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Comparative Studies of Liquefaction Natural Gas (LNG) & its Demand

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Abstract: Natural gas has been formed by the degradation of organic matter accumulated in the past millions of years. Two main mechanisms (***biogenic*** and ***thermogenic***) are responsible for this degradation. Natural gas is a complex mixture of hydrocarbon and non-hydrocarbon constituents and exists as a gas under atmospheric conditions. The objective of gas processing is to separate: Natural gas, Condensate, Non-condensable, Acid gases, Water. The raw gas is first treated to remove typical contaminants. Next, the treated gas is chilled, cooled and condensed to -162°C in succession using propane, ethylene and methane. Last stage is pumping LNG to storage tanks and awaiting shipment. Liquefied natural gas is used to transport natural gas over long distances, often by sea. In most cases, LNG terminals are purpose built ports used exclusively to export or import LNG. Natural gas consists almost entirely of methane (CH_4), the simplest hydrocarbon compound. India is the 14th largest gas consumer 58 bcm (~158 mmscmd), 4th largest LNG importer 31 bcm (~82 mmscmd), Economy growing at CAGR of about 6-7% with similar growth in Energy Consumption. Government aims to significantly increase share of Natural Gas in Indian Energy basket to in coming years. Despite increase in domestic gas production dependency on imported gas to increase substantially. Pipeline network developing into a national grid needs to grow faster, connecting new markets. ExxonMobil's history in China dates back to 1892. This paper provides the present demand of LGN in India and also predicts future requirements, to help India's economic and social growth.

Keywords:- *LNG (Liquefied Natural Gas), Hydrate, Methane, Phase-Transition, CNG & LPG.*

I. BACKGROUND

Natural gas is one of the world's most important sources of energy. Today, approximately 30% of the world's energy needs are met with this gas. Most of it is supplied in gaseous form by pipeline. However, over the past two decades, Liquefied Petroleum Gas (LPG), Natural Gas Liquids (NGL) and ***Liquefied Natural Gas*** (**LNG**) have become much more important in the world's energy market. Typically, LNG is 85 to 95- plus percent Methane, along with a few percent Ethane as dissipated in Figure (1). Natural gas has been formed by the degradation of organic matter accumulated in the past millions of years. It also contains varying amounts of: Heavier gaseous hydrocarbons: ethane (C_2H_6), propane (C_3H_8), normal butane (n-C_4H_{10}), iso-butane (i-C_4H_{10}), pentanes and even higher molecular weight hydrocarbons. ***Acid gases:*** carbon dioxide (CO_2), hydrogen sulfide (H_2S) and mercaptans such as methanethiol (CH_3SH) and ethanethiol (C_2H_5SH).

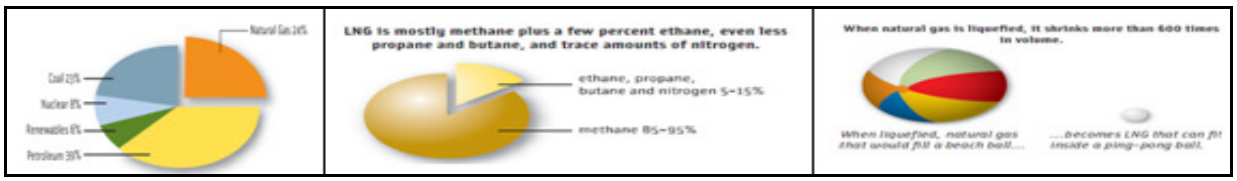
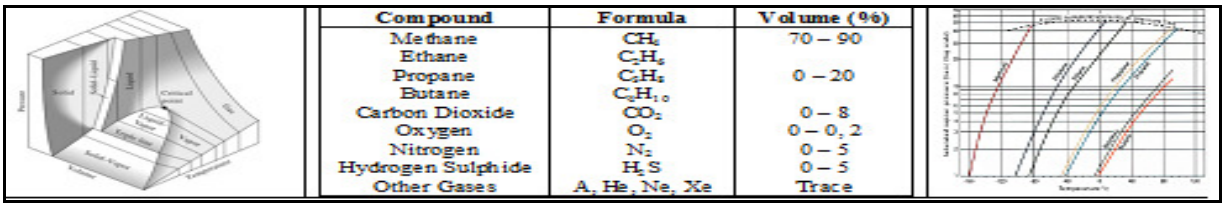


Figure (1):- Typically, LNG is 85 to 95- plus percent Methane, along with a few percent Ethane [1].

Natural gas exists in nature under pressure in rock reservoirs in the Earth's crust, either in conjunction with and dissolved in heavier hydrocarbons and water or by itself. It is produced from the reservoir similarly to or in conjunction with crude oil. Two main mechanisms (***biogenic*** and ***thermogenic***) are responsible for this ***degradation***. The general chemical composition of natural gas includes a mixture of mostly methane but as well as ethane, propane and butane with the addition of other hydrocarbons which are heavier. In addition to this, impurities such as nitrogen or hydrogen sulfide are extracted before the point of liquefaction. The boiling point of this liquid is able to define the moment at which the gas is able to transform into a liquid. The saturation dome as shown in Figure (2) provides graphically represents the relationship between pressure, temperature and volume of the substance in a unit percentage.



Compound	Formula	Volume (%)
Methane	CH_4	70 – 90
Ethane	C_2H_6	
Propane	C_3H_8	0 – 20
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0 – 8
Oxygen	O_2	0 – 0, 2
Nitrogen	N_2	0 – 5
Hydrogen Sulphide	H_2S	0 – 5
Other Gases	A, He, Ne, Xe	Trace

Figure (2):- Showing Saturation Dome with Comparative Present in a unit percentage [2].

Further, the density of LNG depends slightly on the composition of the gas but in general it should sit at around 420 kg/m^3 and 480 kg/m^3 (3.5 lb/gal to 4 lb/gal). Specific gravity of the gas is relative to the density of the gas to the density of water ratio. The specific gravity of Methane at ambient temperature is about 554 and therefore this is lighter than air and this allows the gas to disperse easily in open areas. LNG in ambient conditions becomes a vapor and forms a cloud until it is able to diverge. The "***Flammable Range***" depicts the range of which the concentration of a certain gas or vapor is able to burn with the presence of an ignition source. These limits are referred to as the "***Lower Flammable Limit***" and the "***Upper Flammable Limit***" (**LFL** and **UFL**). LNG vapors are flammable if there is the presence of 5%-15% concentration of natural gas in the air.

The industrial sector relies on natural gas as a feedstock or fuel for manufacturing many of the products we rely on today, including pulp and paper, metals (for computers, automobiles, and telecommunications), chemicals, fertilizers, fabrics, pharmaceuticals, and plastics. The gas produced from hydrocarbon deposits typically contains a wide range of hydrocarbon products, which usually includes methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). All these products have wide ranging boiling points and also different heating values allowing different routes to commercialization and also different uses. The "**acidic**" elements such as hydrogen sulphide (H_2S) and carbon dioxide (CO_2), together with oil, mud, water, and mercury, are removed from the gas to deliver a clean sweetened stream of gas. Failure to remove such acidic molecules, mercury, and other impurities could result in damage to the equipment. Corrosion of steel pipes and amalgamization of mercury to aluminum within cryogenic heat exchangers could cause expensive damage. Due to its cryogenic nature, LNG will freeze any material it contacts as flow chart is shown in Figure (3). The natural gas is into a liquid at close to atmospheric pressure by cooling it to approximate -162°C (−260°F); maximum transport pressure is set at around 25 kPa**.**

Figure (3):- LNG's liquefaction / refrigeration and nitrogen rejection is 32%, Utilities & offsets 27%, Storage & loading is 24%, gas treatment 12%, and fractionation 5% [4].

II. INTRODUCTION

Liquefied Natural Gas LNG is natural gas in liquid form. In order to liquefy natural gas, it must be cooled to cryogenic temperatures of approximately -160°C (-260°F). LNG is odorless, colorless, noncorrosive, and nontoxic. Hazards include flammability after vaporization into a gaseous state, freezing and asphyxia. The visible Methane at Seabed to phase transitions to the LNG is shown in Figure (4). The liquefaction process involves removal of components, such as dust, acid gases, helium, water, heavy hydrocarbons, which could cause difficulty downstream.

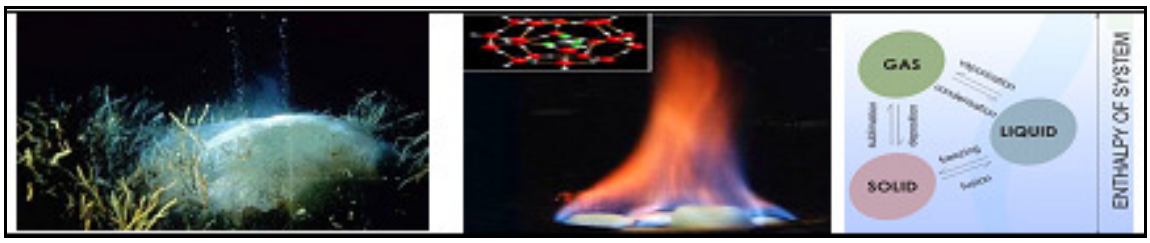


Figure (4):- Methane at Seabed to Phase Transitions to the LNG [5].

Natural gas produced from geological formations comes in a wide array of compositions. The varieties of gas compositions can be broadly categorized into three distinct groups:

- Non-associated gas it occurs in conventional gas fields.
- Associated gas it occurs in conventional oil fields.

The varieties of gas compositions can be broadly categorized into three distinct groups; non-associated gas it occurs in conventional gas fields, associated gas it occurs in oil fields with the enthalpy of fusion is the change in enthalpy, is as shown in Figure (5).

Figure (5):- Enthalpy of fusion is the change in enthalpy resulting from heating a given quantity of a substance to change its state from a solid to a liquid [6].

Raw natural gas after transmission through the field-gathering network must be processed before it can be moved into long-distance pipeline systems for use by consumers [7]. Raw natural gas typically consists primarily of methane (CH_4), the shortest and lightest hydrocarbon molecule. It also contains varying amounts of: ***Heavier gaseous hydrocarbons***: ethane (C_2H_6), propane (C_3H_8), normal butane (n-C_4H_{10}), iso-butane (i-C_4H_{10}), pentanes and even higher molecular weight hydrocarbons. ***Acid gases***: carbon dioxide (CO_2), hydrogen sulfide (H_2S) and mercaptans such as methanethiol (CH_3SH) and ethanethiol (C_2H_5SH). Phase transition is the transformation of

thermodynamic system from one phase (referred to as "***state of matter***") to another energy transferred to environment as shown in Figure (6).

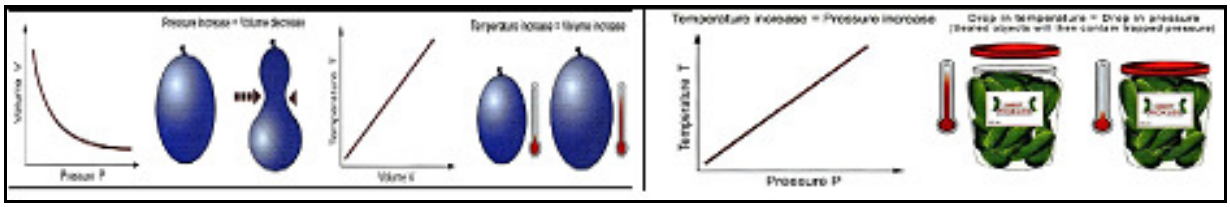


Figure (6):- Enthalpy change accounts for energy transferred to environment at constant pressure through expansion or heating, Gas has three quantities: - Volume, Temperature, and Pressure.

Three major Gas rules govern the behaviour of gases: - Boyle's Law, Charles' Law, Gay-Lussac's Law their behaviour is shown in Figure (6). The LNG industry developed slowly during the second half of the last century because most LNG plants are located in remote areas not served by pipelines, and because of the large costs to treat and transport LNG. Constructing an LNG plant costs at least $1.5 billion per 1 MTPA capacity, a receiving terminal costs $1 billion per 1 bcf/day throughput capacity and LNG vessels cost $200 million – $300 million.

Figure (7):- Sector-wise Natural Gas Demand and Processing of LNG for (2030) [8].

The enthalpy of fusion is a latent heat, because during melting the introduction of heat cannot be observed as a temperature change, as the temperature remains constant during the process. The industrial sector relies on natural gas as a feedstock or fuel for manufacturing many of the products we rely on today, including pulp and paper, metals (for computers, automobiles, and telecommunications), chemicals, fertilizers, fabrics, pharmaceuticals, and plastics the sector-wise natural gas demand and processing of LNG for up-to 2030 is shown in Figure (7). The transportation sector is beginning to see natural gas as a clean and readily available alternative to other fossil fuels.

III. METHODOLOGY

The concept of Liquefied Natural Gas (LNG) is a response to the inefficiency of natural gas pipelines and the technical and economic problems of running pipelines over long distances [9]. If natural gas is cooled at minus 160.5°C, it becomes liquid and more compact, occupying just 1/600th of the gaseous volume. This is because most of the heavier hydrocarbons are removed during liquefaction. The cargo that is transported in bulk by sea is predominantly methane (over 80%) a colourless, odourless, transparent liquid which is non-toxic, non-corrosive and less dense than water. As LNG is highly volatile, specialist operators are involved in its transportation. Natural gas pretreatment typically consists of mercury removal, gas sweetening and drying. Depending on the downstream processing steps and the hydrogen sulfide (H_2S) and carbon dioxide (CO_2) concentration in the natural gas, it may be necessary to remove H_2S and CO_2 from acid natural gas. Scrubbing processes such as MDEA, Benfield or SULFINOL are used for these steps. If the H_2S concentration is low, the acid components and water can be removed by means of adsorption. Mercury guard beds are recommended to protect people and equipment. Major international oil companies (**IOCs**) such as

ExxonMobil, Royal Dutch Shell, BP, Chevron. Total and national oil companies (**NOCs**) such as Pertamina, and Petronas are active players.

3.1 Primary LNG Project / Chain Components are: Upstream development of long-term natural gas supply for feed gas to an LNG plant, downstream development of liquefaction , storage and loading facilities, Marine transportation, Downstream development of receiving terminals for re-gasification and pipeline transportation to market [10]. Typical LNG is about 87-92% methane, with most of the remainder being liquid ethane. With additional processing, ethane and nitrogen components can be removed as well, yielding a product that is 99 + % pure methane. An important concern with use of liquid methane/ethane mixtures is possibility of changes in fuel composition during handling & processing. This is known as "**weathering"**, or "**enrichment**".

3.2 Four liquefaction processes can be distinguished: - C3MR or ACPI (designed by Air Products & Chemicals), Cascade (designed by ConocoPhillips), Shell DMR & Linde are shown below in Figure (8). In these processes the raw gas is first treated to remove typical contaminants. Next, the treated gas is chilled, cooled and condensed to 162°C in succession using propane, ethylene and methane. Last stage is pumping LNG to storage tanks and awaiting shipment [11].

3.2a CASCADE: - The raw gas is first treated to remove typical contaminants. Next, the treated gas is chilled, cooled and condensed to -162°C in succession using propane, ethylene and methane. The ConocoPhillips cascade process includes proprietary technology necessary to efficiently and effectively liquefy natural gas, while recovering heavier hydrocarbons as a separate product to prevent freezing, and removing nitrogen, if required. The methods we use to integrate the technologies result in a lower cost and maximum efficiency of the overall LNG plant. The Optimized Cascade process is based on three multi-staged, cascaded refrigerant circuits using pure refrigerants, brazed aluminum heat exchangers and insulated cold box modules. ConocoPhillips has optimized the heat integration to closely approach the natural gas and refrigerant cooling curves, resulting in a highly efficient process. Pure refrigerants of propane, ethylene and methane are utilized, since their physical properties are ideal for heat integration. The refrigerant properties are also well known and predictable, contributing to unrivaled operating ease and flexibility. Brazed aluminum heat exchangers and cold box modules allow for highly efficient heat transfer and can be designed to accommodate a wide range of LNG plant sizes. Depending on the natural gas feed stream composition, design of LNG train could be included an integrated heavy's removal unit (HRU) and a nitrogen rejection unit (NRU) to achieve LNG plant performance and economic targets [12].

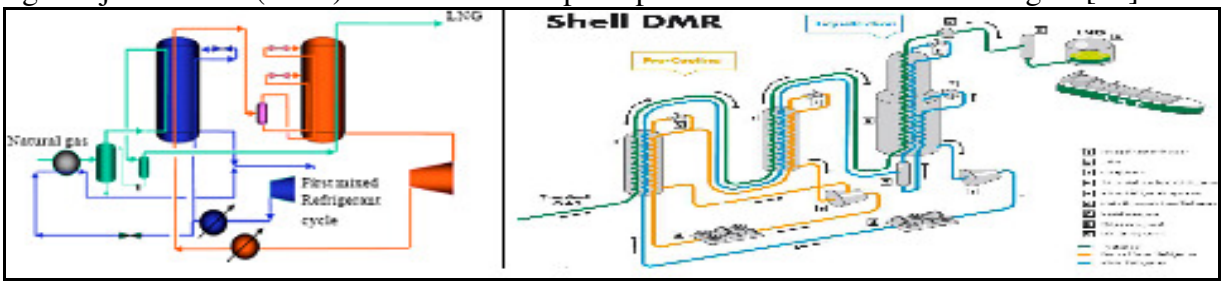


Figure (8):- Shell DMR, Linde. In CASCADE Process the raw gas is first treated to remove typical contaminants.
1st. stage cools natural gas to 50°C while 2nd. Column cools natural gas to LNG at -160°C.

3.2b DMR – Dual Mixed Refrigerant is very similar to C3MR

- The difference is in utilization of a second pre-cooling refrigerant component.
- Use of two mixed refrigerant cycles allows full utilization of power in a design with two mechanically driven compressors.

- The natural gas stream is cooled via two stages. The first stage cools natural gas to -50°C while the second column cools natural gas to LNG at -160°C.

LNG must be kept cold to remain a liquid, independent of pressure. Despite efficient insulation, there will inevitably be some heat leakage into the LNG, resulting in vaporization of the LNG. This boil-off gas acts to keep the LNG cold. The boil-off gas is typically compressed and exported as natural gas, or it is re-liquefied and returned to storage. Although diesel has a higher energy density than LNG [13], volume of greenhouse gas (GHG) and criteria air contaminant (CAC) emissions associated with both upstream & downstream sectors is for natural gas Table [1].

Table [1]:- Emission from Natural Gas.

	Carbon Dioxide (kg/m^3)	**Methane (kg/m^3)**	**Nitrous Oxide (kg/m^3)**
Extraction	0.043	2.3×10^{-3}	4×10^{-6}
Processing	0.090	3×10^{-4}	3×10^{-6}
Combustion	1.918	3.7×10^{-5}	3.5×10^{-5}
TOTAL	**2.051**	**2.64×10^{-3}**	**4.2×10^{-5}**

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. LNG typically contains more than 90 percent methane. It also contains small amounts of ethane, propane, butane, some heavier alkanes, and nitrogen. The purification process can be designed to give almost 100 percent 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. The largest LNG train in operation is in Qatar, with a total production capacity of 7.8 million tonnes per annum (**MTPA**). These facilities recently reached a safety milestone, completing 12 years of operations on its offshore facilities without a Lost Time Incident, [14].

3.2c The StarLNG concept originally targeted small-scale LNG liquefaction capacities ranging between 100 and 600 tpd (tonnes per day). Such plants typically consist of natural gas treatment (acid gas removal and dehydration) and liquefaction units, an LNG storage tank and an LNG truck filling station. The natural gas is cooled, liquefied and sub cooled in a plate-fin heat exchanger (PFHE) mounted in a cold box using Linde's highly efficient single mixed refrigerant cycle process, LIMUM®1. This mixed refrigerant cycle uses four refrigerants: nitrogen, methane, ethylene or ethane (depending on availability) and butane as basic schematic is shown in Figure (9). The Proven PFHEs manufactured by Linde Engineering, Once-through liquefaction of pretreated (dry and sweet) NG, Alternative process technology based on double nitrogen, Compact modular design.

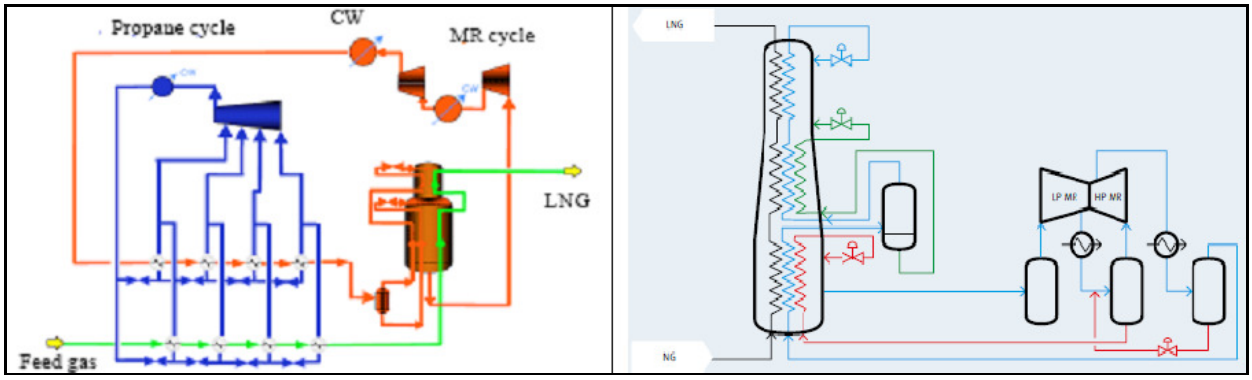


Figure (9):- Mid-scale Star LNG:- Building on the StarLNG concept, the mid-scale LNG designs support capacities ranging from 600 to 3000 tpd (equivalent to approx. 1 mtpa). Here we use our LIMUM[3] liquefaction process based on our proprietary coil-wound heat exchangers (CWHEs).

3.2d Mid-scale Star LNG: - Building on the StarLNG concept, the mid-scale LNG designs support capacities ranging from 600 to 3000 tpd (equivalent to approx. 1 mtpa). Here we use our LIMUM[3] liquefaction process based on our proprietary coil-wound heat exchangers (CWHEs). This avoids multiple parallel blocks of PFHEs, which can result in complex piping arrangements, higher plot space requirements and flow distribution issues. CWHEs offering extremely robust design, and ease of operation, same exchangers as those used for most world-scale plants, extended for liquefaction capacities >1 mtpa per train. Three separate refrigerant fractions provide refrigeration duty separately for pre-cooling, liquefaction, & sub-cooling bundles, Part load capability of less than 30% [15]. The trade of LNG is completed by signing an SPA (sale and purchase agreement) between a supplier and receiving terminal, and by signing a GSA (gas sale agreement) between a receiving terminal and end-users.

IV RESULTS & DISCUSSION

Quality regulations serve three purposes:- to ensure that the gas distributed is non-corrosive and non-toxic, below the upper limits for H_2S, total sulphur, CO_2 and Hg content; to guard against the formation of liquids or hydrates in the networks, through maximum water and hydrocarbon dew points; to allow interchangeability of the gases distributed, via limits on the variation range for parameters affecting combustion: content of inert gases, calorific value, Wobbe index, Soot Index, Incomplete. The quality of gas or LNG is measured at delivery point by using an instrument such as a gas chromatograph. The most important gas quality concerns involve the sulphur and mercury content and the calorific value. Due to the sensitivity of liquefaction facilities to sulfur and mercury elements, the gas being sent to the liquefaction process should be accurately refined and tested in order to assure the minimum possible concentration of these two elements before entering the liquefaction plant, hence there is not much concern about them. Although diesel has a higher energy density than LNG, the volume of greenhouse gas (GHG) and criteria air contaminant (CAC) emissions associated with both the upstream and downstream sectors is greater for diesel than it is for natural gas as shown in Table [2];

Table (2):- GHG and CAC emission from diesel and Natural Gas.

	DIESEL		
	Carbon Dioxide (kg/m^3)	**Methane (kg/m^3)**	**Nitrous Oxide (kg/m^3)**
Diesel Production	138	10.9	0.004
Diesel Combustion	2663	0.133	0.4
TOTAL	**2801**	**11.03**	**0.404**
		Natural GAS	
	Carbon Dioxide (kg/m^3)	**Methane (kg/m^3)**	**Nitrous Oxide (kg/m^3)**
Natural Gas Extraction	0.043	2.3×10^{-3}	4×10^{-6}
Natural Gas Processing	0.090	3×10^{-4}	3×10^{-6}
Natural Gas Combustion	1.918	3.7×10^{-5}	3.5×10^{-5}
TOTAL	**2.051**	**2.64×10^{-3}**	**4.2×10^{-5}**

CNG is **Compressed Natural Gas**, which is mainly methane compressed at a pressure of 200 to 248 bars. **LPG** is **Liquefied Petroleum Gas**, a mixture of propane and butane liquefied at 15 °C and a pressure of 1.7 - 7.5 bar. Some variants of LPG are primarily propane so LPG is often colloquially called propane. CNG is cheaper and cleaner, but LPG has a higher calorific value. Distribution is easier for natural gas over long distances via pipelines is as shown in Table (3).

Table (3):- CNG VERSUS LPG COMPARISON

	CNG	**LPG**
Constituents	Methane	Propane and Butane
Source	Obtained from natural gas-and-condensate wells, oil wells, coal bed methane wells.	Automatically generated from gas fields when natural gas is extracted from the reservoir. By-product of cracking process during crude-oil refining.
Uses	Substitute for gasoline in automobiles.	Heating and cooking in homes, refrigeration, industrial, agricultural, catering and automobile fuel.
Environmental effects	Releases lesser greenhouse gas.	Releases **CO_2** which is a greenhouse gas but is cleaner when compared to gasoline.
Properties	It is lighter than air and hence disperses quickly in the event of spillage.	Highly inflammable. It is heavier than air and on leakage will settle to ground and accumulate in low lying areas.
Safety	Easily disperses, hence risk of ignition is minimized.	Since it is difficult to disperse risk of fire is more.

LPG, vaporized and at atmospheric pressure, has a higher calorific value (94 MJ/m^3 or 26.1kWh/m^3) than natural gas (38 MJ/m^3 or 10.6 kWh/m^3). This LPG produces more energy than the equivalent amount of natural gas. Although CNG does produce greenhouse gases upon combustion, it is a more environmentally clean alternative to other fossil fuels like gasoline or

LPG. CNG is also safer than other fuels in the event of a spill because natural gas, being lighter than air, disperses quickly when released. **Substituting LPG for CNG: -** Because LPG produces more energy than CNG, it cannot simply be substituted for natural gas. Only gases that have the same Wobbe Index are interchangeable. For LPG to have the same Wobbe index as CNG, it has to be mixed with air. A 60:40 ratio for LPG: air mixing is common but it depends upon the composition of LPG because LPG itself is a mixture of propane and butane. This mixture of LPG and air to substitute natural gas is called synthetic natural gas (SNG). Use of SNG is common before the CNG distribution network is fully operational. Odorant: - Ethanethiol or ethyl mercaptans is commonly added to both LPG and CNG. Mercaptans have a foul, rotten-egg smell that makes it easy to detect gas leaks.

V IMPACTS on LNG Uses & Applications

- **Automobiles;** Any vehicle running on gasoline can be converted to a bi-fuel vehicle (gasoline/CNG). It involves installing a CNG cylinder in the trunk, installing the plumbing system, installing CNG injunction system and the electronics. In California, transit agency buses run on CNG. Coco Cola Enterprises delivered its beverages to London Olympics Games 2012 in bio methane fueled Lorries. A large number of vehicles, light, medium and heavy duty, around the world are fueled by LPG. There about 1,600 bi-fuel Ford F-150 pickup trucks in the California state fleet. Propane fueled forklifts are used both inside and outside warehouses and at construction sites.
- **Locomotives**: Napa Wine Valley Train has been converted to be run with CNG. FerroCarril Central Andino in Peru has been running a freight line on CNG run locomotive since 2005. Iran, Pakistan, Argentina, Brazil and India have the highest number of CNG vehicles run.
- **Heating**: LPG is used an alternative to heating oil and electricity in places where there is no natural gas pipe line.
- **Cooking**: LPG is the most common cooking fuel in India and urban Brazil.
- **Refrigeration**: Gas absorption refrigerators and air conditioning systems use LPG. But its use in motor vehicles for air conditioning has been discouraged due to the risk of fire.

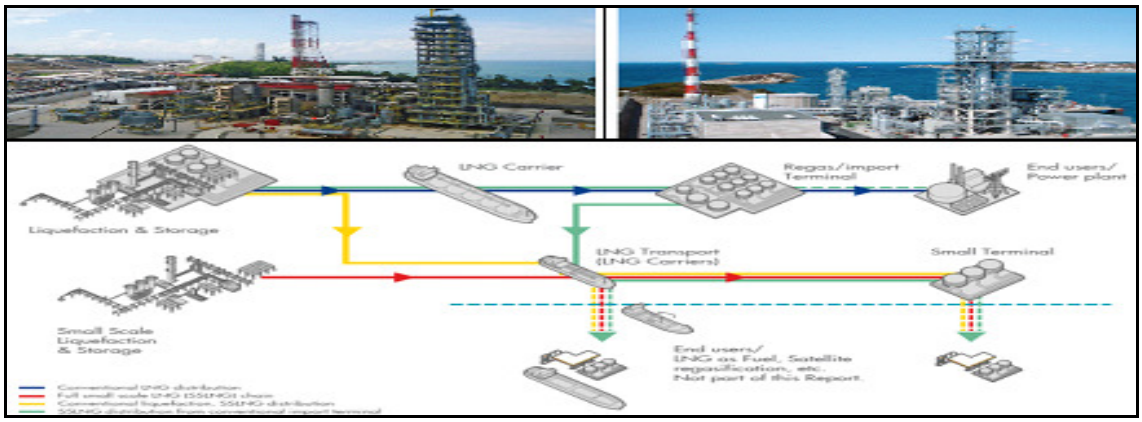


Figure (10):- Today, approximately 30% of the world's energy needs are met with this gas.

Natural gas vehicles have lower maintenance costs when compared with other fossil fuel-powered vehicles. The fuel systems are sealed. This prevents any spill or evaporation losses. The emission of greenhouse gases is reduced 80% when compared to gasoline vehicles. Natural gas disperses easily in air and is not flammable. CNG occupies more space than gasoline. Additional space in the trunk of a car or the bed of a pickup truck is used to store the CNG tanks. This problem has been mitigated in factory-built CNG vehicles by installing the tanks under the vehicle body, e.g. Fiat Multipla, Fiat Panda, Volkswagen Touran Eco-fuel, Volkswagen Caddy Eco-fuel, and Chevvy

Taxi. LPG has lower energy density than gasoline or diesel and hence the equivalent fuel consumption is more. LPG provides less upper cylinder valve lubrication. If a LPG-fueled engine is not suitable modified, it will lead to valve wear. It does not disperse easily and is readily inflammable.

Table [4]:- List of Countries by Natural Gas Imports.

Rank	Country / Region	Natural Gas Imports (cu m)
	World	957,600,000,000
	European Union	420,600,000,000
1	Japan	99,774,000,000
2	Germany	99,630,000,000
3	India	80,600,000,000

CNG is cheaper and cleaner, but LPG has a higher calorific value. Liquefied natural gas (LNG) is often regarded as extremely dangerous and toxic with container ships called floating bombs. LNG spills on water do not harm aquatic life or damage waterways in any way. A very high level of investment is required to set up an LNG plant. A typical plant would cost in the range of 2 to 4 billion US Dollars. In addition, investment is required to build receiving terminals and LNG carriers. LNG transportation is at atmospheric pressure so any leakage of the liquid will vaporize to the atmosphere. Small-scale liquefaction plants are suitable for peak shaving on natural gas pipelines, transportation fuel, or for deliveries of natural gas to remote areas not connected to pipelines. They typically have a compact size, are fed from a natural gas pipeline, and are located close to the location where the LNG will be used. This proximity decreases transportation and LNG product costs for consumers. It also avoids the additional greenhouse gas emissions generated during long transportation.

VI COST & Pricing OF LNG Gas

There are 3 major pricing systems in current LNG contracts. Oil indexed contract used primarily in Japan, Korea, Taiwan and China; Oil, oil products and other energy carriers indexed contracts used primarily in Continental Europe;[14], Market indexed contracts used in the US and the UK Figure (11) showing the comnparative studies of LNG production with different methods of production.

The formula for an indexed price is as **CP = BP + β X**

BP: constant part or base price + β: gradient * X: indexation

The formula has been widely used in Asian LNG SPAs, where base price represents various non-oil factors, but usually a constant determined by negotiation at a level which can prevent LNG prices from falling below a certain level. It thus varies regardless of oil price fluctuation.

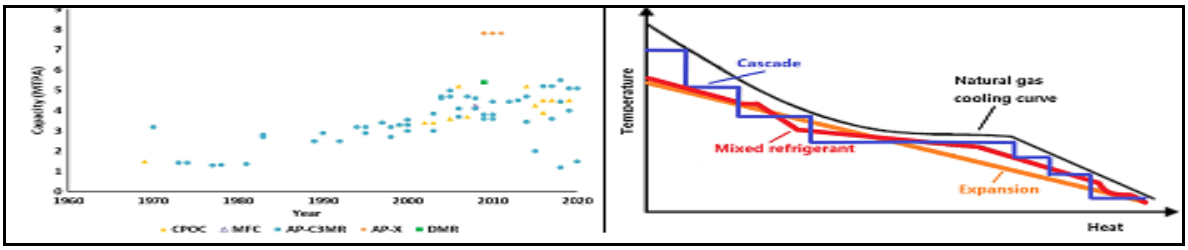


Figure (11) showing the comparative studies of LNG production with different methods of production.

Some LNG buyers have already signed contracts for future US-based cargos at Henry Hub-linked prices. Cheniere Energy's LNG export contract pricing consists of a fixed fee (liquefaction tolling fee) plus 115% of Henry Hub per MMBtu of LNG. Oil parity is the LNG price that would be equal to that of crude oil on a Barrel of oil equivalent (BOE) basis. If the LNG price exceeds the price of

crude oil in BOE terms, then the situation is called broken oil parity. A coefficient of 0.1724 results in full oil parity. In most cases the price of LNG is less than the price of crude oil in BOE terms. Most of the LNG trade is governed by long term contracts. Many formulae include an S-curve, where the price formula is different above and below a certain oil price, to dampen the impact of high oil prices on the buyer, and low oil prices on the seller.

VII CONCLUSIONS

Natural gas is created over hundreds of years deep within the earth. It has to be extracted (pumped to the surface) and cleaned to remove impurities including water to be marketable. The byproducts of natural gas processing are ethane, propane, butane, pentane and higher molecular weight hydrocarbons. LPG is manufactured during the refining of petroleum (crude oil), or extracted from petroleum or natural gas streams as they emerge from the ground. LPG production happens during the refining of crude oil. The composition is predominantly propane, butane, or a mix of these and other gases. In addition, extraction of LPG takes place directly from some of the oil wells. The calorific value is higher than the Natural gas in the range of 95 MJ /kg. LPG can be in liquid form at a relatively low pressure of 2 to 5 bar at atmospheric temperature. This makes it convenient to handle in small cylinders. Comparing the volumetric Energy Density of Diesel, which is 34 MJ/L, Natural gas, has 0.364 MJ/L, LNG 21 MJ/L, and CNG 9 MJ/L. LPG has a volumetric Energy Density of 25 MJ/L. As LNG vaporizes, the vapor cloud can ignite if there is a source of ignition, but otherwise LNG dissipates completely. Most of it is supplied in gaseous form by pipeline. However, over the past two decades, Liquefied Petroleum Gas (LPG), Natural Gas Liquids (NGL) and Liquefied Natural Gas (LNG) have become much more important in the world's energy market. Ultimately, it is the Volumetric Energy Density that decides the convenience of use. Comparing the volumetric Energy Density of Diesel, which is 34 MJ/L, Natural gas, has 0.364 MJ/L, LNG 21 MJ/L, and CNG 9 MJ/L. LPG has a volumetric Energy Density of 25 MJ/L. Besides LNG vessels, LNG is also used in some aircraft.

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