Requirement for LNG tanker operations are governed by the US Coast Guard regulations in 33 CFR Part 127, Liquefied Natural Gas Water front Facilities. Standards published by the Society of International Gas Tanker and Terminal Operations (SIGTTO) and Oil Companies International Marine Forum (OCIMF) provided additional dock safety and operating systems and procedures.

Other standards that supplement the above include ANSI B31.3 (American National Standards Institute, Refinery and Chemical Plant Piping Code), the ASME International Pressure Vessel Code Section VII, and standards issued by the American Gas Association (AGA), American Society for Testing and Materials (ASTM), and American Concrete Institute (ACI).

Japan

In Japan, provision for LNG facilities is contained in the High Pressure Gas Control Act, the Gas Utility Industry Act and the Electricity Act. Which jurisdiction an LNG facility falls under will be governed by the end use for the gas (gas utility, power generation, or other uses). Requirements of the Factory Location Act, Petroleum Industry Complex Casualty Prevention Act, Labour Safety and Health Law, Fire Prevention Law etc. also govern the design and operation of LNG facilities. In addition, Japan Gas Association has codes and standards pertaining to safety practices in LNG facilities, and for LNG in-ground storage.

European Standards

In 1997 the new European Standard Installation and equipment for liquefied natural gas – Design of onshore installations, was published. It has been published as British Standard EN 1473. The European Standard was approved by the European Committee for Standardisation (CEN). According to CEN internal regulations the national standards organisations of most Western and Southern European countries are bound to implement this European Standard. The list of these countries can be found on the standard.

The British Standard for low temperature tanks, BS 7777, Flat-bottom vertical cylindrical storage tanks for low-temperature service, is applied in many countries.

Indian Standards

OISD – STD – 194 is a standard for the storage and handling of Liquefied Natural Gas (LNG). This standard provides for safety and design aspects of all the major components of LNG receiving terminal facility including unloading, storage and distribution of LNG. This standard also outlines the operating practices for protection of persons & properties and provides guidelines to all the persons concerned with the operation of LNG receiving, storage, regasification and other associated facilities.

▪ What are the modes of transportation of Natural Gas?

The most natural way of bulk transportation of gas is by pipeline. Wherever a pipeline is not feasible, natural gas is liquefied and transported in ocean going vessels.

▪ How is LNG transported?

LNG is usually transported through cryogenic ships. The size of LNG ships is slowly increasing. Current vessels have capacities around 138 - 145,000 m3, but designs are now on the table for capacities of 165,000 and 200,000 m3 and over.

LNG tankers are double-hulled ships specially designed and insulated to prevent leakage or rupture in an accident. The LNG is stored in a special containment system within the inner hull where it is kept at atmospheric pressure and -256ºF. Three types of cargo containment systems have evolved as modern standards. These are:

• The spherical (Moss) design 52%

• The membrane design 43%

• The structural prismatic design 5%

(Source: LNG One World)

The figure above shows that currently most of the LNG ships use spherical Moss) tanks and they are easily identifiable as LNG ships because the top half of the tanks is visible above the deck. The typical LNG carrier can transport about 125,000 - 138,000 cubic meters of LNG, which will provide about 2.6 - 2.8 billion standard cubic feet of natural gas. The typical carrier measures some 900 feet in length, about 140 feet in width and 36 feet in water draft, and cost about $160 million. This ship size is similar to that of an aircraft carrier but significantly smaller than that of Very Large Crude oil Carrier (VLCC). LNG tankers are generally less polluting than other shipping vessels because they burn natural gas in addition to fuel oil as a fuel source for propulsion.

The LNG shipping market is expanding. According to LNG One World as of December 2002, there were 136 existing tankers, with 57 on order. Twelve new LNG tankers were ordered in 2002 of which eight tankers have been delivered. About 20 percent of the fleet is less than five years old. The LNG tanker fleet size is estimated to continue to grow to 193 tankers by 2006.

LNG Shipping