UPES Centre for Continuing Education

LNG IMPORT TERMINAL AND REGASIFICATION PROJECT ROLE IN INDIA

By

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Guided By
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A DISSERTATION REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

MBA (OIL AND GAS MANAGEMENT)

CENTRE FOR CONTINUING EDUCATION

UNIVERSITY OF PETROLEUM & ENERGY STUDIES,
DEHRADUN, INDIA

APRIL 2020

Kamesh S Sahare

From: Santosh J Kale
Sent: Sunday, April 26, 2020 3:38 PM
To: Kamesh S Sahare
Subject: RE: Willingness for guiding dissertation of Mr. Kamesh Sahare (Registration no. 500072352)

Dear Sir,

I am ready to guide Mr. Kamesh Sahare for his Dissertation study.

Thanks and regards,

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Dear Sir,

Please find below format for Acceptance letter.
Provide your reply by written mail.

ACCEPTANCE LETTER

Mr. Santosh J. Kale
Deputy Manager
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Subject: Willingness for guiding dissertation of Mr. Kamesh Sahare (Registration no. 500072352)

Dear Sir,

Mr. Kamesh Sahare is registered for Masters in Business Administration (**Oil and Gas Management**), with the University of petroleum & Energy Studies, Dehradun in July 2018 batch.

I hereby give my acceptance to guide the above student through the dissertation work titled **"LNG Import Terminal and Regasification project role in India"** which is a mandatory requirement for the award of EMBA degree.

Thanking you,

Yours Sincerely

Santosh J. Kale

Best regards,
Kamesh Sudam Sahare
Senior Engineer,
Piping Engineering.
Extn no:- 7831

TOYO

स्वच्छ भारत,एक कदम स्वच्छ्ता की ओर .

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I am also thankful to my seniors, colleagues and other project team members worked together on LNG Mundra project. Also my other friends and colleagues who share their knowledge on LNG plants working on similar projects in India.

Signature

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DECLARATION BY THE GUIDE

This is to certify that Mr. Kamesh Sahare, a student of MBA (Oil and Gas management), SAP ID 500072352 of UPES has successfully completed this dissertation report on "LNG Import Terminal and Regasification plant role in India" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analysed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA.

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ABBREVIATIONS

LNG	Liquefied natural Gas
R-LNG	Regasified Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NGL	Natural Gas Liquid
H2S	Hydrogen Sulfide
CO2	Carbon dioxide
MTOE	Million Tonnes of oil equivalent
MMT	Million Metric Tone
BTU	British thermal unit
IEA	International Energy Agency
CBM	Coal Bed Methane
MTPA	Million Tonne per Annum
NG	Natural Gas
GDP	Gross Domestic Product
ONGC	Oil and Natural Gas Corporation
OIL	Oil India Limited
NELP	New Exploration Licensing Policy
RIL	Reliance Industries Limited
PLL	Petronet LNG limited
EGOM	Empowered Group of Ministers
APM	Administered Price Mechanism
MMSCMD	Million Metric Standard Cubic Meter per Day
RPT	Rapid Phase Transition
CGD	City Gas Distribution
MOU	Memorandum of Understanding
GAIL	Gas Authority of India Limited
EHS	Environment Health and Safety

EXECUTIVE SUMMARY

Energy is key factor of economic growth in a country. Reliable, efficient and affordable energy is essential for sustainable development and growth of the overall economy of India. India at present is fastest growing large economy of the word. To maintain that growth India needs to satisfy his growing energy demand. In India energy mix, coal and oil has occupied a significant place, out of which coal contributes about 50% of total energy production. However in recent times there has been increase in the use of natural gas as a primary source of energy. Today because of its nature being clean, cost effective reliable and being available in abundance, natural gas becomes the choice of most growing countries in the world. Demand of natural gas is continuously increasing in India also. The indigenous source available in country is no longer adequate to meet those requirements. So there is a great need to import the natural gas from gas producing countries. Natural gas is import from other countries in liquefied from called liquefied natural gas (LNG).

Natural gas is well positioned to be the choice of energy in the new millennium for the sheer reason of its being clean, economical and plentiful in the world. LNG is in well position to attract even greater share of global gas demand. This is because the geographical distribution of natural gas is not even in the world. And it may not be always economically and politically viable to lay down pipelines for supply of natural gas. As potential supply is plentiful, the challenge now faced by India, is to bring LNG to the market at competitive rates.

As LNG projects are long term in nature and high capital investment, it is most important to have a strong LNG chain during the complete tenure of the contract or project. If there is any weak link it might fails overall LNG project. Today there must be required a global optimisation of the LNG chain. LNG in itself is high cost industry and it involves production and transportation as well. While the transportation is cost plays major role LNG project cost optimization.

The dissertation describes about LNG chain, its financial structure, components of LNG chain. The study deals Indian energy mix, role of natural gas and LNG in India economic growth. It also deals with the project design and development of LNG import terminal and Regasification plant in India. Critical factors involve in successful completion of LNG project, safety and other environmental related problems and risk mitigation.

I would, like to mention here that, LNG being a very closed trade there is a great deal of difficulty in getting information, especially regarding the financial aspects, hence the figures that have been used for making the financial analysis in the dissertation, are not very accurate as they are assumed figures.

CHAPTER-I

INTRODUCTION

INTRODUCTION

1.1 Overview:-

Today there is great concern about the world environment and that natural gas is considered to be the cleanest and most environmentally friendly fuel, it has gained a lot of importance. About fifty years ago, natural gas was more or less dismissed off as a by-product of oil production. But today because of its nature of being clean, cost effective, reliable and available in abundance, natural gas has become the choice of most of the energy consumers in the world.

Demand for natural gas has been increasing continuously. But indigenous sources are not adequate to meet the demand, because the geographical distribution of natural gas is not even. The transport of natural gas from gas producing countries is need of today's time. It is not always possible to lay down pipelines across a country. Marine transport of LNG is the most obvious and economical choice of natural gas transport. LNG carrier's ships now form an integral part of the world energy transport.

There has been a recent renewal of interest in LNG import terminals, as the worldwide gas market continues to grow to supply domestic/industrial users and in many cases new power generation projects. The costs of LNG projects are tremendous. Project-financing arrangements become major issue among the companies. It is beyond a single company to finance the project. The regulatory bodies in the consuming countries are engaged in a race against time deciding whether or not to grant approval to imports of LNG.

India has been mostly relying on coal, lignite, crude oil and hydroelectric power as its main sources of energy. Also reserves of above sources being limited. There is rapid industrialisation in the country. Because of this, it is essential that India must find an alternate source of energy before it is too late.

India has been trying hard to find new resources of crude oil and natural gas. Also increase the production from existing field but not able to fulfilled the current energy demand. This is resulting in more and more oil and natural gas importing every year. That's why there is need of more LNG terminals and Regasification plant in India. The study reveals the same and also critical success factors in LNG project.

CHAPTER – II

LITERATURE REVIEW

LITERATURE REVIEW

2.1 Natural gas, Liquefied Natural gas and its trade

Natural gas today, enjoys the status of the cleanest and most environmentally friendly fossil fuel. It is also the world's third largest source of energy, after coal and oil. India is getting in the business of LNG trade; hence it is important to study what the trends of the LNG business are in the world scenario. The basic purpose of this chapter is to provide a general review on natural gas, its composition, properties and uses. To distinguish the difference between natural gas and liquefied natural gas, and define the characteristics of LNG.

2.1.1 Natural Gas

Natural gas is defined as gas obtained from a natural underground reservoir. It generally contains a large quantity of methane along with heavier hydrocarbons such as ethane, propane, isobutene, nitrogen, hydrogen sulphide (H2S) and carbon dioxide (CO2). There are some impurities traces of helium, carbonyl sulphide and various mercaptans. It is generally saturated with water. Gas that is sold for commercial use is quite different in composition to that of traditional composition of the gas. The gas that is sold is not specified by chemical composition, but rather by a series of specific properties that have to meet.

For our study we shall, deal with natural gas which is predominantly methane, but also present in varying proportions are smaller quantities of ethane, propane and butane. Natural gas occurs as a mixture of the gaseous minerals, including both hydrocarbon and non-hydrocarbon gases, in reservoirs beneath the earth's crust. Natural gas is a fossil fuel.

World's most crude oil fields have deposits of natural gas associated with them. When natural gas comes out of the well along with crude oil it is called associated gas. Besides associated gas, there are also many sizeable gas fields which occur independently of any oil, or where the amounts of oil are so small that they are only of minor importance. This is called non-associated gas. The non-associated gas tends to be a purer gas with very high calorific values. When acid gases like CO2 and H2S are present in substantial quantity, the gas is called sour gas. Otherwise it is called sweet gas. Like most other fossil fuels the origin of the natural gas lies in the decaying plant and animal life over millions of years.

2.1.2 Composition Natural Gas

In natural gas methane is most prevalent hydrocarbon, accounting for almost 70% to 95% by volume. The other heavier hydrocarbons with higher boiling points like ethane, propane and butane make up most of the remaining. Impurities like nitrogen, carbon-di-oxide and sometimes hydrogen sulphide are also present in small quantities. The proportion of methane gives the calorific value of gas and this varies from source to source.

The natural gas obtained from different gas field has different composition and depending on composition different treatment is required for every gas fields.

Table - 1 gives the breakdown of the natural gas compositions from some typical gas fields

Table -1

Natural gas compositions from some typical gas fields

COMPOSITIONS	ALGERIA	LIBYA	BRUNEI	NORTH SEA	IRAN	ALASKA
Methane	86.3	66.8	88.0	85.9	96.3	99.5
Ethane	7.8	19.4	5.1	8.1	1.2	0.1
Propane	3.2	9.1	4.8	2.7	0.4	-
Butane	0.6	3.5	1.8	0.9	0.2	-
Pentane & others	0.1	1.2	0.2	0.3	0.1	-
Nitrogen	-	-	0.1	0.5	1.3	0.4
Carbon dioxide	-	-	-	1.0	-	-

Source: Fairplay report on LNG carriers.

As from the above table, Alaskan gas has a methane content of 99.5% can be used practically without any treatment. While the less pure forms of gas must be treated to remove the heavier hydrocarbons and impurities. Propane and butane are liquefied under pressure and used as LPG. Pentane and other hydrocarbons are liquids at normal atmospheric conditions and can be removed from natural gas by simple treatment processes.

2.1.3 Uses Natural Gas

Natural gas can be used depending on its components present in it.

Table-2 shows typical composition of gas and use of various components towards high value products.

Table -2

Gas composition and Utilization

Component	Composition Volume %	Utilization
Methane(C1)	50-98	Fuel, Petrochemical feedstock's, Power generations
Ethane(C2)	2-15	Petrochemical feedstock's
Propane(C3)	1-12	Petrochemical feedstock's, LPG
Butane(C4)	0.5-3	Petrochemical feedstock's, LPG
Heavies(C4+), NGL	0.1-1	Refinery blending stock, Petrochemical feedstock's
Hydrogen Sulfide	0-15	Toxic, Corrosive and undesirable component
Carbon dioxide	0-30	No fuel value, Corrosive and undesirable component
Nitrogen	0-30	No fuel value, Corrosive and undesirable component
Water	Saturated	Undesirable component
Total	100	

Natural gas is presently emerging as the primary source of fuel in the energy consuming areas of the world. The sector wise use of natural gas is described below.

- Residential/commercial: Natural gas is most extensively used in this sector basically for household appliances, water heating, space heating, offices, shops, hotels etc.
- Industry: Natural gas in the industries is used as boiler fuel for steam raising and for large heating applications, in glass, ceramic and baking industries as its clean burning characteristics makes it superior to alternative fuels.
- Power generation: Natural gas is used in power projects not only because of its technical advantages but also because it is convenient and economical.
- Petrochemical industry: Natural gas is used as a feedstock for the manufacture of fertilisers, plastics, adhesives etc., using base chemicals like ammonia, methane and acetylene.

2.2 Liquefied Natural Gas

When natural gas is cooled to a temperature of minus 162°C under the normal atmospheric pressure, it condenses into a liquid and is called Liquefied Natural Gas (LNG). LNG is about 618 times less in volume than the gaseous equivalent. It is a clear and colourless liquid having a weight of about half that of water of the same volume. For this reason, if gas has to be transported, it is best done in the liquefied form.

2.2.1 Production and Properties of Natural Gas

Natural gas is liquefied by an initial compression process, cooling and then expansion. The cooling process is carried out in a number of closed refrigeration cycles using a progressively lower temperature refrigerant at each stage. In the expansion process at this lower temperature, part of the gas is liquefied and the remainder is fed back to start the cycle again. This method of liquefying natural gas is called the cascade process and is most commonly used for LNG production.

Table -3

Properties of LNG

Boiling point of LNG	Generally – 157 to –163 °C under normal atmospheric conditions.
Boiling point of pure methane	– 161.5 °C
Specific gravity of LNG	0.47 to 0.53
Specific gravity of methane	0.415
Calorific value of LNG	25 – 34 BTU*/M^3 #
Calorific value of methane	29 BTU/ M^3
Density of dry gas/dry air	0.58 to 0.67 ##
Density of methane/dry air	0.555
Lower explosive limit (%age by volume in air)	5.3
Upper explosive limit (%age by volume in air)	14.0
Ignition temperature	595°C

Source: Fairplay report on LNG Carriers

* BTU – British thermal unit

\# More of the heavier hydrocarbons give higher values and more of CO2 and/or nitrogen give lower values.

\## More the heavier hydrocarbons can give higher

2.2.2 Characteristics of LNG

Now we will see the principal characteristics of LNG from the point of view of storage and transportation.

1. It's extremely low temperature (about -160° C) requires special consideration for:
   - Use of extremely low temperature-resisting materials
   - Effective use of heat insulating systems and insulation materials.
   - Protection against low temperature hazards.
   - Appropriate structure that allows expansion/contraction of materials and avoids heat stress caused by temperature difference.

2. The volume of LNG has been reduced by liquefaction to 1/600 of the volume of corresponding natural gas:
    - This is very useful in transportation and storage.
    - Tank pressure rises when boiling off.
3. The density of LNG is about half that of water.
4. LNG combustible, but its vapour has a narrow range of inflamability.
5. LNG is a colourless and odourless liquid.
6. LNG is very volatile.
7. When leaked into the air, LNG evaporates quickly and condenses in the air to develop white cloud.
8. LNG has a high latent heat of evaporation.
9. LNG viscosity is very low.
10. LNG is corrosion resistant and non-toxic.
11. LNG has small surface tension.
12. LNG is scarcely soluble in water.

2.2.3 World Production and Consumption of LNG

Fig 1 provides the details of the region-wise gas reserves in the world.

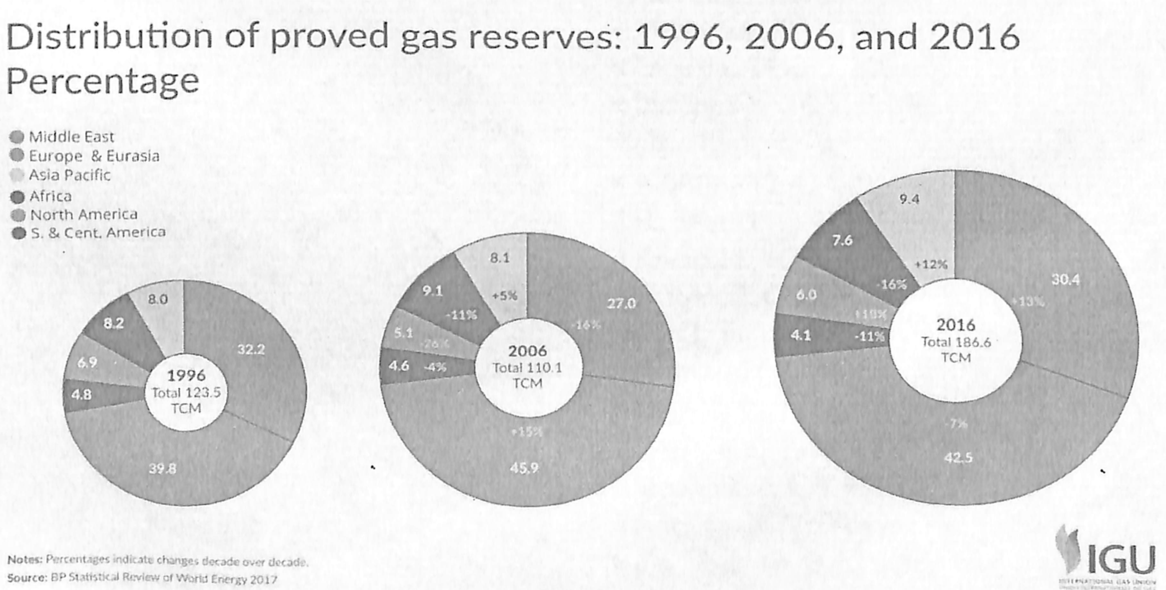


Fig-1 Region wise gas reserves in the world

The world's largest natural gas reserves are held by Middle East and constitute about 42.5% of the total reserves. While Europe and Eurasia holds 30.4%, together they hold more than 70% of world's natural gas reserves.

"The remaining resources of natural gas are sufficient to comfortably meet the projections of global demand growth to 2040 and well beyond" as per (IEA, 2017). At the end of 2016, proven reserves were about 215 trillion cubic metres (tcm), equal to around 60 years of production at current output rates. Global resources of natural gas are estimated at nearly 800 tcm, around 45% of which are unconventional gas (tight gas, shale gas, CBM), deposits of which are geographically more widespread than conventional resources, as per (IEA, 2017) report.

These proved reserves are sufficient for the next couple of hundred of years at the present levels of production. With an increase in demand, reserves in the Middle East will lead to significantly increased exports of LNG during the next decades. Fig-2 provides the details of LNG exports and market share by each country in year 2017.

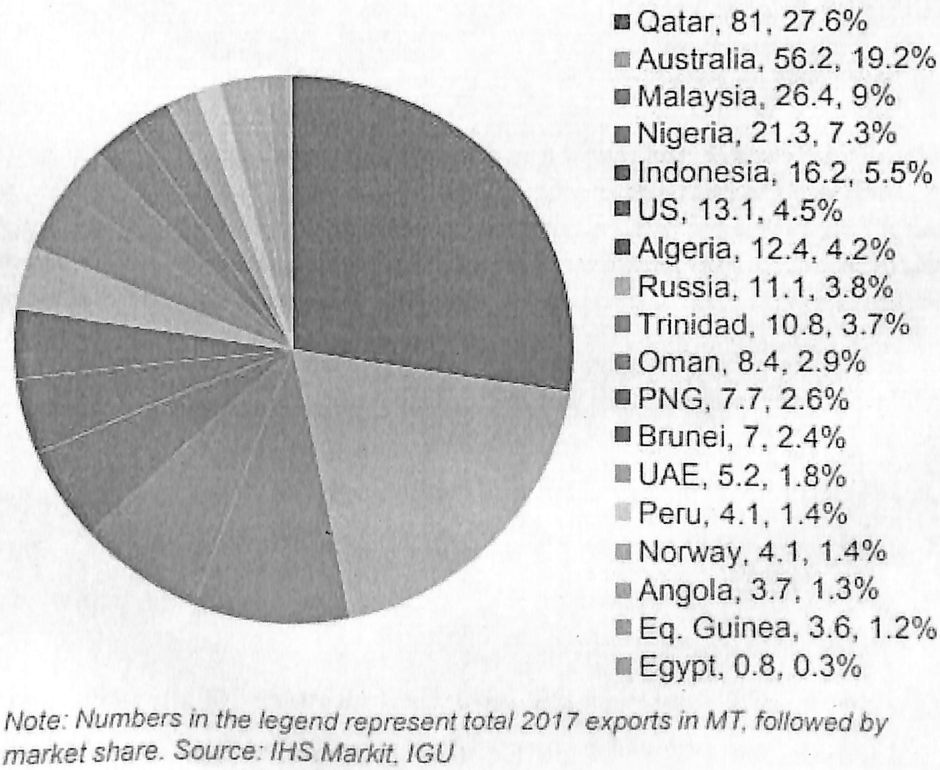
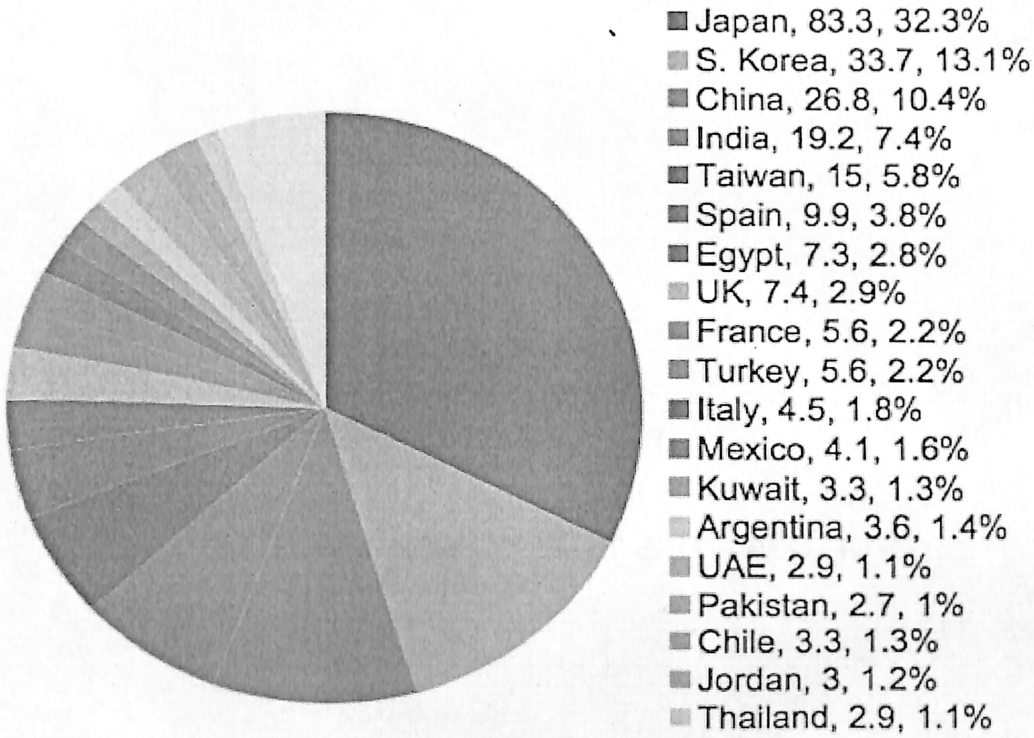


Fig-2 LNG Exports and Market share by country (in MTPA)

As such, the number of exporting countries stayed at 18 during 2017. Qatar continued to be largest LNG exporters from decade. The LNG exports are increasing due more new liquefaction plants. The top 5-6 countries dominated the LNG production and exports from last decades. Now similarly we see the LNG imports and market share by country in 2017.



Note: Number legend represents total imports in MT, followed by market share %. "Other" includes countries with imports less than 2.5 MT (by order of size): Singapore, US, Portugal, Puerto Rico Belgium, Malaysia, Brazil, Lithuania, Poland, Dominican Republic, Greece, Netherlands, Israel, Canada, Jamaica, and Colombia. Sources: IHS Markit, IGU

Fig-3 LNG Imports and Market share by country (in MTPA)

Asia pacific remains the largest importing region in 2017, with 50.3% share. Japan is the largest LNG importing country in the world with 32.3% share, while India is at fourth place with 7.4% share.

India is planning to import its LNG from Qatar, Bangladesh, Oman, Middle East, etc. To find out what is the requirement of importing LNG in India, we shall in the next chapter deal with the present energy scenario and the proposed upcoming projects for LNG, in India.

CHAPTER - III

INDIAN ENERGY SCENARIO AND LNG

INDIAN ENERGY SCENARIO AND LNG

Energy plays a vital role in the development of a country for either developed or developing country. It plays an important role in enabling and sustaining development. This is most obviously created by under pinning the economic growth of a nation and raising overall standards of living. In developing countries energy is crucial to economic and social aspirations but access to reliable commercial energy sources remain limited. Building an effective energy sector is costly and complex particularly when limited financial resources are there and it must also meet other pressing development needs.

Energy is also essential for fuelling power generation plants, construction, domestic consumption, heating, transportation, industrialisation etc. India is developing at a rapidly and is going in for industrialisation, power generation, construction etc in a big way. To meet this India has a tremendous appetite for energy. India primarily depends on coal and oil for its energy and it is high time that now natural gas be looked at as a major alternate source of energy. In this chapter we shall try to analyse the role that natural gas could play in Indian energy scenario.

3.1 Primary Energy Consumption in India

Before defining the role of gas in the Indian energy scenario it is necessary to define existing primary energy resources in India. Primary energy resources are divided into Non-commercial primary energy resources and Commercial primary energy resources. In India's energy mix, coal has since ages occupied a significant role and contribute to 50% total energy production. However, in recent times, there has been increase in the use of natural gas as primary source of energy. India primary energy consumption is 701MTOE against world 13147 MTOE. Now we look briefly at various primary source of energy.

3.1.1 Non Commercial Primary Energy Resources

Fuel wood was an important source of energy for cooking and heating in rural parts of India. The total forest area in the country adds up to nearly 75 million hectares. However, due to cutting down of forests there has been a gradual deforestation with adverse impact on environment. Fuel wood is supplemented by dung and crop residues in meeting the domestic energy needs of rural areas.

3.1.2 Commercial Primary Energy Resources

- **Coal:** One quarter of the world's primary energy is provided by coal and it generates about 40% of world's electricity. India stands third in the world in terms of coal consumption. Coal deposits are mainly confined to eastern and south central parts of the country. As on 2018 report, in India the estimated reserves of coal were 319.04 billion tonnes.

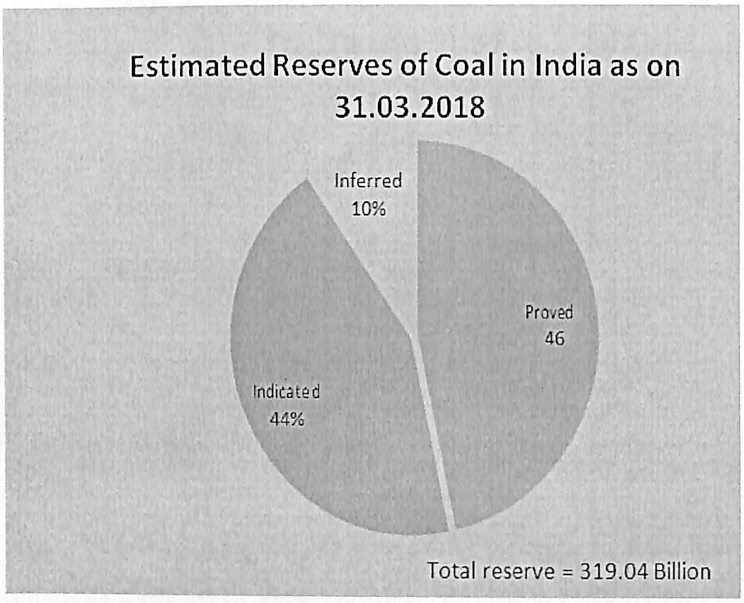


Fig-4 Estimated Reserves of coal in India 2018 source: energy statistics 2019

- **Lignite:** Lignite reserves are estimated to be at 45.66 billion tonnes as per energy statistics 2019 and lignite deposits have been found to be suitable for power generation. Considerable emphasis has been laid on exploration of lignite in some states of India as they are located at a considerable distance from the coal fields.

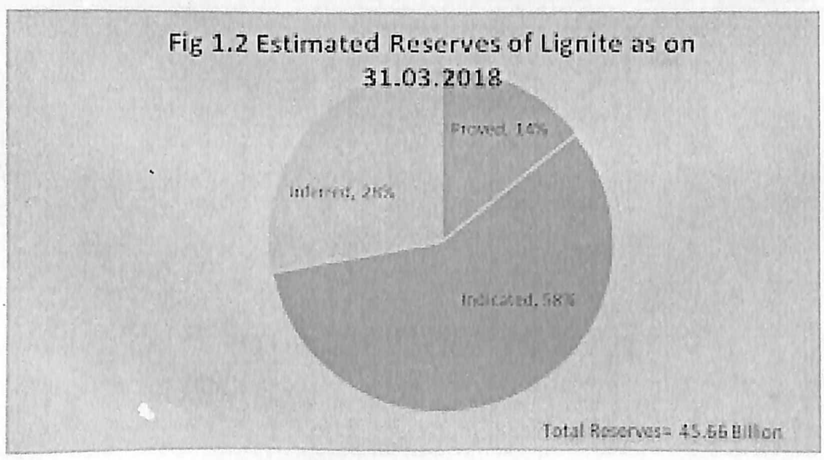


Fig-5 Estimated Reserves of lignite in India 2018 source: energy statistics 2019

- **Crude Oil:** Crude oil reserves are estimated to be at 594.49 million tonnes as per energy statistics 2019. Geographical distribution of Crude oil indicates that the maximum reserves are in the Western Offshore (40%) followed by Assam (27%), whereas the maximum reserves of Natural Gas are in the Eastern Offshore (38.13%) followed by Western offshore (23.33%)

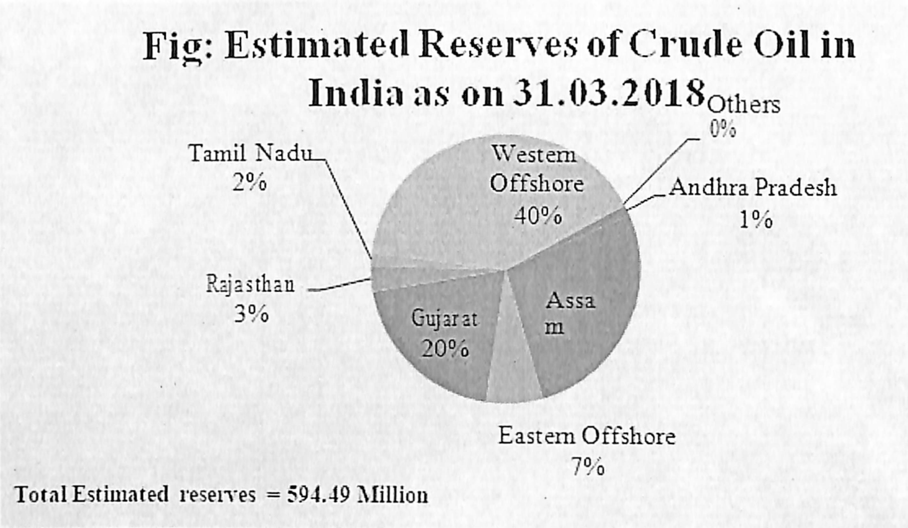


Fig-6 Estimated Reserves of crude in India 2018 source: energy statistics 2019

- **Natural gas:** Natural gas reserves are estimated to be at 1339.57 billion cubic meters as per energy statistics 2019. The estimated reserves of Natural Gas increased by 3.87% over the last year. The maximum contribution to this increase has been from Arunachal Pradesh, and Rajasthan followed by Andhra Pradesh and Tamil Nadu.

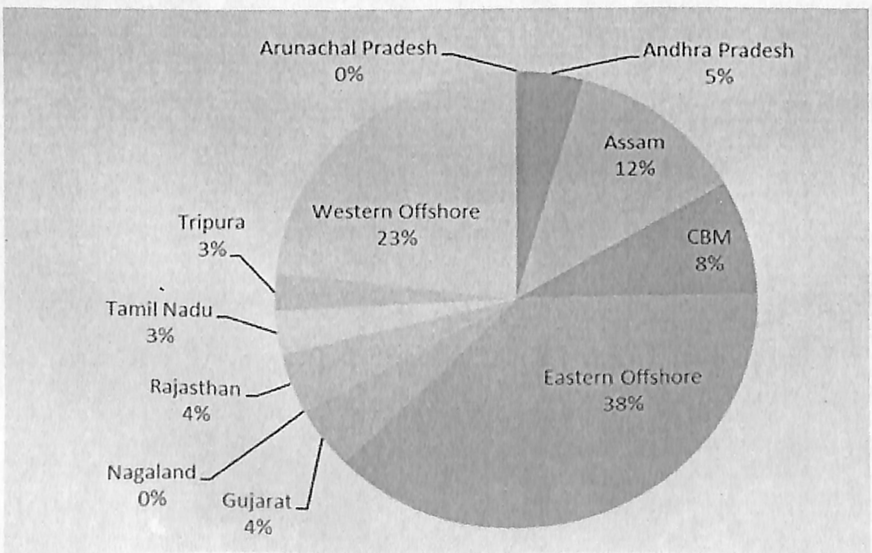


Fig-7 Estimated Reserves of natural gas in India 2018 source: energy statistics 2019

- **Renewable energy sources:** There is high potential for generation of renewable energy from various sources- wind, solar, biomass, small hydro and cogeneration bagasse. The total potential for renewable power generation in the country as on 31.03.18 is estimated at 1096081MW (Table 1.3). This includes solar power potential of 748990 MW (68.33%), wind power potential of 302251 MW (27.58%) at 100m hub height, SHP (small-hydro power) potential of 19749 MW (1.80%), Biomass power of 17,536 MW (1.60%), 5000 MW (0.46%) from bagasse-based cogeneration in sugar mills and 2554 MW (0.23%) from waste to energy.

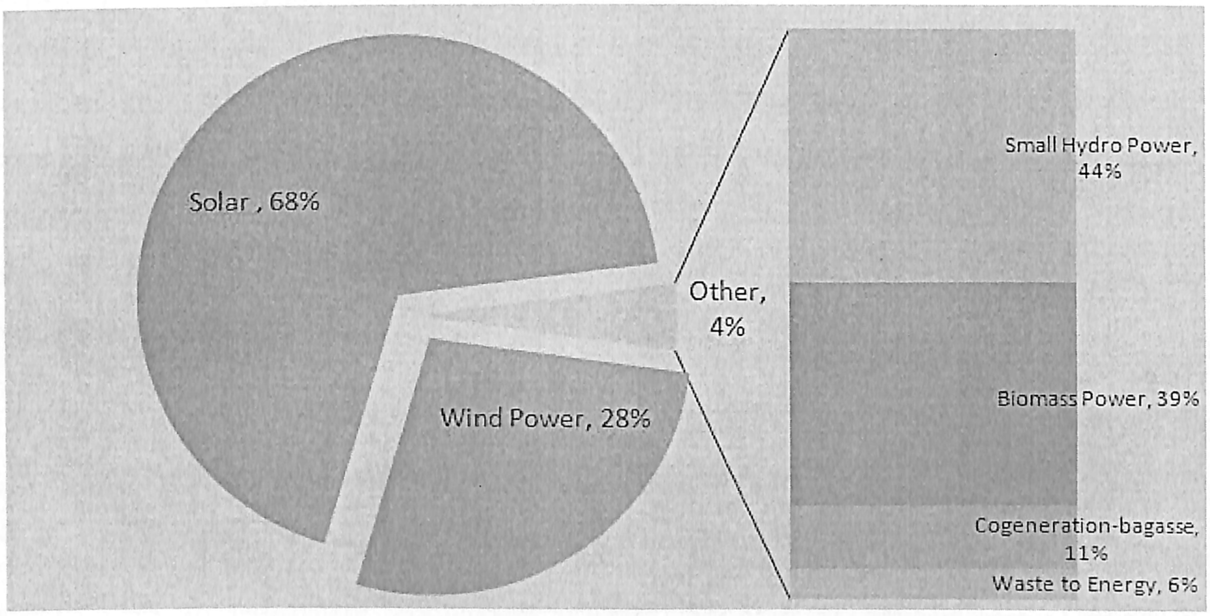


Fig-8 Estimated Reserves of renewable power in India 2018 source: energy statistics 2019

Coal continues to be the main source of primary commercial energy followed by oil and natural gas. However, with the stagnation of crude oil in the recent years, there have been additions to nuclear power generation capacity as well as power generation from nuclear power plants. The share of coal is declining in the final energy consumption whereas that of oil and gas and electricity is increasing. India is interested in investing in cleaner fuels. According to the Indian Energy Policy, India is going to stress on the development of hydroelectric power, oil and natural gas, and nuclear power, leading to lesser pollution and maximising of the natural resources. As there is a growing overall need for energy in India, indications for expansion and investment in a gas market appear to be very good.

3.2 Comparison between India's Oil and Gas Reserves, Consumption and Production

Oil and gas have very similar sources and exploration techniques; hence, it is worthwhile to make a comparison between the reserves, consumption and production of the two. Also, oil and gas can be mutually substituted in a wide range of energy uses.

3.2.1 Oil Reserves, Consumption and Production in India

Next to coal, oil is the major source of energy consumption in India and the economy of India is progressively becoming oil intensive in view of the increasing share of petroleum products in final use of commercial energy. Production of oil in India in 2008-09 was 33.51 million tonnes and it increased to 38.09 million tonnes (MT) in 2011-12. However, production then started to decline and fell to 35.68 MT in 2017-18. On the other hand, consumption for oil has been increasing year after year. Consumption of oil in 2008-09 was 160.77 MMT and increased to 251.93 MMT in year 2017-18. The trends in production and consumption of oil are illustrated in Table 4 below

Table 4

Production and consumption of oil in India

Year	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Production (million tonnes)	33.51	33.69	37.68	38.09	37.86	37.79	37.46	36.94	36.01	35.68
Consumption (MMT)	160.77	186.55	196.99	204.12	219.21	222.50	223.24	232.86	245.36	251.93

Source: Energy statistics 2019

With a growing deficit between availability and demand for crude and petroleum products in the country there is tremendous pressure on the balance of payments. With proved reserves of oil at March 2018 standing at 594.49 MT and keeping the fact that demand and consumption for oil is increasing faster than production, there is a need to enhance the pace of exploration and development in the oil sector and also look at an alternate source/s for expioitation.

3.2.2 Natural Gas Reserves, Consumption and Production in India

Natural gas has in some parts of India been used since the 1960's. About 60% of natural gas is produced along with crude oil as associated gas and rest is produced as free gas. Natural gas is currently the source of half of the Liquefied petroleum gas in the country. Natural gas, being environmentally friendly and clean, has started to gain a lot of importance as a fuel/feed stock for power plants industries, iron and steel plants, etc, in India and has come to be recognised as the fuel of the next century. The reserve position of natural gas as per the statistics of the Ministry of Petroleum and Natural Gas is as under:

Prognosticated resource base:	41872 MMTOE
Discovered resources:	12076 MMTOE
Undiscovered resources:	29796 MMTOE

Above shows that there is still a substantial resource base unexplored.

Table 5 illustrates the production and consumption of natural gas in the last few years

Table 5

Production and consumption of natural gas in India

Year	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Production (billion cubic meter)	32.85	47.50	52.22	47.56	40.68	35.41	33.66	32.25	31.90	32.65
Consumption (billion cubic meter)	32.99	48.34	52.02	60.68	53.91	48.99	46.95	47.85	50.78	52.83

Source: Energy statistics 2019

It can be observed from the table that in the initial periods the production and consumption of natural gas has been more or less going hand in hand, but in the last few years the consumption of natural gas has been higher than production. This gap between production and consumption is growing wider from last 3-4 years and will likely grow much wider in coming years.

So far, the exploration and production of oil and gas has predominantly been in the hands of two national oil companies "Oil and Natural Gas Corporation Ltd" and "Oil India Limited" and distribution of the gas has been with the national company "Gas Authority of India Ltd". However, with the growing deficit between the availability and demand of both oil and gas, Government of India has started inviting private investors to increase exploration and production efforts in the country to augment oil and gas production. Also to harness a new source of energy, the Government of India, in 1997 approved a Coal Bed Methane (CBM) policy for exploration and exploitation of CBM gas.

3.3 Influence of Pricing on Gas Trade

Natural gas as a substitute for oil could technically absorb almost all of the fuel oil market in industry and electricity generation and the entire gas oil market in industry and the residential/commercial sectors. But in practice, the limits of technical demand for gas are set by its price relative to competing fuels and by government policies. In fact in the past use of natural gas for electricity generation had been discouraged by some governments since it was not consistent with the premium characteristics of natural gas whereas other governments sought to expand the market for natural gas by introducing pricing controls on gas or higher tax levels on competing fuels.

The price of bulk natural gas is almost invariably determined by long term contracts with producers, but end use natural gas sales are generally controlled or regulated by the governments, with the exception of sales to utilities or large industrial customers, prices for which are often negotiated independently. Virtually all governments also control and regulate prices of electricity, and there remain many instances where prices of natural gas are set by governments in order to support achievements of specific regional development or social goals unrelated to the cost of supply.

Natural gas has to be priced competitively with alternative fuels at the point of burning if markets are to be secured, retained and expanded. Although the situation differs markedly from country to country, natural gas prices have often been slow to adjust to the changes in price of oil. In part, this is a reflection of the nature of natural gas business, which requires dedicated and capital intensive infrastructure and long term contract arrangements. But it is also due in some cases to specific elements of national policy alluded to above.

Two critical issues come to mind while looking at the relationship between market penetration and natural gas pricing, which are

1. What price level, at the input to the national transmission grid, can importers afford to pay and still be able to sell the contracted quantities in a competitive market?
2. Do these prices, after deducting production and transportation costs, result in a return to producers adequate to encourage production of gas to export.

These are complex issues and precise answers to them will vary from case to case. In particular, the amount importers can reasonably be expected to pay will be affected by considerations such as:

- Existing distribution systems age, capacity and expected utilisation rate.
- Distribution of existing and incremental natural gas supplies to alternative markets.
- Competing fuels future price development expectations.
- Structure of domestic taxation on energy products.
- Security considerations.

The producers will base their decisions on whether or not to export gas, on factors such as cost of production, fiscal and price regime, and alternative uses. The critical issue appears to be whether the gas producer's desire for economic return can be reconciled with competitive prices in consumer/end user markets. Natural gas future business particularly depends on the relationship between pricing and trade.

Unless there is some unforeseen advancement in technology, natural gas is regarded as the least offensive of fossil fuels, while its only other real competitor, nuclear power, is discredited for its own reasons. Most experienced market observers believe that trade in natural gas will expand rapidly in future as:

- There is a definite change in regulatory attitudes to gas.
- There is growth in the US and Far East spot markets
- There is a desire on behalf of producers to export as much gas as possible
- Oil production is subject to quotas and uncertainty.

3.4 Natural Gas Pricing

Gas pricing has evolved from cost plus basis to alternate fuel parity basis in India. While the prices for around 50 MMSCMD gas produced from ONGC and OIL India assets and allocated to various consumers by erstwhile Gas Linkage Committee are being fixed by government of India (GOI). The prices for gas produced from various joint ventures producers like PMT, Cairn Energy are as per prices fixed as part of Production Sharing Contracts signed with GOI. Further, producers under NELP like RIL are getting the Market determined price based on the formula duly approved by EGOM. The prices for RLNG imported in the country by PLL are governed by the fuel oil linkages as part of the contracts signed between individual companies like Ras Gas and PLL.

For a reference Gas Prices prevailing in India from different sources is given in table 6.

Table 6

Natural gas pricing in India

Source	Customers	Gas price	Gas price (US S/MMBTU)
ONGC & OIL (APM)	Customer outside North East	$4.2/mmbtu	4.2
ONGC & OIL (Non APM)	Customer outside North East	$4.5/ mmbtu ($5.25/mmbtu for offshore production	4.5-5.25
ONGC & OIL (APM)	Power & Fertilizer Customers in North East	$ 2.52/mmbtu	2.52
Panna Mukta & Tapti JV (PMT)	Weighted average price of PMT except RRVUNL & Torrent	$5.65/mmbtu	5.65
Ravva	GAIL	$3.5/mmbtu	3.5
Ravva Satellite	GAIL	$4.3/mmbtu	4.3
KG-D6	All Consumers	$4.2/mmbtu	4.2
Amguri Fields (Canero)	GAIL	$2.52/mmbtu	2.52
Term R-LNG	For all (vary on monthly basis)	$9.0 - $10.5/mmbtu	9.0-10.50
Spot-R-LNG	Vary on cargo to cargo	$ 12 - 17/ mmbtu	12-17

3.5 Role of NG/LNG in Indian Energy Scenario

As has been discussed and observed earlier in this chapter, coal and oil being the major sources of energy in India, and specially keeping in mind that the quality of coal is not too good, there is a great deal of pollution which is hazardous not only to the local but also the global environment. There is therefore a great potential for a cleaner fuel in India. The role that natural gas or liquefied natural gas can play in the Indian energy scenario is as discussed in the ensuing paragraphs.

Natural gas is typically the best energy value for industry. Natural gas is clean, safe to handle, and common to most equipment. What this means to industry is: low maintenance expenses due to clean burning, low liability due to its safety and ease and variety of equipment acquisition due to how common natural gas is as an energy source.

Stability is another area, which impacts economics as well. A constant supply of high quality natural gas, regardless of weather, war, embargo or other supply disruptions has enormous value to a plant. Stability also means stable prices. Natural gas prices have been historically low and are expected to remain that way for years to come. The reason for this is that the global supply is much greater than demand. Depending on a particular country's location and consumption volume, purchase of natural gas from LNG with multiple years, fixed price contracts can be made. Stability also means consistent quality. Natural gas from LNG has consistent fuel consistency, Btu value and quality. These features are essential in heating critical applications such as glass manufacturing and electronics to name a few.

Natural gas burns clean; therefore it is easy for a business to comply with tough State regulations and state air pollution laws. It reduces the expenses a business has to incur on costly smokestack cleaning devices and reduces the maintenance on all associated equipment.

Natural gas is also important for the transportation industry. Natural gas a non-reactive hydrocarbon, is refined and separated from other gases present and, since it is the only hydrocarbon that does not photo-chemically react to form ozone, it has the cleanest burning and, therefore, has a reduction in particulate matter and other emissions. LNG is also being considered widely for use in transport industry, in locomotives, buses and heavy duty trucks. Some of the lead engine manufacturers are also developing either dual fuel or dedicated fuel engines to accommodate LNG fuel use. In India CNG (compressed natural gas) is used as an alternate source of fuel.

Natural gas constitutes about 9% in the India's energy profile, as compared to about 25% world average. About 45% of natural gas is consumed by power sector and about 40% by the fertilizer sector. The balance 15% goes for other consumption. At present about 65 million cubic meters of gas per day is being consumed and it has the potential for increase.

Both the Power Sector and Fertilizer Sector have been planning for larger consumption of gas and increased capacities so as to produce more power through this environment friendly fuel. However, the recent trends in gas prices globally has created a dampening impact on the power plant planners both from the point of view of lack of predictability about availability of this fuel and more so on account of lack of predictability of its price behavior. In the power sector, about 12,500 MW of capacity out of the 1, 25,000 MW of total capacity is gas based combined cycle power plants. Because of lack of availability of gas, almost 35% of the capacity remains unutilized and these plants then need to resort to naphtha as a substitute fuel which is excessively costly. Some of the power plants, which were planned and are in the process of being commissioned, face the problem of non-availability of gas. There are couples of LNG terminals in the country each with a capacity of 5 million tones. Their capacities of processing LNG are not fully used in view of the recent excessive rise in the price of LNG, which has made it unaffordable for the power producers to access LNG and use it in their power plants.

Huge resources of gas which have been discovered by Reliance Industry, ONGC, Gujarat Gas, Cairn Energy and others, when produced and supplied, there will be greater clarity on adequacy of supply and predictability of price. Till then power developers have adopted a dual approach for existing capacities of power plants where assets face a situation of idleness, a higher price for gas/LNG is accepted to utilize the existing capacities.

Gas discoveries in KG Basin and in some of the Western Coast areas have created a positive impact. It is expected that these discoveries when exploited - and it is targeted that some time in the year 2008, a substantial amount of production would flow from the KG basin, power plant developers and those in the Fertilizer Sector and other areas could expect to get larger amount of natural gas. If there is predictability about its price, it would be possible to enhance the present projection of gas based power capacity to a higher level. Domestic reserves will not sufficient. Gas supply will need to be supplemented through LNG import with appropriate enhancement of LNG Re-gasification facilities.

3.6 Natural Gas Demand- Supply Dynamics

The Indian economy has been projected to achieve an average real GDP growth of 6.4% during 2008. Energy availability is key to economic growth and therefore, high economic growth would lead to increase in the energy consumption of the country. The primary energy mix of India is also set to alter on account of the substitution of oil by natural gas. The share of natural gas in the energy mix is expected to increase to 20% in 2025 and beyond as compared to 11% in 2010. Based on the plans for expansion in natural gas supply in the country with the help of additional RLNG terminals, nationwide transmission pipeline network and transnational pipelines expected to materialize in next 5 to 10 years, it is envisaged that the share of natural gas in the primary energy mix would reach 20% till 2030. However to achieve a 20% share of natural gas in the primary energy it is required to attract and sustain investments in the gas infrastructure including the cross country pipelines.

In recent years the demand for natural gas in India has increased significantly due to its higher availability, development of transmission and distribution infrastructure, the savings from the usage of natural gas in place of alternate fuels, the environment friendly characteristics of natural gas as a fuel and the overall favorable economics of supplying gas at reasonable prices to end consumers. Power and Fertilizer sector are the two biggest contributors to natural gas demand in India and continue to account for more than 55% of gas consumption. India can be divided into six major regional natural gas markets namely Northern, Western, Central, Southern, Eastern and North-Eastern market.

In future, the natural gas demand is all set to grow significantly at a CAGR of 6.8% from 242.6 MMSCMD in 2012-13 to 746 MMSCMD in 2029-30 as study done by Petroleum and natural gas regulatory board. Gas based power generation is expected to contribute in the range of 36% to 47%, up to year 2029-30. The share of fertilizer sector in the overall gas consumption in the country is expected to go down to 15% in FY 2030 due to higher growth in other sectors. The contribution to the overall demand from the CGD sector is set to increase from 6% to 11% during the projected period.

The consolidated demand for natural gas from 2012-13 to 2019- 30 has been summarized in Table 7.

Table-7

Consolidated segment wise demand for Natural gas from 2012 to 2030

MMSCMD	2012-13	2016-17	2021-22	2026-27	2029-30
Power	86.50	158.88	238.88	308.88	353.88
Fertilizer	59.86	96.85	107.85	110.05	110.05
City Gas	15.30	22.32	46.25	67.96	85.61
Industrial	20.00	27.00	37.00	52.06	63.91
Petchem/Refineries/Internal Cons.	54.0	65.01	81.99	103.41	118.85
Sponge Iron/Steel	7.00	8.00	10.00	12.19	13.73
Total Realistic Demand	**242.66**	**378.06**	**516.97**	**654.55**	**746.03**

Source: vision by Petroleum and natural gas regulatory board 2030.

The supply of natural gas is likely to increase in future with the help of increase in domestic gas production and imported LNG. However, the expected increase in domestic production at present is significantly lower than earlier projections due to a steady reduction in gas output from the KG D6 field. The capacity of RLNG terminals in India is expected to increase from 17.3 MMTPA in 2012-13 to 83 MMTPA in 2029-30 assuming all the existing and planned terminals in India would materialize. Natural gas availability through non-conventional sources like Shale Gas and Gas Hydrates has not been considered in gas supply projections in the absence of clarity on key variables like data as most of India remains unexplored/underexplored, regulatory policy and lack of domestic infrastructure.

The total supply of natural gas is expected to grow at a CAGR of 7.2% from 2012 to 2030 reaching 400 MMSCMD by 2021-22 and 474 MMSCMD by 2029-30. The supply profile for the projected period has been provided in Table 8.

Table-8

Consolidated source wise supply for Natural gas from 2012 to 2030

MMSCMD	2012-13	2016-17	2021-22	2026-27	2029-30
Domestic Sources	101.1	156.7	182	211	230
LNG Imports	44.6	143.0	188	214	214
Gas Imports (Cross border Pipelines)	0.0	0.0	30.0	30.0	30.0
Total	**145.7**	**299.7**	**400**	**454**	**474**

India, currently, has a network of about 13,000 km of natural gas transmission pipelines with a design capacity of around 337 MMSCMD. This pipeline network is expected to expand to around 28,000 Km with a total design capacity of around 721 MMSCMD in next 5-6 years, putting in place most of the National Gas Grid that would connect all major demand and supply centre in India. This would ensure wider availability across all regions and also potentially help to achieve uniform economic and social progress.

The natural gas sector in India is at rapid growth due to a) increasing demand for natural gas in the country b) increased exploration efforts under NELP c) commissioning of the LNG import terminals in the West Coast d) projected upcoming LNG terminals and e) the Government's initiatives in the direction of development of a nationwide natural gas pipeline grid. However, there is a need to provide a proactive enabling environment to support the fast-paced development of natural gas infrastructure. An enabling environment includes providing desired policy support and the correct pricing signals for investment in the sector, reforming the present set of regulations to adopt to changing needs and making them more robust and addressing the distortions in the fiscal regime applicable for natural gas.

Overall the gas sector in India has shown modest growth in the past. Substantial investment in infrastructure relating to import of LNG and transportation of domestic gas across India is planned for the next 5-6 years. The current planned investments along with incremental investments in future would be sufficient to meet the growing demand for gas from various consumers segments. In order to ensure the projects get implemented on a fast tract basis, Government of India and petroleum and natural gas regulatory board need to take various policy and regulatory measures.

3.7 LNG Sector in India

Currently oil and natural gas constitutes about 38% of the energy consumption in the country and with increasing reliance on road transport and the sustained growth rate of the economy, this percentage is expected to reach over 40% in the next few years. Recently, natural gas, being environmentally friendly and clean, has gained a lot of importance in the fertiliser industry, power generation, iron and steel and in the transport industry. Natural gas requires special infrastructure for distribution and with the setting up of the Gas Authority of India Ltd, in 1984, Government of India took the initiative to create an infrastructure to transport gas to various locations in the country.

The Oil and Natural Gas Corporation (ONGC) and Oil India Limited (OIL) are the main producers of gas. OIL is operating in the Assam and Rajasthan areas where as ONGC is operating in western offshore fields and in other States. Contracts in respect of five medium sized fields have been entered into for development through joint ventures of ONGC/OIL with private parties and contracts for 13 small fields have been signed for development by private parties.

Projections of gas requirements made by various agencies indicate a wide and growing gap between demand and supply. To meet this gap GOI has taken steps to import natural gas from the Middle East. An MOU was signed with Iran in 1993 and a feasibility study for laying a pipeline between Iran and India is under consideration. Due to technical and political reasons, these projects are held up. Prospects for importing gas from Bangladesh and Myanmar to eastern/southern parts of the country are also being explored.

India is the 4^{th} largest importer of LNG in the world. Due the continual growth in economy and rising concern on using cleaner source of energy has increase the share of natural gas in energy mix of India, this lead to increase in demand of LNG. A number of new infrastructure e.g. Regasification terminals and natural gas pipelines are being developed in various parts of India. This will strengthen the development of LNG market in India. Presently India has Regasification capacity 30mmpta, which is expected to go up to 55mmpta by 2025. It is likely that India would become 3^{rd} largest importer of LNG in the world by 2025.

In recent years the demand for natural gas in India has increased significantly due to its higher availability, development of transmission and distribution infrastructure, the savings from the usage of natural gas in place of alternate fuels, the environment friendly characteristics of natural gas as a fuel and the overall favorable economics of supplying gas at reasonable prices to end consumers. Power and fertilizer sector remains the two biggest contributors to natural gas demand in India and accounts for nearly 75% of gas consumptions. Balance 25% is consumed by petrochemical and other industries, city distributions for vehicles and domestic consumptions.

Currently the natural gas demand exceeds the domestic supply and situation remains same in future as well. It is possible that the gap of demand and supply will increase in more in coming years too. This additional demand is catered through Regasified natural gas in future. India increasing appetite for LNG has resulted in dozen plans of LNG import terminals across the east and west coast of India. The existing facilities and new construction of LNG terminals could theoretically more than triple current capacity to over 80mmpta of regasified LNG over the next 10years of span.

While the Middle East, particular Qatar was sole supplier of LNG to India till 2004 and remains the largest LNG supplier at present also. India stared to diversifying its supply portfolio from 2006 onwards and imported LNG from many countries including Algeria, Nigeria, Yemen, Australia, Russia, UAE, Norway, Indonesia and Oman. India is also looking to diversify its long term portfolio as well.

While India is emerging as major LNG market of future with all round development in LNG terminals, gas pipelines to attain desired sustainable growth. A comprehensive approach which can meet supplier expectations on one side and meet consumer's price expectations on other side needs to be firmed up. India would also need to take strategic decisions like upstream participation in liquefaction projects, tax efficient structures, and a consumer friendly regulatory environment to be successful in LNG market.

The existing, under construction and proposed LNG ventures in India are given in detailed in Table 9

Table 9

LNG terminal infrastructure in India

No	Terminal	Developers	Capacity (MMTPA)
Existing Terminal			
1	Dahej	Petronet LNG limited	17.5
2	Hazira	Royal Dutch Shell	5.0
3	Dabhol	GAIL, NTPC	5.0
4	Kochi	Petronet LNG limited	5.0
5	Ennore	Indian oil corporation	5.0
	Total Existing		37.5
Construction completed			
6	Mundra	GSPC, Adani	5.0
Under Construction			
7	Jaigarh(FSRU)	H Energy	4.0
8	Dhamra	Adani	5.0
9	Jafrabad(FSRU)	Swan	5.0
10	Chhara	HPCL & Shapoorji Pallonji	5.0
	Total under construction / construction completed		24.0
Proposed			
11	East coast	Petronet LNG limited	5.0
12	Kolkata / Digha Port	H Energy	2.5
13	Kakinanda / krishnapatanm / karikal	Others	2.5
	Total Proposed		10.0
	Grand Total		71.5

Source: Petronet & PPAC

Government realises the importance of Gas in the energy sector and is, therefore, investing heavily in the same. Also, it is seen that there are a lot of foreign investors who are ready to help. Some of the companies have applied to set up fully-owned Indian subsidiaries and want to invest heavily in Indian LNG related and power related business in the coming years. Therefore, issues relating to project finance, design and development of import terminals are dealt in details in the next chapter.

CHAPTER - IV

LNG PROJECT FINANCE

4.1 LNG Project Finance

In the preceding chapter we have seen that there is a tremendous demand for energy in India and that India is in the process of initiating a number of LNG projects. Since local production of natural gas is not sufficient to meet the growing demands of gas, it is necessary to import the same. However, since every LNG project requires a tremendous amount of capital, it is not possible for a single party to undertake the entire project independently; projects are usually undertaken as a consortium of various companies and government agencies, preferably with a foreign investor. Also the investment is usually for a long period of time, ideally for 18 to 20 years. Hence, in the chapter we shall briefly deal with LNG project finance. However, since LNG trade is a much closed trade, prior to embarking on the project finance, elements in LNG project and the LNG chain shall be explained.

Every LNG project comprises of several distinct elements which are necessary for the successful implementation of the project. An LNG chain has to be developed and maintained throughout the period of project. We shall deal with the basic elements in the LNG projects i.e. the LNG chain, LNG project planning and LNG project finance.

4.1.1 Elements of LNG Project

The main elements which are necessary for the successful implementation of LNG project are listed below:

- **Source of natural gas**: A successful LNG project must have sufficient proven reserves of natural gas to support liquefaction capacity for a minimum of 18 to 20 years. To ensure adequate deliverability of gas even at the end of the project, reserves ought to be 25 to 35 times larger than the annual capacity of the plant.
- **Liquefaction facility:** Liquefaction facilities are large and expensive and are the costliest link of the entire chain. It's costing goes to several billion dollars. A typical set of facilities would include facilities for stripping liquids from natural gas, processing and export of liquefied petroleum gas, the liquefaction facility itself, insulated pressurised LNG and LPG storage tanks with sufficient capacity to load the largest tanker expected to call, a jetty and LNG loading facilities with

sheltered, deep water access to the ocean and associated infrastructure, including roads, electric power, water and housing for employees.

- **Dedicated fleet of tankers:** Each project requires a dedicated fleet of LNG tankers, which are amongst the most expensive and complex merchant ships ever built. The number of tankers required for a project depends primarily on distance between the liquefaction plant and the customer. In general transportation costs increase with increase in distance.
- **LNG Regasification terminals:** LNG can be unloaded only in specialised design terminals. It typically includes a jetty and unloading facilities, LNG storage tanks, regasification facilities, metering skids and pipelines connections to ship the gas to customers. The cost of regasification terminals varies with capacity, local construction costs and the amount and type of site preparation costs.

4.2 The LNG Chain

To make LNG available for use in country, energy companies must invest in number of different operations. These are highly linked and dependent upon one another, this is best shown in fig-9

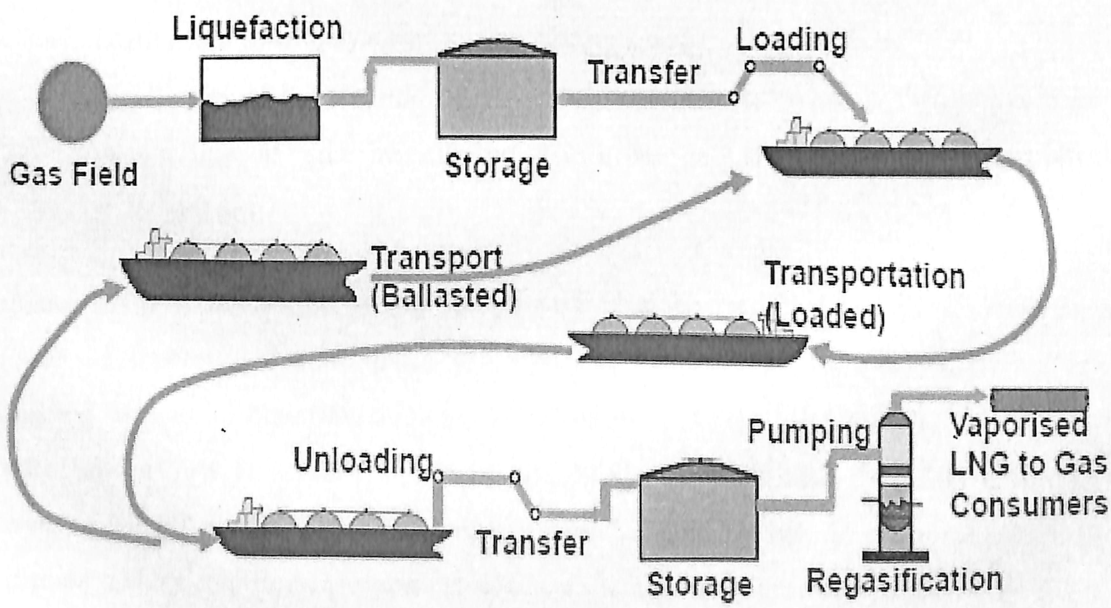


Fig-9 The LNG value chain Source: Presentation on LNG by sham sunder

The capital investment required for a LNG industry is massive and every individual project needs to be carefully structured with an integrated plan to ensure a robust chain with all the links forged to ensure that none of them are weak. Each of the elements in the chain forms an integral part of a LNG project and can only be properly satisfied and economically used if all parts of the chain remain commercially and technically robust and compatible. To make LNG available for use in country, energy companies must invest in number of different operations. These are highly linked and dependent upon one another. The major stages of LNG value chain as shown in fig-9 consist of following.

Production: The production stage involves the supply of gas and condensate from the wells in offshore/on shore facilities through the pipelines to gas processing facilities.

Liquefaction plant: Natural gas and condensate supplied from wells contain various types of contaminates or impurities. These need to be removed from natural gas for reasons such as product specification, compliance with environmental regulations and safety considerations. The process of condensate stabilization, gas treatment and gas liquefaction is achieved in liquefaction plant.

The liquefaction plant usually contains below main facilities.

- Storage and loading facilities
- Utility and offsite systems and infrastructures
- Process unit include inlet gas reception unit, condensate stabilization unit, gas treatment and sweetening facilities, gas liquefaction unit, sulphur recovery unit

Shipping: LNG is transferred in to ships through loading system. LNG ships are designed to handle extremely low temperature. LNG is carried in insulated metallic tanks constructed by special materials such as nickel stainless steel or the suitable materials who can withstand at low temperature. The insulation system maintains the LNG temperature to prevent heat inflow from the surrounding which would otherwise evaporate the liquid. The highest safety standards are employed in the design and operation of LNG vessels.

Regasification Terminal:. The LNG receiving terminal consist of pipelines, ship berthing facilities, unloading facilities, storage tanks, vaporization system, units for handling boil off from the tanks, metering stations and ancillaries. At the receiving terminal LNG is regasified before distribution to consumers via pipelines.

The LNG project is 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. Also the LNG projects are international in character as they have multiple partners, which require all partners to agree on the same project at the same time and also remain in agreement throughout the life of the project. Selling of LNG is not a onetime transaction, but is continual in nature and will last for at least 18 to 20 years. In the same way, buyers of LNG are also limited and because of the magnitude of investments involved, such projects have been developed only on the basis of long term commitments. Investors in all parts of a LNG chain will thus not only need to make sure that the whole chain is complete, but also ensure that each part of the chain is thoroughly reliable and that there is no chafing between the links.

Failure of any link in LNG chain adversely impacts all other players in the LNG chain.

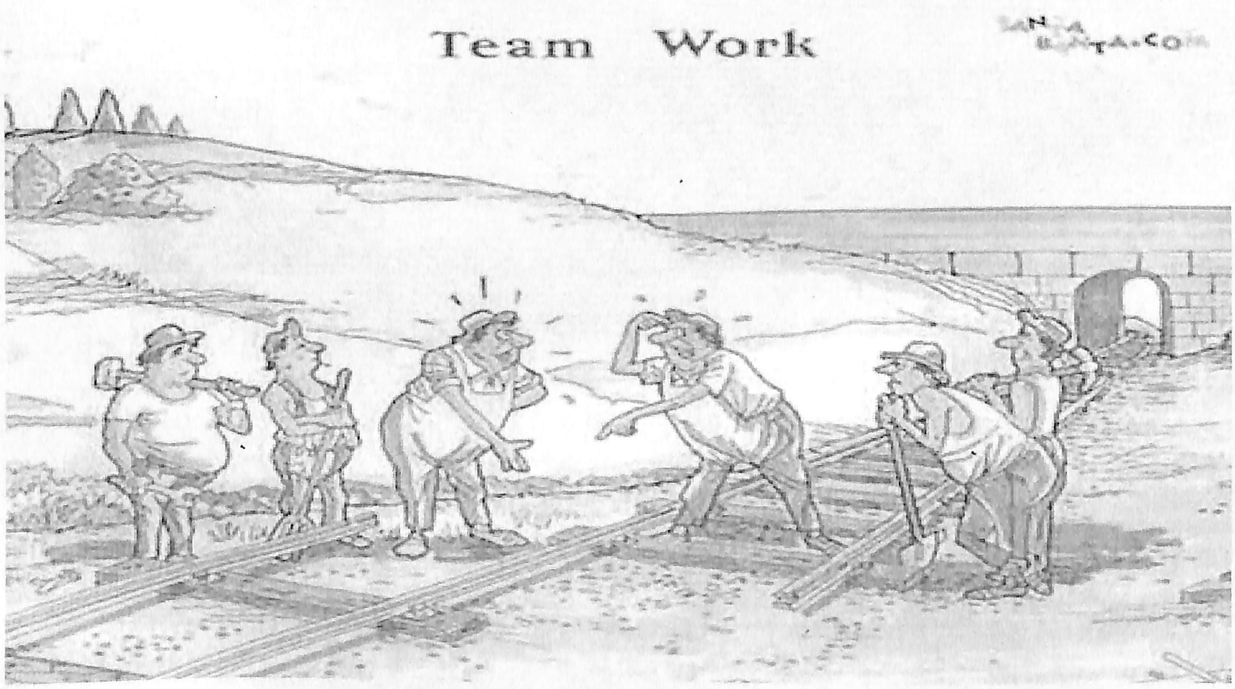


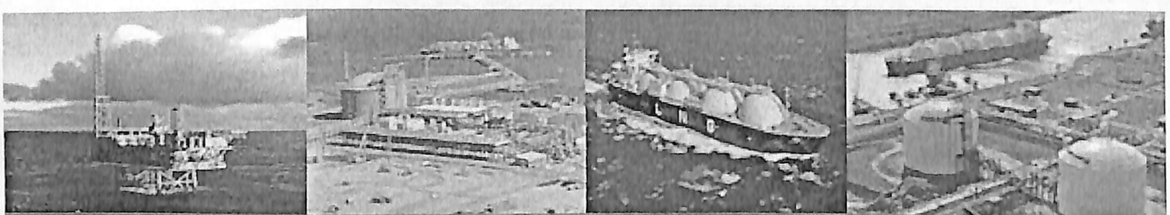
Fig-10 LNG value chain linkage Source: Presentation on LNG by sham sunder

4.3 Project Finance

Price competition plays a major role as LNG must be sold cheaply enough to compete with other forms of energy and also at a high enough prices for the gas producer to make a profit. Hence, the factor that makes up the difference between two prices i.e. the capital cost of the entire LNG chain must be kept sufficiently low and the structure of the project and the scales of reward and incentives for each part of it should be equitable to all parties.

As discussed earlier capital requirements of an LNG industry are greater than in any other sector of marine operations. There are many similarities in the geological occurrence and in exploration, development and production process for oil and gas. Gas projects are more costly than oil projects and the total costs of LNG projects have reached a point where the largest oil companies are also finding it difficult to finance it individually. New means of raising capital are needed and one method is widening of the equity ownership pattern in the project so that gas distribution companies in importing countries are joined by the government agencies of the exporting countries to help oil companies finance the project.

The total capital cost of an LNG project is very high and includes all aspects of gas liquefaction, marine transportation, and regasification which is given Fig -11



EXPLORATION & PRODUCTION	LIQUEFACTION	SHIPPING	REGASIFICATION & STORAGE
$1.0 - $2.5 billion	$1.5 – 2.0 billion	$0.8 - $2.3 billion	$0.5 - $1.0 billion
$0.5-$1.0/MMBtu	$0.8-$1.20/MMBtu	$0.4-$1.0/MMBtu	$0.3-$0.5/MMBtu

TOTAL = $3.7 - $8.8 billion or $2.00 - $4.70/MMBTU

Greatest variability is in upstream feedstock for liquefaction and shipping distance.

Fig-11 LNG Chain Cost Source: Industry with BP academic use

- Variability in upstream costs is due to variable exploration and production expenses
- Variability in shipping costs is due to differential distance (from less than 500 to 13500 NM)
- Wide variation in delivered prices on account of different margins, taxes and other obligations.

The final delivered price of LNG is normally quoted as the cost at the receiving terminal. This overall price is made up of various variable prices that are integral part of the total project and are incurred throughout the transfer of gas from the producer to consumer. The main heads of these prices are:

1. Well head gas price
2. Gas delivery cost to the liquefaction plant
3. Liquefaction cost
4. Marine fright charges

There is usually some fluctuation in the non marine costs, but these prices are stable compared to widely varying marine freight costs.

In the past, oil companies were responsible for financing a large number of projects. Now, it is, however, difficult for one company to generate all of the funds required to finance a large new LNG project. The financing of the earlier projects was carried out in a piecemeal fashion, with separate financing for liquefaction, transportation and regasification. With a view to aid the purchaser of a vessel, major shipbuilding countries of the world, USA, France and Norway, have each developed financing schemes which promote either domestic sales of ships or the export of ships. However, now the ownership of the LNG projects has moved beyond and the new owners are multiple equity syndicates, with the gas utilities in the consuming countries, the major oil companies and the government agencies in the producing countries being the equity holders. This new ownership pattern is influenced to an extent; by the attitudes of the producer governments who wish to take a further interest in the export schemes in order to eventually assume greater control of other export activities.

CHAPTER - V

LNG IMPORT TERMINAL

5.1 Basic Design data of an Import Terminal

We shall now study the basic design data that have to be established prior to commencement of the pre engineering phase of LNG import terminal. This is generally developed during feasibility and optimisation studies and includes process engineering, ship, marine and project design data. System evaluation and optimisation studies also require defined economic criteria, which are dependent on site location, current financial conditions, operating company guidelines etc. The basic design data is expected to include the following:

1. **LNG composition**: Subject to the location of the proposed import terminal, alternate sources of LNG from existing export plants must be considered. Allowance must be made for ship boil off during transport and the subsequent effects on the properties of the LNG as delivered to the terminal.
2. **Send out quality**: Gas quality specifications generally include heating value, sulphur compounds, carbon dioxide, water content and hydrocarbon dew point. All potential sources of LNG are considered in assessing the range of imported LNG compositions. A review of the resultant gas product leaving the terminal is made to assess compatibility with the export gas specifications, which could be related to compatibility with existing distribution gas specifications. Blending of natural gasses from different sources within the distribution network should also be considered in assessing export gas quality. The variation in gas demand during a year is an important design parameter and is used to optimise the design of the storage, vaporisation and send out system. Sufficient flexibility must be incorporated in the design of the terminal to enable the send out of gas over specified capacity range. Gas utilisation varies, depending on location and application.
3. **LNG ship data:** Details of ships expected to deliver LNG to a terminal must be provided in order to evaluate marine and jetty requirements. This will not only influence marine considerations and berthing facilities but will also have an impact on LNG ships unloading facilities. The design, safety and commercial criteria for ship operations generally require that a ship be unloaded in 12 hours, so that it can be turned around in 24 hours. With larger ships the unloading rates will increase, which in turn will result in larger unloading lines on the jetty and into the terminal. Facilities at liquefaction plants will also need to reflect these changes.

4. **LNG tank data:** Most recent LNG storage tank designs have used concrete outer tanks with either membrane or self supporting nickel steel inner tanks. The construction of larger, fewer tanks results in reconsidering in-tank pump sizing and installation philosophy.

5.2 Site Selection for LNG Terminal

Site selection for LNG terminal is one of the first concerns for investor when he thinks about investing in LNG regasification plant. The selection must combine the technical, environmental and economic aspects. It must also consider the specific characteristics of the area, in order to avoid surprises resulting from in additional and unforeseen costs during the further stages of the project. While selecting the site for a typical LNG terminal, besides the potential market survey, the legal and political context, the below mention issues need to be considered:

1. **Site pre selection:** During site pre selection, attention needs to be paid to the onshore land availability, the possibility of reclaiming, the potential for future expansion, the topography of the land to ensure a sound geological base over which the plant foundations will be built, the on-land accessibility to the area, the tanker accessibility to the site, the surrounding area which includes industrial area, population, environment, etc.
2. **Local site data:** Need to compile all available local site data which help to determine the characteristics of all parameters that could affect the feasibility of the preselected areas. Such as the weather conditions i.e. Temperature, wind rain, snow, storm, earthquakes etc., the sea conditions like water, draught, waves, current, tides, sea water temperature, ease of approach, dredging required, sea traffic and safe anchorage areas, etc.
3. **Geological site validations:** The suitability of the intended site will be checked with regard to soil conditions. All geological phenomena which could affect the plant feasibility, design and construction, or which could modify the risk level or the investment costs, will be reviewed during site validation step. A review of the seismic faults in the vicinity and the potential soil liquefaction will be made to determine the geological site validation and area geology and soil properties.

4. **Preliminary assessment of environmental impact:** During this phase attention must be paid to surrounding areas and to the impact on the adjacent facilities, urban areas, etc. Even though LNG is considered, as a clean industrial operation, there could be some constraints in the local regulations which could affect the terminal choice. The local regulations must be studied in this phase.
5. **Preliminary assessment of safety impact:** The proximity of neighbouring communities and facilities in the immediate area of the proposed terminal has to be considered from a safety as well as public relation point of view. While LNG terminals do not pose an immediate threat to surrounding communities, it is preferable to locate them as remote as possible from such areas. This is not only safer but also in most cases economical.
6. **Economical validation:** Proximity to an industrial environment may be convenient and economic, for instance, the possibility of using in place bunkering facilities. The potential for utilisation of other production facilities such as nitrogen and steam, if they are dependable and of acceptable quality and purity, have to be considered in the early stage of site selection. Other advantages could include the possibility of integrating two or more industries such as one providing its hot cooling water return to the LNG terminal for LNG vaporisation purposes, while receiving back low temperature cooling water, or the possible utilisation of the cold potential of the LNG in processes such as power generation, air separation, CO2 liquefaction, hydrogen and helium production and commercial refrigeration. From an environmental stand point, an LNG terminal is a very clean facility with limited emissions of any type. The main environmental impact will be the disruption caused.

5.3 Safety Requirements LNG Industry

Safety in LNG industries is a sensitive issue with not only technical ramifications but also social and political aspects. In general, safety is the most important consideration in the design, construction and operation of in complete LNG chain. Existing design codes, standards and procedures are being continuously reviewed and updated and new standards are being developed to ensure that all new developments are incorporated, thus minimising risk and potential hazard to life and property. There is an ongoing activity in improving safety and reducing risk associated with LNG installations.

Since accident in Cleveland (USA) in 1942, LNG has been considered as hazardous product various regulations have been developed, some are listed below.

- **Transport by sea**: If LNG is transported by sea then IMO rules, SIGTTO recommendations, OCIMF rules, classification, insurances requirements all these need to be followed.
- **Plants and storage:** In LNG plants and storage NFPA 59A (USA), EN 1473(Europe), JGA rules are applicable.
- **National regulations:** Safety and regulatory bodies, Environment protection bodies and regulations
- **Companies polices and engineering standards**

Safety and environment protection are considered since preliminary design studies, codes and regulations mainly provide:

- **Design criteria:** such as seismic design, impounding systems, jetty design etc...
- **Minimum safety distances:** minimum safety distances considering accident scenarios and consequences, vapour clouds, fire radiation, cold explosion etc...
- **Hazardous area classifications:** Fire proof requirements, Electric and instrumentations equipment classifications etc...
- **Design and construction rules:** Minimum safety systems, minimum protection, fabrication, construction and control standards

A safe and smoothly operating facility can be generally ensured, if the applicable codes and standards are followed in true senses. Some of the special codes followed for the LNG terminals are:

- National fire Protection Associations (NFPA-59A)
- British standards (BS 7777)
- European committee for standardisations (EN 1473)
- Oil companies international marine forum (OCIMF)
- Society international gas tanker and terminal operators (SIGTTO)
- Oil industry safety directorate (OISD 116, 118, 194)

Process Hazard Analysis reviews and hazard operations studies must be used during project execution in order to ensure integrity of the facilities as they are being engineered as well as during subsequent operation. Risk evaluation and hazard analysis are employed for environmental impact assessment and to assist in site selection. This activity not only involves the LNG terminal but also extends to marine requirements for LNG ships approaching the terminal and berthing at the jetty.

For the safe operation of any LNG terminal it is vital to have a proper design of the emergency shutdown systems and communication systems as well as the monitoring and loss protection systems. Loss protection systems are designed in such a way that they respond automatically in the event of lack of operator attention.

5.4 LNG Receiving Terminal Facility Design

The LNG receiving terminal receives liquefied natural gas from special ships, stores the liquid in special storage tanks, vaporises the LNG, and then delivers the natural gas into a distribution pipeline. The receiving terminal is designed to deliver a specified gas rate into a distribution pipeline and to maintain a reserve capacity of LNG. The amount of reserve capacity depends on expected shipping delays, seasonal variations of supply and consumption, and strategic reserve requirements

Receiving terminals are expected to operate close to 365 days per year and have spared equipment to achieve this availability. The one exception is that a shutdown may be necessary for a statutory inspection of vessels or maintenance of some critical items such as the flare. Spare equipment can be eliminated and cost savings achieved if line packing can be used or if some of the gas consumers can tolerate interruptions in the send- out supply.

The schedule for completion of LNG terminal is approximately 48 months from the start of front end engineering design (FEED), or 33-36 months from the date of engineering, procurement and construction (EPC) contract award. The critical path will be LNG tanks, which will take 32-34 months for completion. In addition, permitting can add significantly to the total duration of project completion.

The cost of LNG receiving terminal is mostly dependent on selected site. A typical cost distribution is given in below table:

Area	Percentage
Jetty	11 %
Storage tanks	45%
Process units	24%
Utilities	16%
General Facilities	4%
Total	100%

Table -10 Cost distribution LNG terminal

The above may varies depending upon many factors some of main factors are given below:

- **Marine condition:** The cost of jetty depends upon jetty length. If the sea bed depth increase which results increase in cost of jetty gradually, but sometime it may increase dramatically. Dredging is also an option which lowers the capital cost but operating cost increases due maintenance of dredging. The cost of jetty also depends on submarine soil conditions if substantial piles are required. Another major item that may be needed is a breakwater if the site has an unprotected shoreline. The breakwater reduces shipping delays, and pays out if the site frequently has high waves. But it can significantly increase both cost and schedule.
- **Onshore site conditions:** The ideal soil allows the use of spread foot foundations. If the soil does not support enough load for spread foot foundations there are several other options, but all add to the project cost. These are pre loading to accelerate settling stone column pilings, but all these increase project cost. Soil improvement by any means is expensive.
- **Storage tank type:** Single containment tank is less expensive than other type of tanks but it requires more land and may not be available or practical in some cases. Full containment tank cost approximately 25-50% more than single containment tank. LNG tank specified for a full height hydro test will have over twice the hydrostatic pressure and weight during the test compared to actual operation. The shell thickness and tank foundation must be designed for the full hydro test load and this

adds to the cost. LNG storage tanks on past projects have been hydro tested to the full inner tank height, but current industry practice is now partial hydro test.

- **Power generation on site:** One of the more costly utilities in a receiving terminal is power generation, however many facilities import power from the local grid to reduce capital cost expenditure. Regardless of the source of power, LNG terminals have small emergency generators to enable orderly shutdown in the event of a power supply failure.
- **Labour:** Construction labour is a major cost factor that varies widely from site to site. Unlike liquefaction plant, Receiving terminals are often located near population centres so it may be possible to obtain much required skilled labour locally. This local labour option reduces the cost required for housing camp construction.

The key drivers that govern the design of LNG receiving terminal are:

- Location
- Regulatory requirements and codes used in design
- Site characteristics
- Capacity of terminal plant
- Operating issues
- Source of LNG supplies and its characteristics
- Gas send out characteristics
- Safety and security considerations
- Availability of local infrastructure and labour
- Owner's risk requirements

5.4.1 Location

Till date all LNG import terminals have been constructed onshore. Due to local opposition, lack of undeveloped land and remote from population, cost of land, and general permitting obstacles, it is very likely that some of new terminals under considerations will be constructed offshore. This facility could either be founded on seabed (gravity base structure or GBS) or floating with anchor lines to the seabed. GBS facilities would be located in waters less tnan 35meters, while the floating terminal could be located in water depths up to 1500meters. LNG terminal at Kakinada developing by H-energy is based on GBS while the LNG terminal under construction at Jaigarh and Jafrabad are floating type. The primary issues associated with offshore terminals compared to an onshore terminal are secondary containment of LNG in the tanks and safety issues associated with facilities, LNG storage.

5.4.2 Regulatory Requirements and Design Codes

Regulatory requirements and applicable design code is a key issue in LNG receiving terminal design. Generally terminals located in North America use NFPA code 59A as the basis, while the terminals located outside of North America will generally use EN code 1473 as the basis. Both codes are similar, but as different considerations for storage tank types. Other local and national codes are also need to take into considerations while design.

5.4.3 Operating issues

The sparing, maintenance and staffing philosophy for the facility should be determined by the owner in conjunctions with both regulatory authorities and the design engineers before commencing the design process. This will ensure that the facility reliability cost and impact on the local community are all evaluated as to the most practical and cost effective solution during detailed design work. Normally in onshore terminal for operating staff onsite housing would not be provided. While in case of offshore facility which are operated similar to typical offshore production oil or gas platform, with personnel based on the facility. However the shifts used and the necessity of housing facility depend upon condition and proximity to shore. The site would have maintenance and warehouse facilities, but the location of facility and existence of third party maintenance facility must be carefully evaluated before taking final decision.

5.4.4 Safety and Security

In LNG receiving terminal design safety and security is also an important consideration, but in recent in time have taken an added scrutiny and importance. The facilities are often in remote locations so safety and security must be evaluated properly considering various aspects emergencies. As facility is located in near to navigable waterways makes design difficult and important considering safety issue. It is also more approachable by any marine vessels makes it vulnerable. The use of exclusion zones and thirty security measures are mandatory if facility security is to be achieved.

5.4.5 Risk

Another area to be considering prior design is the risk tolerance of both owner and regulatory authorities. This will depend upon experience of all parties, and can be mitigated as long as the design engineer achieves an early understanding and strategic planning.

5.5 Key Components of LNG Receiving Terminal

Typical key components of an LNG receiving terminal with marine ship, marine facilities LNG storage tank and regasification facilities are shown in fig-11.

Fig-12 LNG terminal and regasification plant Source: Internet image

The key components of an LNG receiving terminal are:

- Marine facilities and LNG unloading systems
- LNG storage tanks
- Regasification process including vaporizers
- Utilities and other infrastructure requirements

5.5.1 Marine Facilities and LNG Unloading

A marine facility has significant impact on overall economics of LNG terminal. Marine facilities includes jetty head which comprising berthing and mooring facilities, LNG and vapour unloading arms, fire water monitors, gangway tower, flare platform, jetty trestle and protection dike.

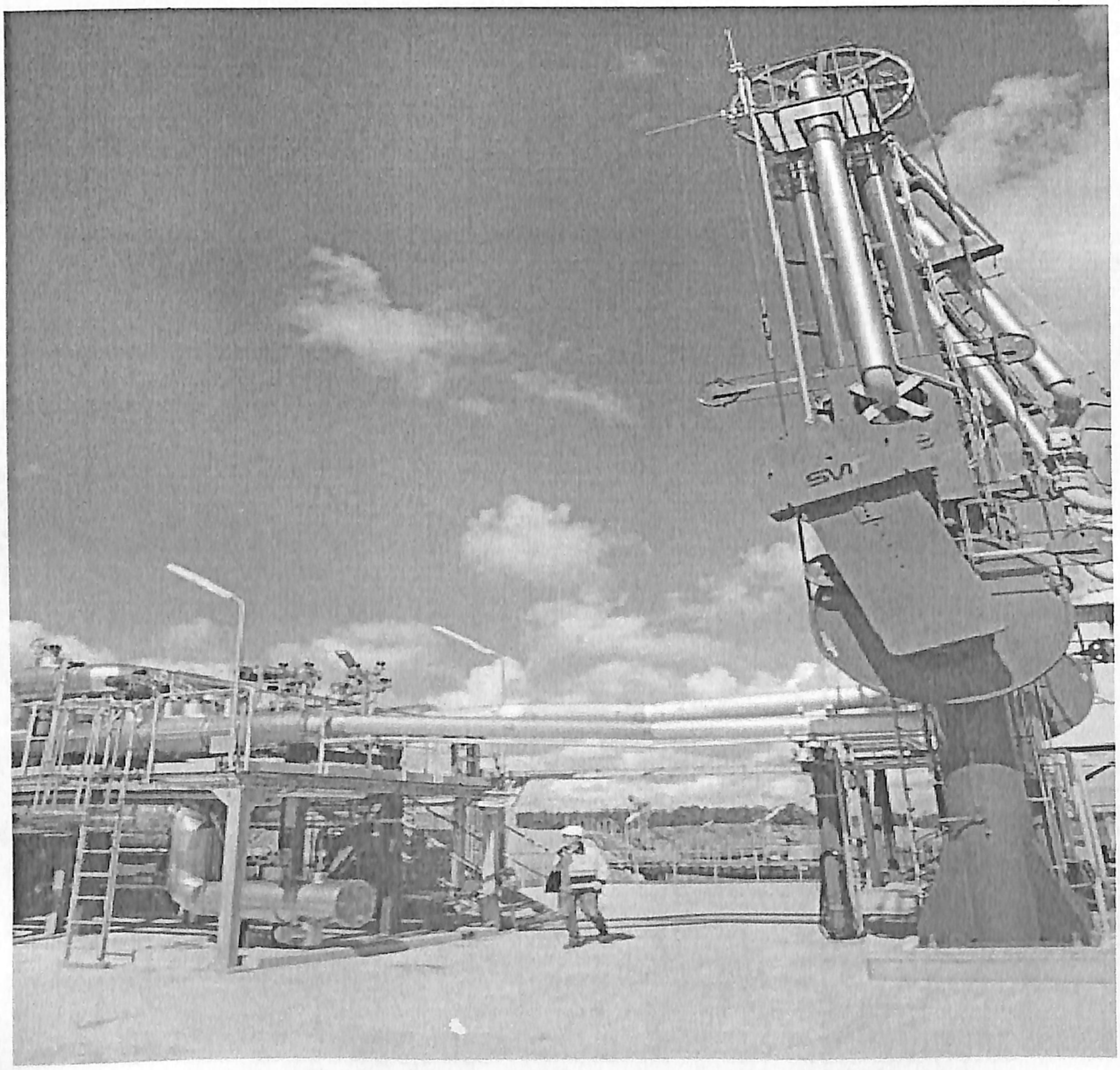


Fig-13 LNG Unloading arm Source: Nynashamn LNG terminal Sweden

The key design variables of unloading systems are:

- Distance from ship to tanks
- Ship discharge pump capacity
- Desired discharge rate
- Storage tank elevation
- Hydraulic design of line
- Top versus bottom fill of LNG tanks
- Number of lines desired for reliability

The availability of berthing, range of ship size desired and discharge rate tend to be the determining factors when positioning and sizing the unloading components. Depending upon wave condition in area, breakwater may be required. Typical LNG carriers of 135000 m^3 are widely used ship for LNG marine transport. This ship is approximately 300 meters in length, 50 meters in width and has a draft of 11-12 meters and requires approximate 15 meters water depth. Newer ship has more capacity and range up to 250000 m^3. These ships are longer and wider than traditional 135000 m^3 ship but have same similar maximum draft so that they can operate at existing LNG terminals also.

The marine facilities can easily be the most expensive part of LNG terminal and cost up to $200 million, depending on requirement of breakwater. The LNG tanks second most expensive part of terminal cost up to $50-60 million per tank. Extensive shipping simulations will be required to optimize the number of ships and storage tanks ensuring the availability of the facility and the supply chain are not comprised.

5.5.2 LNG Storage Tanks

LNG storage tank are classified as single containment, double containment and full containment. Single containment tanks have only a single shell and use a secondary bund or dike to limit the LNG spill, while double containment tanks have an outer shell to contain spills and full containment tanks have added feature of roof structure that will contain all vapours emanating from spill for a limited period of time. Tanks can be circular, membrane or self supporting prismatic (SPB) in design. LNG tanks are primarily constructed of special materials such as nickel steel, stainless steel or aluminium.

All these tanks are used in various locations and are technically acceptable. But the cost, land requirement and layout requirement are different for each tank. Single containment tank require significantly more land area than other tanks to ensure safe separation to account for the effects of safety analyses for both potential thermal radiation and gas dispersion events, and thus must be carefully analyzed. Single containment tanks cost approximately 30% less than that of full containment tanks and 10% less than double containment tanks. Careful analysis of land, cost, and safety requirements must be performed while deciding tank type in design.

In the design of an LNG terminal an economic study can be made to determine the optimum design pressure of the storage tanks. The use of higher pressure tanks could allow the elimination or reduction in the capacity of ships vapour return compressors, while low pressure tanks would necessitate use of compressors. The tanks are normally protected against over pressure by control valves to the flare, trip valves on rundown lines and relief valves to the atmosphere. They are protected against vacuum by hot gas from the process plant, trip off loading pumps and boil off gas compressors and ultimately by vacuum breakers to the atmosphere.

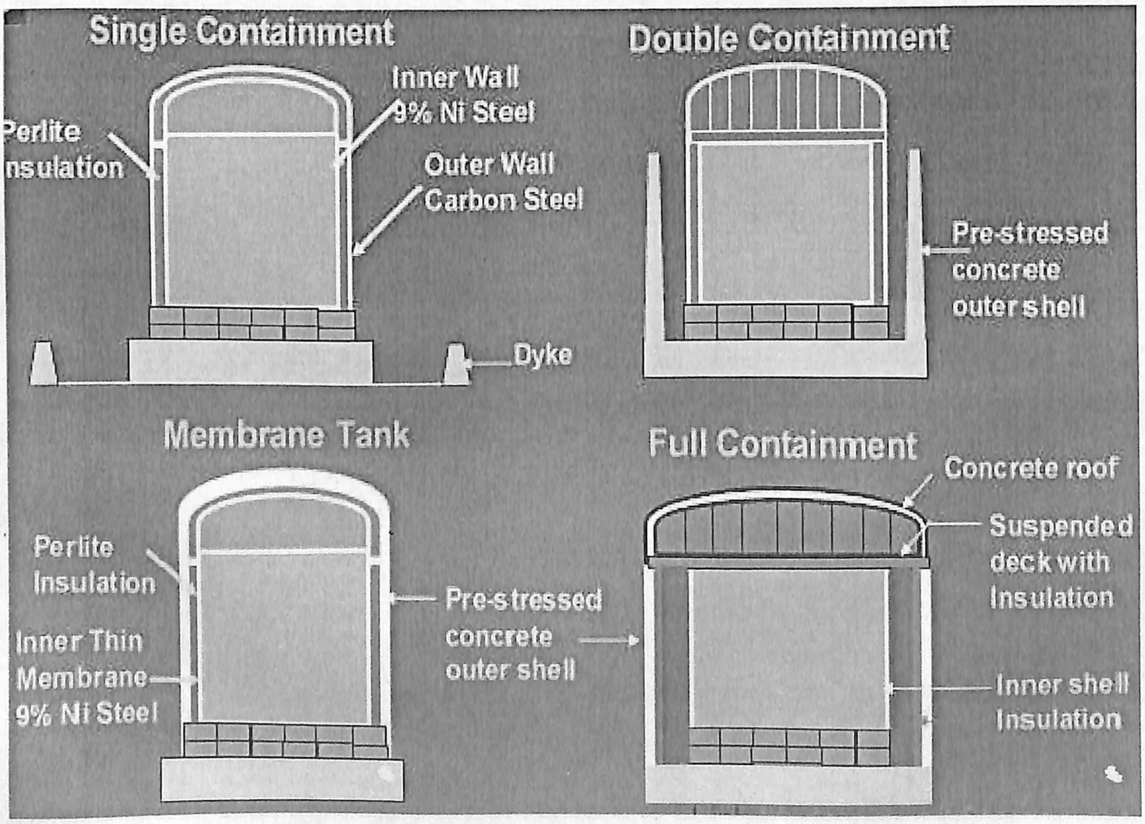


Fig-14 LNG storage tanks Source: Internet image

5.5.3 Regasification

The LNG is send to the regasification section by high pressure send out pumps. These pumps provide all of the pressure required to send out gas, this can avoid more costly compression. These pumps are typically centrifugal, multistage with submerged electric motors using an electrical system designed for hazardous areas and have self contained suction vessel. Typical send out pump shown in fig-15 below

Fig-15 LNG Send out Pump Source: Courtesy of Ebara International

The regasification of LNG before its send out to a low-high pressure pipeline can be performed by various equipments or methods, these are:

- **Open Rack Vaporisers (ORV):** ORV units use seawater to vaporise LNG inside vertical tubes while water runs down the outside of the tubes as films. ORV has higher capital cost but its operating is lower. It requires large quantity of sea water, means large sea water handling system required. Sea water quality is important for proper operation of ORV. Sea water returned at 5-8 ^{o} C which is cooler than intake sea water and can cause potential environmental impact. Operation and maintenance of ORV is easier.

- **Submerged Combustion Vaporisers (SCV):** In SCV units, fuel is burnt and the fuel gases heat a water bath in which a coil is located. LNG passes through the tube side of the coil and is vaporised. These units are cheaper to install but expensive to operate as they consume up to 1.5% of the vaporised LNG as fuel gas. These units are smaller in size and required less space. They have higher thermal efficiency, over 95%. This unit has wide variability for send out rate. Heat of vaporization produces excess water which required treatment and disposal.
- **Combined heat and power heat exchanger system (CHP):** This is very efficient process by utilizing the flue gas heat. It requires less capital than ORV but more than SCV. Air emission is more than ORV but less than SCV. For complete reliability may have to install 100% backup vaporization system when power plant is offline.
- **Shell and Tube Heat Exchangers:** Shell and tube heat exchangers using various heating media such as district heat, glycol/water or hot oil.

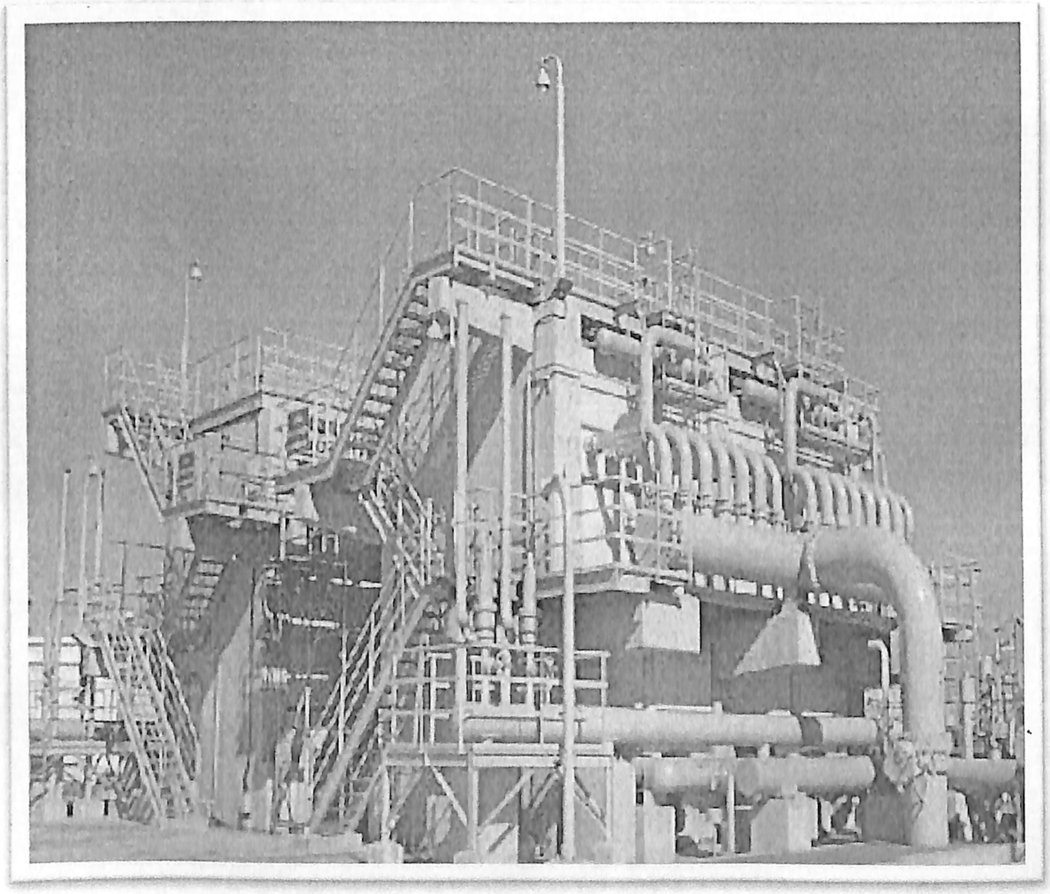


Fig-16 ORV   Source: Courtesy of Sumitomo precision product company

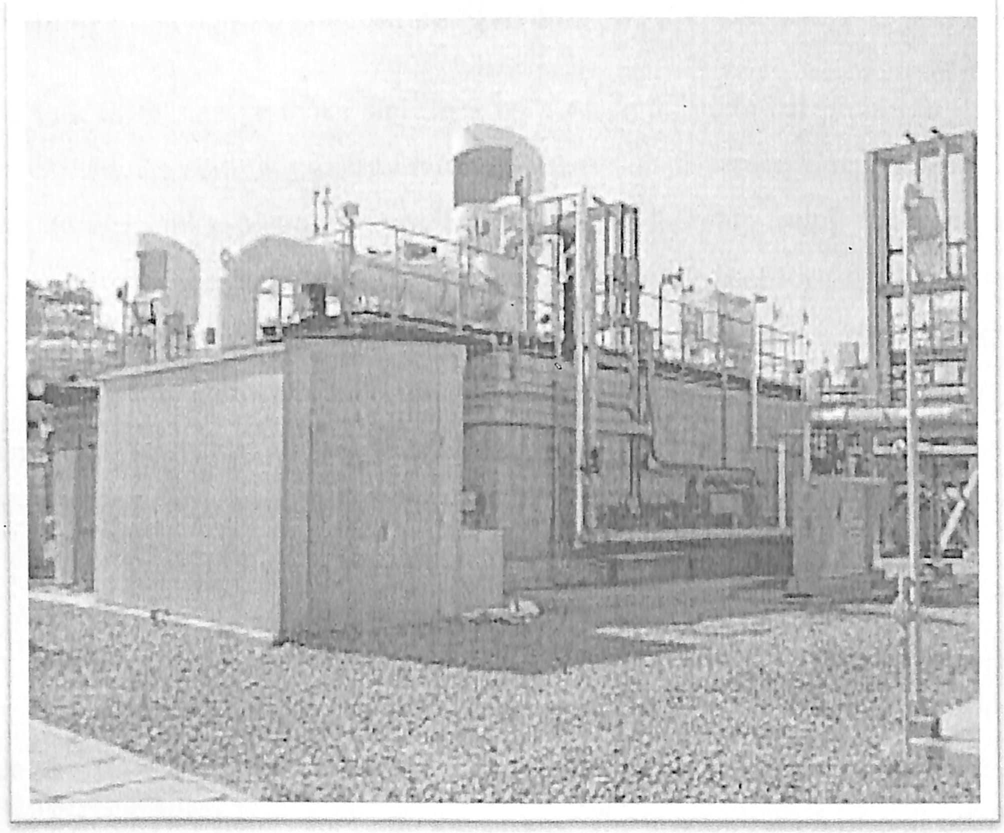


Fig-17 SCV Source: Courtesy of Sumitomo precision product company

A combination of above system can also be possible. The decision on which type or types of vaporiser to install is generally determined on the basis of an economic study. The specific site condition must be carefully evaluated to decide the best choice of vaporizers. The choice of vaporiser type must also consider the environmental impact of these units. As a general thumb rule, if the sales gas price is above US$3 per million BTUs, The ORV system will be most cost effective.

For the selection of vaporization system, the following criteria can apply:

- Capacity
- Available plot area
- Availability of heating media or sea water (ORV)
- Environmental aspects like air and water emission
- Capital, heat or fuel cost

5.5.4 Vapour or Boil off Gas handling System

Heat in-leak to storage tanks and lines on a receiving terminal produces vapour. During ship unloading, pumping energy and volumetric displacement increases vapour evolved from storage tanks. Vapours must be returned to the ship being unloaded, to maintain cargo vapour space pressure and can be used to provide fuel for fired vaporisers. Boil off gas generated through heat ingress as well as intermittent gases from product unloading and loading operations require continuous removal from storage tank. There are various possibilities to handle this volume of gas, ranging from temporary pressure increase in LNG storage tank to send out to a low pressure pipeline or to the installations of recondensation or even liquefaction facilities.

The system designs of vapour handling is mainly influenced by storage tank capacity, operating pressure, degree of insulation, the imported LNG product properties, the expected operating scenario of terminals loading and send out facilities as well as the possibility of continuous consumption of gas. The customization of boil off gas handling system and also the optimisation of the capital and operational expenditure for the overall LNG terminal are facilitated by profound cryogenic process design.

5.6 Cold Recovery

LNG is most commonly vaporised in ORVs against the seawater or in SCVs where the cold energy contained in the stored LNG is essentially wasted during the regasification process. The cold potential can be harnessed in several ways by integrating LNG vaporisation process for improved performance, lower capital and operating costs. Utilisation of the cold potential of LNG, normally wasted during vaporisation processes such as ORVs and SCVs, is of considerable interest to LNG importers, subject to the quantities of LNG involved and local economics for integration with other industries.

Some of the possible methods of LNG cold utilization are listed below:

- Air separation
- Power generation
- Sea water desalination
- Hydrogen purification

- Cryogenic crushing
- Water treatment
- Chilled water for refrigeration and industry
- Cold storage and frozen foods
- CO2 and dry ice production

LNG cold utilization is most economical when gas send-out rates are high and continuous. This concept is most widely used in Japan. The development of these opportunities to utilise 'cold energy' happens progressively so as to allow several disparate business to naturally grow.

5.7 Cold Utilization in Power Generation

The LNG cold can also be more effectively utilized by integrating the receiving terminal with an external simple or combined cycle gas turbine power plant, which will result in increased power production. This has been the focus of integration within a number of projects over the last 10 years; for examples Enron at Dabhol, India. Cold methanol/water used to chill gas turbine inlet air. The integration of terminal and power plant can be done by, Sea water system integration by chilling of cold water or by re-use of hot water and cold transferred to gas turbine inlet air chilling. The sea water usage of a terminal is significantly lower than that of a conventional combined cycle power plant (CCPP). Recovery of cold from the total terminal send out will increase power recovery. However a tenfold increases in send out rate would only increase the additional power to approximately 0.5% making such integration only marginally attractive. Re-use of hot water from the power plant in the terminal provides only a marginal increase in vaporisation capacity since the improvement in overall temperature difference is limited. Some overall substantial CAPEX savings may be possible if the sea water intakes and outfalls of the power plant and terminal can be combined.

In order to prepare a design for this system it is necessary to understand the operating patterns of the terminal and the power plant as well as understanding the weather patterns. Both the terminal and the power plant can be either base load or peaking facilities. Implementation of the air chilling system will generate additional electrical power but it will increase the cost of both the terminal and the power plant. The economics of the integration will depend on the value of the increased power export taking into account the extra fuel usage.

Estimation of the potential benefits takes into account the following steps:

- Obtain weather data, temperature and humidity data throughout the year both averages for economic analysis as well as extremes to ensure the proposed design can cope while providing acceptable gas send out or power production capability.
- Develop monthly send out pattern from terminal design basis.
- Develop maximum cold available from send out vaporization.
- Obtain air chilling available by applying the available cold to the air intake of the operating gas turbines.
- Estimate the incremental power that can be produced for the available chilling.

Co-operation between the LNG receiving terminal operator and the power plant is essential for any mutually beneficial commercial synergy between the two units. One of the major issues is balancing the loads. The production of both the units is dependent on the performance of each facility. The two units must operate consistently close to their optimum level for a successful integration.

5.8 Government Future Plans and Focus Area

The development of natural gas market as well as infrastructure in India today needs an enabling environment so that the intended results could be achieved in the most cost effective manner, in the least possible time and with maximum benefits to all stakeholders including consumers. The natural gas sector in India today is at the threshold of rapid growth supported by ever increasing demand for natural gas, increased exploration efforts under NELP, large scale discoveries of gas in the East Coast, commissioning of the LNG import terminals in the West Coast, new upcoming LNG import terminals and the regulators initiatives in the direction of development of a nationwide natural gas pipeline grid.

The unbundling of natural gas transportation and marketing is still to happen. However, it is envisaged that in the long run, with the maturing of gas market, the authorized entities will have transportation of natural gas as their sole business activity and will not have any business interests in the gas marketing or city or local gas distribution networks. PNGRB has already come out with draft regulations to ensure legal/ownership unbundling of transportation activity from other activities of an entity. Even before the unbundling is affected, PNGRB needs to ensure that the capacity in transportation pipelines is available on a transparent basis to all the shippers and consumers.

The natural gas pricing is moving towards a market determined pricing mechanism and Indian gas market is getting increasingly aligned with the global trends. Although this gets restrictive when volumes for gas produced locally gets allocated by government of India which impedes the development of a gas market and deters imports as it limits the demand for RLNG.

Developing competitive natural gas markets and attracting investment in development of infrastructure may require frequent regulatory changes and interventions. Continuous improvement in the regulatory framework must always support market development. The market forces have also proved to be vital and effective in the natural gas industry, once an appropriate structural and regulatory framework is put in place.

Given the international experience of attracting investments and in the development of the natural gas markets, the major elements that remain critical for creating an enabling environment in India for the development of natural gas market are structural elements and market elements. A structural element are regulatory support, stability of fiscal regime and polices, development of pipeline infrastructure, complete unbundling of gas sales and transportation and fiscal regime to support geographical movement of gas. While market elements are trading hubs spot markets, capacity release mechanism, electronic trading platforms, financial gas market and bulletin boards to provide system and market information.

Taking into consideration the present state of natural gas market and associated infrastructure in India as well as the international experience, the issues for immediate attention could be broadly divided under the heads of Policy Issues and Regulatory issues.

5.8.1 Policy issues

1. Enabling efficient usage of gas - through free market pricing and gas trading & promoting CCHP
2. Infrastructure status to natural gas pipelines.
3. Policy focus on setting up strategic storage post 2020.
4. Sufficient focus on the environmental and social impact linked to natural gas pipeline and LNG projects.
5. Expediting the approval process.
6. Reform and support key gas based consumption sectors.
7. Evaluate alternatives to the present differential tax regime.
8. Focus on securing long term gas supply tie ups.

5.8.2 Regulatory issues

1. Legal and Ownership unbundling of the activities of transportation and marketing of natural gas.
2. Need for a robust open access code for the natural gas pipelines.
3. Bidding guidelines and criteria for city gas distribution and pipelines.
4. Establishment of liquid and transparent primary and secondary markets for trading pipeline capacity.
5. Setting up the gas grid management system run by an independent system operator.
6. Encourage development of liquid trading hubs in India.
7. Development of regional pipelines.

CHAPTER - VI

ENVIROMENT HEALTH AND SAFETY ISSUES IN LNG FACILITIES

6.1 Environment Issues

The following environmental issues should be considered as part of a comprehensive assessment and management program that addresses project-specific risks and potential impacts. Potential environmental issues associated with LNG facilities include the following:

- Hazardous material management
- Wastewater discharges
- Air emissions
- Waste management
- LNG transport related issues

6.1.1 Hazardous Material Management

Storage, transfer, and transport of LNG may result in leaks or accidental release from tanks, pipes, hoses, and pumps at land installations and in LNG transport vessels and vehicles. The storage and transfer of LNG also poses a risk of fire and, if under pressure, explosion, due to the flammable characteristics of its boil-off gas (BOG).

- **LNG Spills:** LNG is a cryogenic liquid and is not flammable in liquid form. However, BOG forms as the LNG warms, and under certain conditions could result in a vapour cloud if released. Uncontrolled releases of LNG could lead to jet or pool fires if an ignition source is present. It may also form methane vapour cloud that is potentially flammable under unconfined or confined conditions if an ignition source is present.
- **Explosion by RPT:** LNG reacts vigorously with water and vapourizes very fast leaving nothing behind posing minimum risk for the marine life. However LNG reacts violently with water and may cause explosion due to rapid phase transition. LNG vaporizes rapidly when exposed to ambient heat sources such as water, producing approximately 600 standard cubic meters of natural gas for each cubic meter of liquid. A potentially significant environmental and safety hazard from LNG shipping is related to RPT that can occur when LNG is accidentally spilled onto water at a very fast rate. The heat transfer from water to spilled LNG causes LNG to instantly convert from its liquid phase to its gaseous phase. The large amount of energy released during

a RPT can cause a physical explosion with no combustion or chemical reaction. The hazard potential of rapid phase transitions can be severe, but is generally localized within the spill area.

Fig-18 Physical explosion: LNG RPT Source: Internet image

6.1.2 Wastewater Discharges

The use of water for process cooling at LNG liquefaction facilities and for re-vaporization heating at LNG receiving terminals may result in significant water use and discharge streams. This wastewater can not directly discharge to sea; it may damage the marine life. Water conservation opportunities should be considered for LNG facility cooling systems. The selection of the preferred system should balance environmental benefits and safety implications. Cooling or cold water should be discharged to surface waters in a location that will allow maximum mixing of the thermal plume to ensure that the temperature is within 3 degrees Celsius of ambient temperature at the edge of the mixing zone.

Other wastewater discharges generated at LNG facilities include: drainage and storm water, sewage wastewater, tank-bottom water, fire water system releases, wash down water, general oily waters, and other waters. Pollution prevention and treatment measures should be considered for these wastewaters before discharge.

6.1.3 Air emissions

Air emissions sources from LNG facilities include combustion for power and heat generation. Power and heat generations required in various operations such as boilers, or dehydration and liquefaction activities in LNG liquefaction terminals, and regasification activities in LNG receiving terminals. Emissions resulting from flaring and venting, as well as from fugitive sources, may result from activities at both LNG liquefaction and regasification terminals. Principal air pollutants from these sources typically include nitrogen oxides (NOX), carbon monoxide (CO), carbon dioxide (CO2), and in case of sour gases, sulphur dioxide (SO2). For LNG plants with important combustion sources air quality impacts should be estimated during facility design and operations planning. Air emission specifications should be considered during all equipment selection and procurement.

Flaring or venting is an important safety measure used at LNG facilities to ensure that gas is safely disposed of in the event of an emergency, power or equipment failure, or other plant upset condition. Flaring or venting should be used only in emergency or plant upset conditions. Continuous venting or flaring of boil- off gas under normal operations is not considered good industry practice and should be avoided.

Fugitive emissions at LNG facilities may be associated with cold vents, leaking pipes and tubing, valves, connections, flanges, open-ended lines, pump seals, compressor seals, pressure relief valves, and general loading and unloading operations. Methods for controlling and reducing fugitive emissions should be considered and implemented in the design, operation, and maintenance of facilities.

6.1.4 Waste management

Non-hazardous and hazardous wastes potentially generated at LNG facilities include general office and packaging wastes, waste oils, oil-contaminated rags, hydraulic fluids, used batteries, empty paint cans, waste chemicals and used chemical containers, used filters, spent sweetening and dehydration media (e.g., molecular sieves) and oily sludge from oil-water separators. Waste materials should be segregated into non-hazardous and hazardous wastes and considered for re-use/recycling prior to disposal. A waste management plan should be developed that contains a waste tracking mechanism from the originating location to the final waste reception location. Storage, handling, and disposal of hazardous and nonhazardous waste should be as per good EHS practice for waste management.

6.1.5 LNG transport issues

LNG transport by marine ships sometime results in LNG spills and Explosion by RPT which is major environmental issue. About LNG spills and RPT phenomena we discussed earlier in hazardous waste management. LNG can be transported by road tankers or trailers to end users and LNG fuelling facilities. Potential risks associated with LNG road transport are traffic accidents, BOG build-up, and leakages from the tank. BOG build-up during road tanker transport is a critical factor that should be addressed properly. LNG road tankers or trailers should be constructed as double-walled, with a combined vacuum and insulation system to keep the cryogenic liquid cool during transportation.

6.2 Occupational Health and Safety

Occupational health and safety issues should be considered as part of a comprehensive hazard or risk assessment, including, a hazard identification study (HAZID), hazard and operability study (HAZOP), or other risk assessment studies. The results should be used for health and safety management planning, in the design of the facility and safe working systems, and in the preparation and communication of safe working procedures. Facilities should be designed to eliminate or reduce the potential for injury or risk of accident and should take into account prevailing environmental conditions at the site location, including the potential for extreme natural hazards such as earthquakes or hurricanes. A formal Permit to Work (PTW) system should be developed for the facilities.

The PTW will ensure that all potentially hazardous work is carried out safely and ensures effective authorization of designated work, effective communication of the work to be carried out, including hazards involved, and safe isolation procedures to be followed before commencing work.

The facilities should be equipped, with an appropriate number of specialized first-aid providers and the means to provide short-term, remote patient care. Depending on the number of personnel present and complexity of the facility, provision of an on-site medical unit and health care professional should be considered.

Occupational health and safety issues associated with LNG facilities operations includes

- Fire and explosions
- Roll- over
- Contact with cold surfaces
- Chemical hazards
- Confined spaces

6.2.1 Fires and Explosions

Fire and explosion hazards at LNG facilities may result from the presence of combustible gases and liquids, oxygen, and ignition sources during loading and unloading activities. Fire and explosions also occur due to leaks and spills of flammable products. Possible ignition sources include sparks associated with the build up of static electricity, lightning, and open flames. The accidental release of LNG may generate the formation of an evaporating liquid pool, or the LNG vapour cloud dispersion. For the prevention and control of fire and explosion hazards LNG facilities should be design, construct and operate as per internationally recognized standards. Implement safety procedures for loading and unloading of the product to transport systems. Prevent potential ignition sources. Locate all fire protection systems in a safe area of the facility, protected from the fire by distance or by fire walls.

6.2.2 Roll-over

Storage of large quantities of LNG in tanks may lead to a phenomenon known as "roll-over." The potential for rollover in LNG storage tanks arises when separate layers of LNG of differing densities exist within the tank. If these layers are mixed inappropriately, then there is rapid release of LNG vapours occur. Due to this there is rapid rise in pressure. In the absence of properly operating safety-vent valves, it could cause structural damage to the tank. Rollover can occur due to, fill-induced stratification caused by loading LNG of varying densities into the storage tank; or auto-stratification if a sufficient quantity of nitrogen exists in the LNG such that it boils off preferentially and results in a reduced liquid bulk density. To prevent roll-over install pressure safety valves designed to accommodate roll-over conditions and prevent damage to the tank.

6.2.3 Contact with cold surfaces

Storage and handling of LNG may expose personnel to contact with very low-temperature product. Plant equipment that can pose an occupational risk due to low temperatures should be adequately identified and protected to reduce accidental contact with personnel. Training should be provided to educate workers handling or dispensing LNG regarding the hazards of contact with cold surfaces. Personal protection equipments like gloves, insulated clothing should be provided to prevent from direct contact with cold surfaces.

6.2.4 Chemical hazards

The design of LNG facilities should reduce exposure of personnel to chemical substances, fuels, and products containing hazardous substances. For each chemical used, a Safety Data Sheet (SDS) should be available and readily accessible at the facility. Facilities should be equipped with a reliable system for gas detection that allows the source of release to be isolated and the inventory of gas that can be released to be reduced.

6.2.5 Confined Spaces

Confined space hazards are potentially fatal to workers. Confined space entry by workers and the potential for accidents may vary among LNG terminal facilities depending on design, on-site equipment, and infrastructure. Confined spaces may include storage tanks, secondary containment areas, and storm water/waste water management infrastructure. Facilities should develop and implement confined space entry procedures as described in the General EHS Guidelines.

6.3 Community Health and Safety

Community health and safety impacts during the operation of LNG facilities or transport of LNG are related to potential accidental natural gas leaks, in either liquid or gas form. Flammable gas or heat radiation and overpressure may potentially impact community areas outside the facility boundary. Although the probability of large-magnitude events directly associated with storage operations in well-designed and well- managed facilities is usually negligible.

The layout of an LNG facility and the separation distance between the facility and the public and/or neighbouring facilities outside the LNG plant boundary should be based on an assessment of risks from LNG fire (thermal radiation protection), vapour cloud (flammable vapour- dispersion protection), or other major hazards.

LNG facilities should prepare an emergency preparedness and response plan that considers the role of communities and community infrastructure in the event of an LNG leak or explosion. Ship traffic, including at loading and unloading jetties, associated with LNG facilities should be considered, with respect to local marine traffic patterns and activities. Location of ship loading/unloading facilities should also consider the presence of other shipping lanes and other marine activities in the area like fishing and recreation. Drivers of LNG tankers and trailers should be trained on road safety and emergency response plans.

CHAPTER - VII

CONCULSIONS AND RECOMENDATIONS

CONCULSIONS AND RECOMENDATIONS

From the foregoing chapters it is seen that natural gas is the cleanest fuel and can be considered to be the fuel of choice of the new millennium. India needs natural gas in view of the increasing energy shortage that the country is facing and the fact that there is a huge potential demand, which will be constrained by the availability of supplies.

The development of natural gas market as well as infrastructure in India today needs an enabling environment so that the intended results could be achieved in the most cost effective manner, in the least possible time and with maximum benefits to all stakeholders including consumers.

The natural gas sector in India today is at the threshold of rapid growth supported by ever increasing demand for natural gas, increased exploration efforts under NELP, large scale discoveries of gas in the East Coast, commissioning of the LNG import terminals in the West Coast, new upcoming LNG import terminals and the regulators initiatives in the direction of development of a nationwide natural gas pipeline grid.

The market for natural gas in India currently lacks depth with only a small number of producers, negligible number of shippers and a fairly limited number of consumers. The Spot market that exists in India owing to a very limited number of players exhibits lack of liquidity as well as a lack of transparency. This lack of liquidity is one of the greatest impediments to the development of a transparent spot market in the country.

The natural gas pricing is moving towards a market determined pricing mechanism and Indian gas market is getting increasingly aligned with the global trends. Equally important is the condition of sectors consuming gas like Power and Fertilizers which form the anchor load for any gas field or RLNG terminal. The affordability of these two key user segments depends upon the policy directives and regulatory reforms in these sectors.

There are currently numerous provisions that facilitate the development of natural gas market as well as infrastructure in India. However, more needs to be done before India can move towards a more open and matured gas market. India has a relatively under-developed gas pipeline infrastructure as compared to some developed countries. However, it is growing rapidly in tune with increasing demand and growing natural gas supplies.

Developing competitive natural gas markets and attracting investment in development of infrastructure may require frequent regulatory changes and interventions. However, increased regulatory risk and risk of political intervention discourage investment in the natural gas sector. Continuous improvement in the regulatory framework always supports market development. The market forces have proved to be vital and effective in the natural gas industry, once an appropriate structural and regulatory framework is put in place.

LNG imports appear to be the best option to satisfy the increasing gas demand. However, there are enormous difficulties related to the organization of the LNG chain and to the marketability of the imported gas in India.

As LNG projects are long term in nature and high capital investment, it is most important to have a strong LNG chain during the complete tenure of the contract or project. If there is any weak link it might fails overall LNG project. Today there must be required a global optimization of the LNG chain.

Substantial investment in infrastructure relating to import of LNG and transportation of domestic gas across India is planned for the next 5-6 years. The current planned investments along with incremental investments in future would be sufficient to meet the growing demand for gas from various consumers segments. In order to ensure the projects get implemented on a fast tract basis, Government of India and petroleum and natural gas regulatory board need to take various policy and regulatory measures.

While India is emerging as major LNG market of future with all round development in LNG terminals, gas pipelines to attain desired sustainable growth. A comprehensive approach which can meet supplier expectations on one side and meet consumer's price expectations on other side needs to be firmed up. India would also need to take strategic decisions like upstream participation in liquefaction projects, tax efficient structures, and a consumer friendly regulatory environment to be successful in LNG market.

Co-operation between the LNG receiving terminal operator and the power plant is essential for any mutually beneficial commercial synergy between the two units. One of the major issues is balancing the loads. The production of both the units is dependent on the performance of each facility. The two units must operate consistently close to their optimum level for a successful integration.

Since LNG trade has been enjoying a rapid growth over 30 years and one of the key reasons has been the design of safe and environmentally acceptable LNG receiving terminals, design of safe, expandable and cost effective LNG receiving terminal should be made and implemented at the earliest.

LNG receiving terminals have been using specialized equipment for years, but there are clearly opportunities ahead to further develop the technology. The interest in moving facilities offshore is high and improving process efficiency is also becoming a high priority.

CHAPTER - VIII

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