A STUDY ON

LNG TERMINALS IN INDIA AND TRANSPORTATION OF NATURAL GAS

PROJECT REPORT

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By

PRABHJOT KAUR
(Reg. No: 2003304022)

Under the guidance of

Dr. Emil Matthew,

Assistant Professor, SMM, IMU CC

SCHOOL OF MARITIME MANAGEMENT
INDIAN MARITIME UNIVERSITY

(A Central University, Government of India)

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DECLARATION

I, Prabhjot Kaur, hereby certify that all the material in this dissertation is my own work to the best of my knowledge and belief, and that which is not my own work has been identified. The views expressed in this dissertation are my own and are not necessarily endorsed by the University.

Supervised by:
Dr Emil Matthew
Assistant Professor
Indian Maritime University

Place: Chennai   Prabhjot Kaur
Date: 25.05.22   2003304022

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Prabhjot Kaur
2003304022

CERTIFICATE

School of Maritime Management

Indian Maritime University, Chennai.

This is to certify that the project report entitled "**LNG Terminals in India and Transportation of Natural Gas.**", submitted to the School of Maritime Management, Indian Maritime University, Chennai Campus; in partial fulfillment for the award of the degree of Master of Business Administration in Port & Shipping Management, is a record of work carried out entirely by **Prabhjot Kaur**, Reg. No. **2003304022**

Dr. Emil Matthew

Project Guide
School Maritime Management
Indian Maritime University
Chennai campus

External Examiner:

Place: Chennai

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ABBREVIATIONS

- GSPL - Gujarat State Petronet Limited
- GAIL - Gas Authority of India Limited
- RGTIL - Reliance Gas Transportation Infrastructure Limited
- RGPL -Reliance Gas Pipelines Limited
- AGCL - Assam Gas Company Limited
- DNPL - Duliajan Numaligarh Pipeline Limited
- IOCL - Indian Oil Corporation Limited
- NRL - Numaligarh Refinery Limited
- DVPL - Dee Vee Projects Limited
- MMT - Million Metric Tonnes
- MMSCM - Million Metric Standard Cubic Meter
- MMSCMD – Million Metric Standard Cubic Meters per Day
- GDP - Gross Domestic Product.
- MTOE - Million Tonnes of Oil Equivalent.
- LNG - Liquified Natural Gas
- MMTPA - Million Metric Tonnes Per Annum
- PLL – Petronet LNG Limited
- PNG - Piped Natural Gas
- GCV – Gross Calorific Value
- MoNPG – Ministry of Natural Gas and Petroleum
- MMBTU - 1,000,000 British Thermal Units
- BCM- Billion Cubic Meters
- ICIS – Independent Commodity Intelligence Services
- PVT – Private
- JV- Joint Venture
- RLNG – Re-gasified Liquefied Natural Gas
- D-Gas – Domestic Natural Gas
- CGD – City Gas Distribution
- Gt – Gross Tonnage
- PPMV – Parts Per Million Volume
- PPAC – Petroleum Planning and Analysis Cell
- PNGRB - *Petroleum and Natural Gas Regulatory Board*

- GA – Geographical Area
- B – Billion
- Bcf/d – Billion Cubic Feet per Day
- MCHE - Main Cryogenic Heat Exchanger
- RGPPL - Ratnagiri Gas and Power Private Limited
- NTPC - National Thermal Power Corporation Limited
- PCI - Product Complexity Index
- kPa – Kilo Pascal

EXECUTIVE SUMMARY

India wants to increase natural gas's contribution of the energy mix from 6.5 percent now to 15 percent by 2030. This would result in a massive increase in LNG imports. COVID-19 has added to the uncertainties surrounding natural gas demand growth, but the fundamentals of the Indian gas market remain strong. The Indian government is promoting natural gas as a cleaner fuel to diversify its energy mix, decrease oil reliance, and combat air pollution in major cities. The goal is to transition to a gas-based economy by 2030, with natural gas accounting for 15% of the energy mix, up from roughly 6.5 percent presently.

Over the last two years, there has been a surge in interest in quickly expanding gas infrastructure, such as inter- and intra-state pipelines, LNG import terminals, city gas distribution networks covering more than 70% of the population, and CNG/LNG stations around the country.

In the next five years, domestic and international investments in the natural industry are expected to total $60 billion. However, the Indian gas market is not without its difficulties. India is one of the most price-sensitive markets, and the affordability of LNG supplies remains a major concern, prompting current LNG contracts to be renegotiated.

LNG customers are also looking for improved contract conditions as the global LNG market changes. Despite India's fast expansion of LNG terminals over the last two years and a fresh wave of LNG import capacity projects, one important limiting factor to additional LNG supply is the terminals' lack of connection with downstream clients.

On India's western shore, there are five LNG re-gasification terminals: Dahej, Hazira and Mundra in Gujarat, Dabhol in Maharashtra, and Kochi in Kerala. On the southern shore, it has Ennore terminal in Tamil Nadu. LNG as a cargo offers ports with consistent revenue for extended periods of time since it is not subject to the policy and regulatory issues that other cargoes, such as iron ore, are. Almost every port in India is planning to build LNG receiving facilities to capitalize on the country's attempts to wean itself off of traditional, expensive fossil fuels and transition to a more economical, cleaner, and environmentally friendly alternative.

Natural gas that has been chilled to minus 162 degrees Celsius is known as LNG. Natural gas condenses into liquid at such temperature, taking up less space and making it easier to transport across long distances. LNG is loaded onto specialized ships and brought to re-gasification stations, where it is re-heated, converted to gas, and piped to users.

CHAPTER I
INTRODUCTION

1.1 History of Natural Gas and LNG

The Arab-Israeli conflict of 1973 and the collapse of oil prices in 1985 came as a major oil shock to a globe that had become comfortable about energy expansion and availability. Suddenly, energy conservation and diversification away from oil toward coal, nuclear power, and natural gas became even more vital. Natural gas has also grown in prominence as a result of widespread environmental awareness and the fact that it is regarded the cleanest and most ecologically friendly fuel.

Natural gas demand has been steadily rising, but domestic supplies are no longer sufficient to supply entire requirements due to uneven geographic distribution of natural gas. Natural gas transportation from gas-producing nations to gas-consuming countries is in high demand. Because pipelines are not always feasible, seaborne LNG transport is presently the most cost-effective solution to meet these demands. LNG carriers, specialized ships, are becoming an important component of the global energy transportation scenario. Even though ship sizes have expanded dramatically, the containment systems created in the late 1950s and early 1960s have fulfilled their initial promise and have gone on to become today's designs.

However, given the enormous cost of LNG projects, project financing has become a challenging undertaking beyond the resources of any single corporation. The regulatory agencies in the consuming nations are racing against the clock to decide whether or not to approve LNG shipments.

India's primary energy sources have been coal, lignite, crude oil, and hydroelectric power. Given the finite reserves of the foregoing sources and India's growing industrialization, it is critical that India investigate other energy sources before it is too late.

Though India has been attempting to access new oil fields and, alternatively, improve oil output in current ones, no big breakthrough appears to have occurred, resulting in India buying more and more oil each year.

India has been responsible for more than 10% of the rise in world energy consumption since 2000. Energy demand in India has increased by more than 60% per capita since 2000, despite vast disparities throughout the country and among socioeconomic categories. In recent years, India has been catching up with the rest of the globe on a variety of economic and energy metrics.

Due to an increasing economy and the pressures of urbanization and industrialization, India has a significant potential for continued increase in energy service demand. However, there are serious concerns regarding how demand growth will be fulfilled. India is typically resource restricted, with the significant exceptions being solar, coal, and wind. India is also highly populated, with significant levels of water stress and land use limits, as well as structural poverty and other socioeconomic problems, making energy affordability a key challenge.

1.2 LNG Terminals in India

India currently has five operational LNG Terminals located in:

1. Dahej (Guajrat)
2. Hazira (Gujarat)
3. Dabhol (Maharashtra)
4. Kochi (Kerala)
5. Ennore (Tamil Nadu)
6. Mundra (Gujarat)

1.2.1 DAHEJ LNG TERMINAL

Petronet LNG Ltd. built South East Asia's first LNG Receiving and Regasification Terminal in Dahej, Gujarat, with an initial nameplate capacity of 5 MMTPA. The infrastructure was built in the lowest amount of time and at a competitive price. The terminal's capacity has been increased in stages, and it now stands at 17.5 MMTPA. Six LNG storage tanks and associated vaporisation facilities are located at the facility. The terminal supplies around 40% of the country's total gas consumption.

Fig. 1 Dahej LNG Terminal

At Dahej, the terminal features two LNG jetties. The first jetty can accommodate up to Q-Flex vessels, while the second jetty can accommodate up to Q-Max vessels. It became operational in 2004. Dahej provides LNG to small clients that do not have access to a gas pipeline, which is delivered using cryogenic trucks.

PLL Dahej was the first terminal to begin loading LNG onto trucks for delivery to places where pipelines do not exist, and it now includes four truck loading bays and a centre for the development of small-scale LNG operations.

1.2.2 HAZIRA LNG TERMINAL

The Hazira LNG terminal is located in Gujarat's Surat district. The $641 million LNG facility was completed in April 2005. The Hazira terminal, which spans 36 acres, has a capacity of 2.5 million tonnes per annum (MTPA) of LNG. The terminal is operated by Shell Hazira Port, a subsidiary of Royal Dutch Shell, which has a 74% stake in the facility. The remaining 26% is owned by Total Gaz Electricité France.


Fig. 2 Hazira LNG Terminal

An LNG re-gasification terminal with a design capacity of 5 million tonnes per annum is included in the plant. The capacity might be increased to 10 million tonnes per year of LNG depending on market demand.

Two full-containment cryogenic tanks with a combined capacity of 160,000m^3 are also available at the plant. The tanks are 80 meters in diameter and 40 meters tall and can store LNG at -165 degrees Celsius. The project also includes a 1.3-kilometer LNG receiving jetty. LNG vessels with a capacity of up to 145,000m^3 may dock at the jetty.

1.2.3 DABHOL LNG TERMINAL

At Dabhol in Konkan region of Maharashtra, India, Ratnagiri Gas and Power (RGP) constructed India's third LNG import and re-gasification facility. The terminal's initial capacity was to be 1.2 million tonnes per year, but it ultimately increased to 5 million tonnes per year.

By December 2010, the terminal had been mechanically finished. After multiple delays, it was anticipated to be completed by the end of 2011. During 2013-14, the project was fully operational. The new terminal was constructed with a $641 million investment.

The LNG terminal was initially intended to fuel the Dabhol gas-fired power station, which is located close the facility. The 1,980MW power plant utilizes about 2.1 million tonnes per annum of the terminal's capacity. The remainder will be auctioned.

Fig. 3 Dabhol LNG Terminal

Receiving, storage, re-gasification, and send-out facilities are all part of the LNG terminal. It also includes the port infrastructure needed to support LNG carrier deliveries throughout the year. Three 160,000m^3 full containment cryogenic tanks will give the terminal with a storage capacity of 500,000m^3. The tanks are 80 meters in diameter and 50 meters tall.

A petroleum jetty with a handling capacity of up to 140,000m^3, unloading arms, a control tower, four berthing and mooring dolphins, and one tug berth are among the terminal's maritime features. The jetty can handle carriers with capacities ranging from 80,000m^3 to 140,000m^3 and extends to a depth of 1,750m in the sea.

1.2.4 KOCHI LNG TERMINAL

Petronet LNG Limited opened a second LNG receiving, storage, and regasification terminal in Kochi, with a capacity of 5 MMTPA, to meet the needs of Southern India. The terminal is located near the Cochin Port entrance in Puthuvypeen's Special Economic Zone (SEZ). The facility was built for Rs. 45 billion ($700 million). The jetty is designed to accept LNG tankers with a capacity of 65,000 to 216,000 cubic meters (Q- Flex). Two above-ground LNG storage tanks with complete containment are available at the terminal. The terminal's mechanical completion was completed by the end of 2012. The LNG terminal was completed in August 2013 and formally opened in January 2014.

Fig. 4 Kochi LNG Terminal

In the lack of the necessary pipeline network to boost terminal use, ancillary services like as storage and reloading, cooling, and bunkering are also available at Kochi port, making it a one-of-a-kind terminal.

Bulk users can also use the Terminal's tolling services. Kochi also supplies LNG to consumers who are not connected to the gas grid using LNG trucks under the Taral brand. PLL is also working with GAIL to build pipes between Mangalore and Bangalore. Following the construction of these pipelines, terminal usage will skyrocket.

1.2.5 ENNORE LNG TERMINAL

The Ennore LNG terminal is India's first LNG terminal on the east coast that began operations in 2019. As a result, the terminal contributes to India's national strategic goal of diversifying its LNG supply base. Because India is the world's fourth-largest LNG importer, establishing new supply lines is crucial.

The terminal has a 5 million metric tonne annual send-out capability (MMTPA). A consortium led by Black & Veatch was awarded the engineering, procurement, construction, and commissioning (EPCC) contract for regasification facilities and utilities at the port by IOCL.

To accommodate the rising demand for LNG, IOCL established and runs an LNG import facility at Kamarajar Port (previously known as Ennore Port) on the outskirts of Chennai, Tamil Nadu, India, through its joint venture firm, Indian Oil LNG Private Limited. Kamarajar Port is a year-round operational port with all of the necessary infrastructure in place, including breakwaters, entrance channels, turning basins, contemporary navigational aids, and berthing equipment for safe cargo movement and berthing.

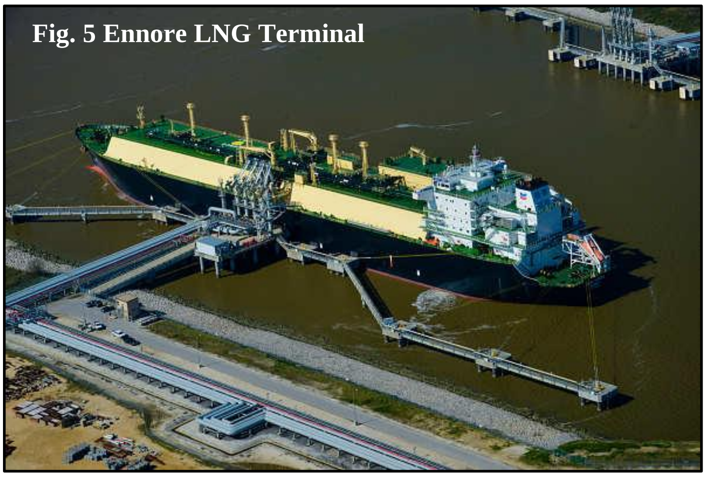


Fig. 5 Ennore LNG Terminal

This LNG import and regasification facility provides clean energy (RLNG/GAS) and helps the states of Tamil Nadu, Andhra Pradesh, and Karnataka build their economies. LNG that has been re-gasified is delivered to power plants, fertilizer facilities, and other industrial units. The gas is also accessible for city gas distribution, which includes the transportation, business, and residential sectors.

1.2.6 MUNDRA LNG TERMINAL

Mundra LNG is Gujarat's third liquefied natural gas (LNG) import station. GSPC LNG Limited (GLL), a joint venture between Gujarat State Petroleum Corporation (GSPC) and Indian conglomerate Adani Enterprises, built the terminal.

The Mundra LNG import facility is located in the Mundra multi-purpose port on the Gulf of Kutch, around 300 kilometers south of Gujarat's capital

Fig. 6 Mundra LNG Terminal

city Gandhinagar. The facility is well connected to the country's western and northern regions. It was commissioned in 2019 and started operating in 2020.

The first phase, which spanned 28 acres, saw the building of two LNG storage tanks, each having a net storage capacity of 160,000m3. The plant has a diameter of 93 meters and a height of 45 meters. The LNG terminal cost Rs50.41 billion ($730 million) to build and was financed using a mix of debt and equity funding.

1.3 Objective

This objectives for taking up this study are to:

- Understand India's contribution in the LNG sector
- Evaluate the role of transportation and redistribution of LNG in India
- Address issues related to development and functioning of LNG terminals in India
- Assess how can LNG be used as an alternate fuel in future

1.4 Methodology

The study is not based on and relies entirely on various secondary data sources available on official platforms of – Ministry of Natural Gas and Petroleum, Petroleum Planning and Analysis Cell, Petroleum and Natural Gas Regulatory Board, various port sites, articles, journals and review of reports done on LNG. Data has been collected, compiled and interpreted as per the requirements of this dissertation.

1.5 Limitations

Limitations are the restrictive conditions under which the study has been carried out. Such restrictions are necessary and even unavoidable to set boundaries by limiting the scope of study. The limitations of this study are:

1. The study is not based on primary data and it relies on secondary data.
2. Data has been collected from the internet, the relevance of which cannot be guaranteed.
3. Data available/found is not up to date in some cases.
4. Numerous contradictory data sources are available making it challenging to get purposeful information.
5. The study is confined to LNG transportation and statistics of Indian subcontinent only, and hence can differ from the global scenario related to LNG statistics and transportation.

6. Due to limited resources, only the content available on the web has been used.

Fig. 7 Map of LNG Terminals in India & Gas Infrastructure of Indian

Operating Indian LNG terminals

	Owner	Capacity (mn mt/yr)	Capacity utilisation factor 2018-19, %
Dahej	Petronet LNG	17.5	106.5*
Hazira	Shell Enegry India	5	79.9
Dabhol	RGPPL	1.7	24.4
Kochi	Petronet LNG	5	9.3
Ennore	IOC	5	n/a
Mundra	Adani/Gujurat State Petroleum Co.	5	n/a

*Based on then capacity of 15mn mt/yr; 17.5mn mt/yr capacity achieved in June 2019

SOURCE: PETROLEUM PLANNING & ANALYSIS CELL, MAY 2019

Source: PPAC/ https://www.naturalgasworld.com/

CHAPTER II
LITERATURE REVIEW

Increased use of primary fossil fuel energy resources such as crude oil and natural gas has been ascribed to India's rising population and developing economy. During the period 2009–2014, India's primary energy consumption increased at a compound annual growth rate (CAGR) of 5.7 percent, reaching 638 MTOE (Million Tons of Oil Equivalent); however, the share of natural gas in India's energy requirements decreased from 10% to 7%, compared to the global average of 24 percent. India's natural gas consumption has fallen throughout that time, owing to rising prices, which has resulted in a reduction in local supply, as well as restricted transmission and distribution infrastructure and insufficient gas import capabilities. India's per capita natural gas consumption is 39 m3 (cm), compared to a global average of 469 m3.

Liquefied natural gas (LNG) is commonly regarded to play a critical role in partially bridging India's natural gas energy supply gap. LNG is a colorless, non-toxic liquid that takes up to 600 times less space than natural gas, making it significantly more convenient to transport and store. During the financial years 2010–15, Indian LNG imports climbed at a compound annual growth rate of 11.1 percent to reach 15.5 MMT, with LNG consumption alone growing from 20 to 38 percent.

India now has six LNG terminals (Mundra, 10MMT; Ennore, 5MMT; Kochi, 5 MMT; Dabhol, 5 MMT; Dahej, 10 MMT; and Hazira, 5 MMT) with facilities to import and process around 25 MMT of LNG per year. The operational capacity, however, is around 17 MMT because the Kochi and Dabhol terminals are substantially underused due to a lack of pipeline connections and other infrastructure. Natural gas is an important source of fuel in India for power generation and industry; nevertheless, it is not widely used for transportation in the city of Cochin.

Impact of Using Liquefied Natural Gas for Transportation in the City of Cochin: A Review (Rejeesh C.R., Anoob Jose, Chinmayakrishan G) marks the potential advantages of using liquefied natural gas for transportation in the city of Cochin are discussed, as well as the present situation in the country and the socio-economic impact of natural gas use.

A new kind of clean and efficient energy is combustible ice (natural gas hydrate), which has vast deposits and produces more pure gas. After being successfully utilized, combustible ice storage and transportation became the most essential aspect of industry and a crucial basis for natural gas consumption. LNG, which is a very developed technology, is currently one of the primary modes of natural gas transportation. For LNG amounts of only 1/600 that of gas, long-distance transportation is more cost-effective and convenient than pipeline transmission in some circumstances. LNG may be delivered to its final destination via cryogenic tank tankers and tank trucks once it has been liquefied in an LNG liquefaction facility. LNG can be stored in LNG storage tanks. LNG may be carried into the municipal pipe network after being vaporized and pressured. Despite the vast deposits of flammable ice, its distribution is inconsistent. In light of this, we propose adopting LNG technology to store and transport flammable ice-produced gas in order to minimize storage and transportation costs.

LNG technology, which is one of the primary modes of natural gas transportation, has matured significantly. For LNG levels just 1/600 that of gas-phase, long-distance transportation is substantially more cost-effective and convenient than pipeline transportation in specific circumstances.

The cost of building LNG plants is higher, and the operating conditions are unique. The operating pressure varies from high pressure to low pressure (atmospheric pressure), and the operating temperature varies from ambient temperature to 162 C or from 162 C to ambient temperature, necessitating the adaptation of production equipment and materials, as well as the strict demanding of facilities.

It may be split into three categories when it comes to cooling methods: cascade liquefaction, mixed refrigerant liquefaction, and liquefaction with expander. One or more LNG complex procedures can store and transport combustible ice generated gas.

The Research about Storage and Transportation of Natural Gas Based on LNG Technology (Shuren Yang, Di Xu, Yue Cui, Ying Ni, Chao Duan)

India aims to increase its natural gas share to 15% by 2030, up from 6.5 percent currently. This chapter discusses recent developments in meeting the government's goals. Furthermore, we address regulatory and policy initiatives to help the country's natural gas sector flourish. We assess the prospects and difficulties to the smooth transition of the green economy with the growing role of natural gas. We discuss infrastructure projects such as LNG import terminals, cross-country natural gas pipeline networks, LNG ships, refueling stations, and city gas distribution (CGD) networks. Finally, we provide a long-term view of natural gas in the energy transition. We believe that because India lacks natural gas, its reliance on imports would increase. This, however, would not hinder the economic rise of natural gas. Proactive actions by the government and its agencies will increase investment in the infrastructure needed to achieve increased natural gas penetration in India.

India has pledged to combat climate change without jeopardizing economic growth. It continues to diversify its energy portfolio and lessen its reliance on coal and oil. India is on the right track when it comes to handling its energy transformation. It plans to expand natural gas's contribution to 15% by 2030, up from 6.5 percent now. Experts believe that India would need to go through several phases of energy transformation. Many people feel that natural gas can serve as a transition fuel in this scenario. However, we believe that natural gas may serve as more than just a bridging fuel. The government is adamant on the use of natural gas as a clean fuel. In keeping with the United Nations' sustainable development objective, natural gas provides a way to ensure that contemporary and clean energy is affordable to millions of customers in India. Furthermore, natural gas is a realistic and cost-effective way to minimize pollution in cities and enterprises. The transportation industry, which is one of the largest CO_2 emitters in the country, looks to profit from increased natural gas penetration.

The natural gas market in India is expanding. Its need for natural gas has been gradually increasing. India's underserved market has the potential to accelerate the growth of gas consumption. This section focuses on natural gas reserves, domestic production, consumption, the deficit, and imports.

India's underserved natural gas market will grow until it reaches saturation. There are several opportunities for growth in north-east, eastern, and southern India. City gas distribution will be a major driver of natural gas industry expansion. The present infrastructure, which includes LNG importing ports, pipelines, and refueling stations, requires an upgrade. Despite the introduction of several green energy choices, natural gas's proportion will grow. The government's progressive policies, such as viability gap funding for cross-country pipelines and the promotion of LNG/hydrogen-CNG as transportation fuels, will drive natural gas market development. Furthermore, the administration is dedicated to reducing bottlenecks in order to increase natural gas penetration throughout the country. Natural gas will be important in the development of India's green economy.

Role of Natural Gas in India: Recent Developments and Future Perspectives (Akhoury Sudhir Kumar Sinha, Sanjay Kumar Kar, Umaprasana Ojha and Marriyappan Sivagnanam Balathanigaimani)

The topic of this article's research is the supply of liquefied natural gas (LNG) and the hazards connected with its management. LNG is a gas combination of hydrocarbons in the following proportions: 87–99 mol percent methane, 0.1–5.5 mol percent ethane, 0–4 mol percent propane, 0–2.5 mol percent butane, 0–2.5 mol percent nitrogen, and traces of sulphur (less than four ppmv) and CO2 (50 ppmv). As a result, the transportation of LNG fuel is included in the transportation of dangerous chemicals that may harm human life, the environment, and societal financial elements. Other logistical procedures, like LNG reloading, might be hazardous as well. The greatest dangers are fires and explosions, which can occur as a result of leaks and spills in ignition sources.

The existence of ignition is a critical factor in this circumstance. In the case of a failure to ignite, LNG swiftly evaporates and distributes without harming the environment (when diluted below the ignition limit). However, if ignited, LNG provides four distinct fire-risk scenarios: vapor cloud flash fire, jet fire, pool fire, and vapor cloud explosion.

As a result, the literature emphasizes that if LNG fails to ignite, it soon dissipates and distributes without harming the environment (when diluted below the ignition limit). There are various articles on risk assessment in relation to LNG transit and handling, as well as storage safety. According to the study of literature, these publications have been steadily increasing over the previous decade.

Poland is undergoing an energy transition in transportation. This change entails a steady shift away from existing energy carriers and toward alternative fuels. Among these fuels, liquefied natural gas (LNG) is now of great interest. Many publications by Polish authors highlight numerous advantages associated with the development of this fuel sector in Poland. Various publications confirm the increased interest in this fuel. According to this data, the volume of LNG supplied by sea increased by 9.7 percent in 2020 compared to 2019. The research also stated that Poland's continuing energy revolution will result in a dramatic growth in LNG demand. This fuel's relevance for the stability of the country's power grid will rise as well. As a result, it is projected that the number of logistic activities associated with LNG fuel transfer by sea would expand in the future years.

The LNG terminal in Winoujcie is Poland's important liquefied natural gas plant. This terminal is one of Poland's most essential investments in recent years. Its operation seeks to increase the security of Poland's gas fuel supply by allowing LNG to be delivered by sea from any direction. The majority of LNG from the Winoujcie terminal is distributed to clients via the gas network. The liquefied gas is also refilled into LNG-transportable cisterns. All reloading procedures are carried out in accordance with. This document has also become the starting point for recognizing potential adverse occurrences during LNG delivery operations at the port.

The risk analysis process in the LNG sector, according to Animah and Shafiee, is critical to guaranteeing health, safety, security, and financial success. As a result, the purpose of this paper is to propose a technique for analyzing the human risk factor that occurs during the logistic handling of LNG supplies at a port terminal, as well as its implementation for a specific LNG terminal in Poland. Due to a lack of access to precise historical data on selected incidents, fuzzy logic approach was employed to estimate the risk. The research takes into account generic LNG delivery methods as well as unique reloading conditions at the Polish gas port under consideration. As a result, the following are the study's primary contributions:

- Development of a risk assessment tool for reloading operations during LNG deliveries based on handwritten recommendations, employing the fuzzy logic notion;
- Identification of unfavorable occurrences induced by the human component based on relevant LNG cargo handling regulations/standards and expert interviews
- Estimation of the value of risk assessment factors based on specialist knowledge, taking into consideration the uniqueness of the functioning of the Polish gas terminal in Winoujcie;
- Identify current restrictions of the proposed solution as well as implementation restrictions.

Risk Assessment of Human Factors of Logistic Handling of Deliveries at an LNG Terminal (written by: Agnieszka A. Tubis, Emilia T. Skupień, Stefan Jankowski, and Jacek Ryczyński)

As economies move away from coal and petroleum fuels, natural gas plays an important role as a transition fuel in a variety of industries (International Energy Agency [IEA] 2019). Natural gas accounts for only 5.7% of India's major energy mix (IEA 2018). The Ministry of Petroleum and Natural Gas (MoPNG) has set a target of 15% by 2030, highlighting the considerable potential for a fuel shift in the Indian economy.

Natural gas is now supplied to residential, commercial, power generating, and industrial users via a 17,000-kilometer network of transmission pipes from different production areas and LNG import ports (Petroleum and Natural Gas Regulatory Board [PNGRB] 2020b). In the north, the present network largely serves Maharashtra, Gujarat, Madhya Pradesh, Uttar Pradesh, Haryana, and the National Capital Region, while in the south, it serves Karnataka and Kerala. Furthermore, more than 15,000 kilometers of pipeline are being built and are expected to be completed by 2023. (PNGRB 2020b). Despite these improvements, the gas network would be unable to serve substantial portions in numerous states, including Tamil Nadu, Andhra Pradesh, Odisha, Chhattisgarh, and Jharkhand (PNGRB 2020a). These states have substantial industrial bases that might be converted to natural gas. Coverage is still contingent on the building of spur lines and CGD networks to link to major demand nodes, which might take up to a decade. Gas pipelines require significant CAPEX investment to build; the proposed Jagdishpur-Haldia-Bokaro-Dhamra pipeline (JHBDPL) is anticipated to cost USD 0.69 million (INR 5 crore) per kilometre (PNGRB 2019b).

As a result, pipeline projects are often unprofitable, particularly without considerable viability gap support from the government (40 percent of CAPEX for JHBDPL) and gas uptake at predicted volumes.

Low, Capacity Utilization Factors (CUF) further reduce pipeline profitability, as seen in the current network, which has a CUF of roughly 48% (Petroleum Planning and Analysis Cell [PPAC] 2020a). These difficulties may impede the rapid development of pipeline infrastructure, restricting potential customers' access.

Given these obstacles, a solution is required to generate demand for pipes while they are being built in order to assure their profitability when completed, as well as to service demand nodes that will not be connected by pipeline networks in the near future, if ever.

The reach of gas transmission pipes and access to city gas distribution (CGD) pipeline networks that provide last-mile delivery to customers determine access to natural gas. CGDs have network infrastructure exclusivity in the geographic region allotted to them. Geographic regions with differing demand densities are assigned to CGDs at the district level. CGDs often prioritise networks in high-density regions within a district, leading in Access to the remaining regions will be delayed. As a result, a CGD may not establish a network up to individual demand nodes placed far from the major grid, denying access to the latter. Such demand nodes might be supplied with gas by the ssLNG (Small- Scale LNG) system.

Because LNG is less expensive than diesel, it might gain widespread adoption in the transportation industry. MoPNG intends to establish a significant number of refueling stations along important routes in the country to encourage the usage of LNG-fueled vehicles. These stations will need a consistent supply of LNG, which natural gas pipelines cannot offer.

Small-scale LNG (ssLNG) might assist raise gas consumption while also providing long-term availability. ssLNG may diversify the natural gas consumer base by utilizing scalable, modular, and mobile assets to target local demand nodes. This can assist develop demand for future pipeline networks, causing the CUF of the network to be greater than projected in the early years. Small-scale LNG can provide gas to demand nodes that are not connected to current or future pipeline networks. Small-scale LNG might be used to supplement existing CGD connections in order to diversify supply choices and reduce procurement costs. ssLNG will be required to service LNG refueling stations located along motorways. ssLNG systems might provide the short-term variable demand requirements of big projects, mines, and quarries.

Small-Scale LNG for Expanding Natural Gas Access in India (Sabarish Elango and Hemant Mallya)

CHAPTER III
DETAILED STUDY ON LNG

3.1 Natural Gas

Natural gas is an essential component in meeting India's energy requirements. It being one of the cleanest and safest energy sources, is anticipated to play a larger role in the near future. The Indian government has made many initiatives to establish a national gas system. As demand and supply grow, the national grid, which includes gas pipelines and a supplemental network, will provide natural gas to industrial, commercial, residential, and transportation sectors across the country.

Natural gas is used as a feedstock for fertilizers and petrochemicals, as well as a fuel for the generation of electricity in other industries, transportation, commercial sectors, and household cooking (PNG – Piped Natural Gas). It's been dubbed "green fuel" and "the fuel of the century." Natural gas contributes significantly to our country's total energy needs and availability. The demand for natural gas continues to grow at around 8% per year. Natural gas has been imported in liquid form since 2003. Liquefied natural gas (LNG) imports now account for over a quarter of our yearly natural gas consumption.

3.1.1 What is Natural Gas?

Natural gas is a fossil fuel that is used to heat and cook homes, as well as to provide hot water and to cook in both domestic and commercial settings. Natural gas is also used to generate energy and to make chemicals, polymers, fertilizers, and other items.

Natural gas is a broad word that encompasses all gases produced naturally, including volcanic gas, hot spring gas, field gas, carbon dioxide gas from carbonated springs, and gases produced during radiogenic processes.

However, in a broad sense, natural gas refers to flammable gas produced spontaneously and mostly composed of hydrocarbons.

3.1.2 Composition of Natural Gas

Natural gas is a combination of hydrocarbon gases that may be ignited. Natural gas is largely composed of methane, although it can also contain ethane, propane, butane, and pentane. Natural gas has a broad range of chemical compositions, as seen in the table below. It's composition varies greatly, but the table below shows the usual nature of natural gas before it is refined/purified.

TABLE 1: CHEMICAL COMPOSITION OF NATURAL GAS

Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen Sulphide	H_2S	0-5%
Rare Gases	A, He, Ne, Xe	traces

Source: http://naturalgas.org/

3.1.3 Properties of Natural Gas

- Natural gas has a gaseous state of substance.
- It is a colorless and tasteless gas.
- It is toxic-free, produces no smoke when burned, and has a high calorific value.
- The gas has no odour. However, a chemical called mercaptan is added in minute amounts to give it the unique egg smell. This aids in the detection of any gas leaks.
- It's both a flammable gas and a fossil fuel.
- It's a concoction of basic hydrocarbon molecules.
- It mostly consists of methane, with traces of ethane, butane, pentane, and propane.
- Water vapor and carbon dioxide are by-products of this gas.
- Natural gas is 60 percent lighter than air.
- It has a high ignition temperature and a low flammability range.
- It can be found in permeable sedimentary rocks under the earth's surface.

3.1.4 Uses of Natural Gas

Natural gas is rapidly becoming the dominant source of energy in the world's energy-hungry regions, with the following applications:

- Residential/commercial: natural gas is mostly utilized in this sector for domestic appliances, water heating, space heating, offices, stores, and hotels.
- Industrial sector: In the glass, ceramic, and baking sectors, natural gas is utilized as an under boiler fuel for steam raising and big heating applications, since its clean burning qualities make it preferable to alternative fuels.

- Power sector: Natural gas is employed in power projects not only because of its technical benefits, but also because it is convenient and cost-effective.
- Petrochemical sector: Natural gas is used as a feedstock for the production of fertilizers, polymers, and adhesives, among other things, employing basic chemicals such as ammonia, methane, and acetylene.
- It is utilized in vehicles as compressed natural gas (CNG).

3.2 Liquefied Natural Gas

Liquefied Natural Gas is formed when natural gas is cooled to minus 162°C under normal air pressure and condenses into a liquid (LNG). The volume of LNG is approximately 618 times less than that of the gaseous equivalent. It's a transparent, colorless liquid with roughly half the weight of water of the same volume. As a result, if gas must be transported, it is ideal to do it in a liquefied state.

3.2.1 Properties of LNG

TABLE 2: PROPERTIES OF LIQUIFIED NATURAL GAS	
Chemical Formula	CH_4
Boiling Point	-161℃
Liquid Density	426 kg/m^3
Gas Density	0.656 kg/m^3
Specific Gravity (Air=1)	0.554
Lower Explosive Limit	5.3
Upper Explosive Limit	14.0
Limits of Flammability	5.3% to 14%
Auto Ignition Temperature	595℃

Source: https://www.elgas.com.au

3.2.2 Characteristics of LNG

1. Its extraordinarily low temperature (about -160℃) necessitates unique considerations, such as:

- The use of extremely low temperature-resistant materials.
- Suitable construction that allows for expansion and contraction
- Thermal stress induced by temperature differences is avoided.
- Heat insulating systems that work.

- Protection against the dangers of low temperatures.

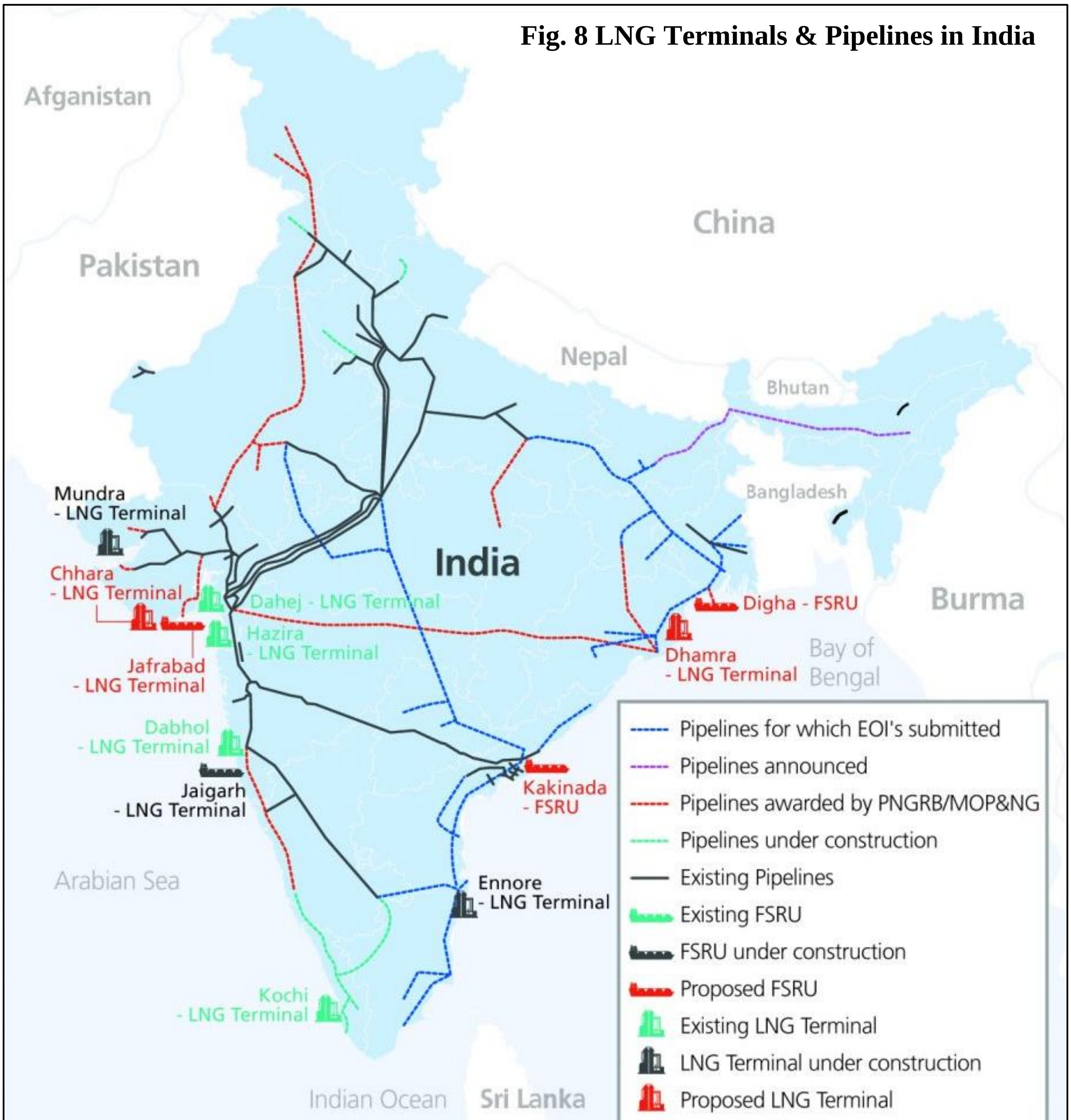
2. Liquefaction reduces the volume of LNG to 1/600 of the volume of comparable natural gas, which is particularly useful for storage and transportation. Tank pressure rises when LNG boils off.
3. LNG remains at boiling point; any change in equilibrium, such as a rise in temperature or a decrease in pressure, causes LNG to boil up.
4. LNG has a density of roughly half that of water.
5. Although LNG is flammable, its vapor has a limited inflammability range. When LNG vapor is released into the atmosphere, it generates an explosive vapor combination. To avoid this, care has been taken not to allow the vapor to come into touch with the air. As a result, tank pressure is normally maintained slightly above atmospheric pressure.
6. When LNG is released into the atmosphere, it immediately evaporates and condenses, forming a white cloud.
7. LNG is odorless and colorless.
8. LNG has a high latent heat of evaporation.
9. LNG is quite volatile.
10. LNG has a low viscosity and a large dielectric capacity, making it a poor electric conductor. It is easily charged electrostatically.
11. LNG is non-toxic and corrosion resistant.
12. In water, LNG is hardly soluble.
13. Surface tension is low in LNG.

3.3 LNG Terminals in India

TABLE 3: DESCRIPTION OF LNG TERMINALS

TERMINAL	STATE	OWNER	CAPACITY (MMTPA)	YEAR OF COMMISION
Dahej	Gujarat	Petronet LNG Ltd.	17.5	2004
Hazira	Gujarat	Shell Energy India	5	2005
Dabhol	Maharashtra	RGPPL	1.7	2013
Kochi	Kerala	Petronet LNG Ltd.	5	2014
Ennore	Tamil Nadu	IOC	5	2019
Mundra	Gujarat	Adani/ GSPL	5	2020

Fig. 8 LNG Terminals & Pipelines in India



Source: https://www.icis.com/

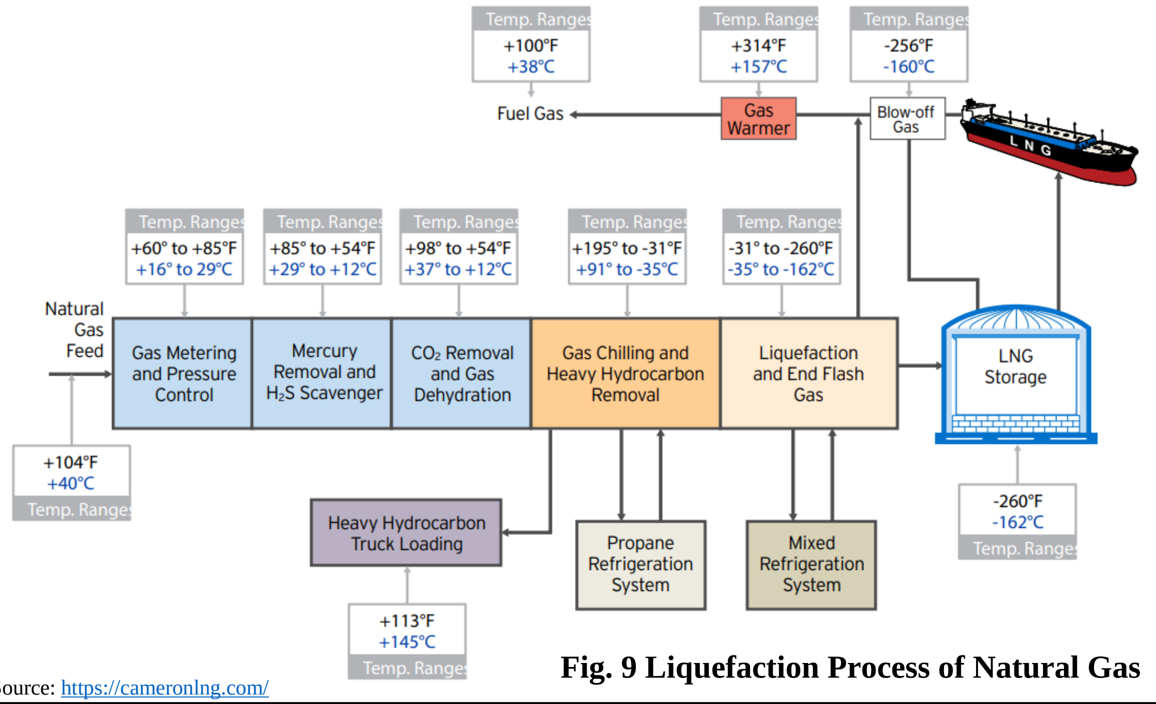
3.4 Liquefaction of Natural Gas

Natural gas is extracted mostly from fields in Algeria, Norway, Qatar, Russia, Nigeria, and the United States. Because of the distance between these nations and their markets, natural gas cannot always be transported via gas pipelines; in this scenario, the most convenient and cost-effective option is to send it by sea in LNG tankers.

To facilitate marine shipping, natural gas is chilled using a refrigeration cycle (compression, condensation, expansion, and evaporation) that converts the gas into a liquid at -160°C: this is known as Liquefied Natural Gas (LNG). When natural gas is cooled to -162°C (-260°F), it creates LNG, a transparent, colorless, and non-toxic liquid. The chilling procedure reduces the amount of the gas by 600 times, making storage and shipping easier and safer. LNG will not ignite in its liquid condition. LNG is odorless, colorless, non-toxic, and non-corrosive, and is mostly made up of methane (85 to 99 percent). There is a 600% reduction in volume when natural gas is liquefied.

Liquefaction takes place in three main processes, which are:

1. Pre-treatment: Hydrogen sulphide (H_2S) and mercury are removed together with dust and slug (water and condensate) (Hg). These contaminants, particularly in aluminium heat exchangers, can cause corrosion and freezing.
2. Acid gas removal and dehydration: An amine absorber (acid gas removal or AGR) absorbs and removes carbon dioxide (CO_2) from natural gas, whereas an adsorbent removes water. These impure chemicals are eliminated in order to prevent ice from forming during the liquefaction process.
3. Heavy Hydrocarbon Separation and Liquefaction: Fractionation is used to remove heavy hydrocarbons before liquefaction. Natural gas is pre-cooled to around -31°F (-35°C) using propane, as indicated in the liquefaction process diagram.



Source: https://cameronlng.com/

Fig. 9 Liquefaction Process of Natural Gas

Natural gas is liquefied and sub-cooled to between -238°F (-150°C) and -260°F (-162°C) by mixed refrigerant after passing through a tube circuit in the main cryogenic heat exchanger

(MCHE) (MR). In addition, the MR is pre-cooled before being separated in a high-pressure separator. In the MCHE, the vapor and liquid streams are separated and chilled, liquefied, and sub-cooled in separate tube circuits.

Liquefied Natural Gas may be stored and delivered in huge quantities on LNG tanker ships once it has been liquefied. The natural gas is delivered in thermally insulated tanks that are particularly built to keep it liquid at -160°C.

3.5 Storage of LNG

Full-containment tanks, with a capacity of 160,000 m3, are used to store LNG. The pressure in LNG tanks is regulated slightly above one atmosphere.

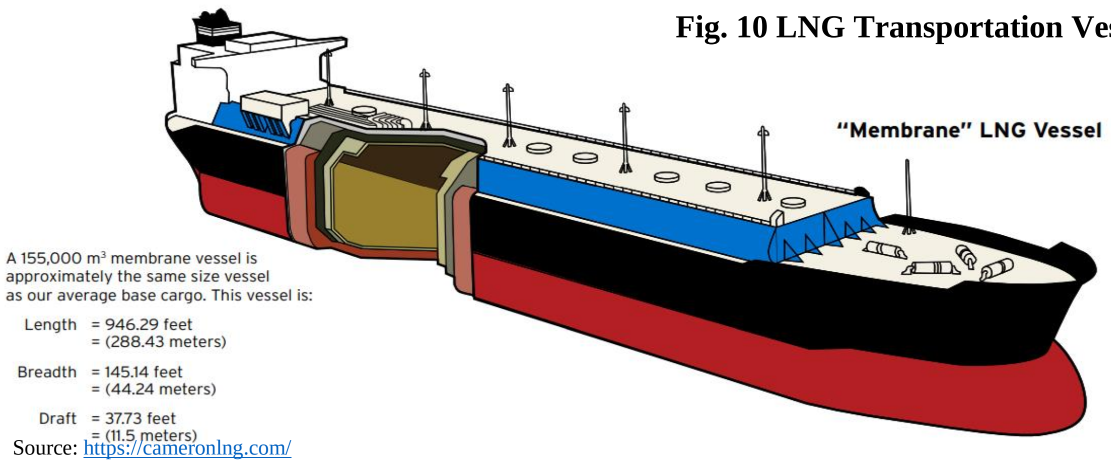
Full-containment systems have two tanks: an inner one for the product and an exterior one for leak protection. The inner shell is built of a low-temperature-resistant nickel alloy, while the outside shell is pre-stressed concrete with a reinforced slab and roof.

Each tank is insulated to keep LNG at -256°F (-160°C) and is equipped with advanced automated protection systems that monitor tank level, pressure, temperature, and any possible leakage.

3.6 Transportation of LNG

LNG is delivered on ships with two hulls. Membrane cargo tanks, which are supported by the ship's hull, and Type B Spherical (Moss) tanks, which are self-supporting, are the two most prevalent cargo tank kinds. Each cargo tank contains cryogenic confinement materials that are insulated to keep cargo boil-off to less than 0.15 percent per day. The LNG is transported from the jetty to the terminal storage tanks, a process that takes 14-16 hours. Throughout the procedure, the LNG remains at -160°C.

Fig. 10 LNG Transportation Vessel



Source: https://cameronlng.com/

LNG is extremely safe to transport, and the industry has an excellent safety record. LNG has been safely transported around the world in tankers for over 50 years. LNG is an odorless, non-toxic, non-corrosive liquid that dissipates with no residue. LNG will not ignite until it has turned into a vapor, and even then, only after it has mixed with air and become severely diluted (5- 15 percent vaporised gas-to-air ratio). There isn't enough gas in the air to burn below 5%, and there isn't enough oxygen above 15%.

LNG is carried by water securely because every precaution is taken to reduce the risk of a leak. In the event of a spill, vaporising LNG is insoluble in water, thus any liquid spilled on land or in the ocean would swiftly evaporate. There is no risk of pollution of the land or water. LNG is non-toxic and does not undergo chemical reactions unless ignited.

3.7 Regasification of LNG

LNG is converted back to gas by regasification plants once it arrives at its final destination. It's then pumped to people's homes, companies, and enterprises, where it's burned for heat or power. LNG is increasingly gaining traction as a cost-effective and environmentally friendly transportation fuel, particularly for shipping and heavy-duty trucking.

One of two popular ways for converting LNG to gas involves reheating it with at least one heat exchanger. A little amount of LNG is burnt in a submerged combustion vaporizer to generate the heat needed to gasify the remaining LNG in one method.

The second approach involves using open rack vaporizers to gasify LNG using heat from ambient water such as saltwater or river water. The LNG enters the vaporizer heat exchanger from the bottom and leaves as gas from the top. The water is collected and then returned to its original source.

3.8 LNG Carriers

A tank ship designed for transporting liquefied natural gas (LNG) is called an LNG carrier. The cargo carrying capacity of LNG ships ranges from 125,000 to 260,000 cubic meters. Up to 180, 000 cubic meters is the most popular size.

In terms of cargo containment systems, vessels are divided into four categories:

- **Moss tanks (Spherical IMO type B LNG tanks)**

This system is named after the Norwegian firm that created it (Kvaerner Moss). The majority of these ships have 4-5 tanks. The operating pressure in these tanks is up to 22 kPa, although it may be increased for an emergency discharge.

- **IHI (Prismatic IMO type B LNG tanks)**

Ishikawajima-Harima Heavy Industries created the self-supporting prismatic type B tank. These tanks were developed to avoid damage from occurrences that occurred within membrane LNG tanks after multiple incidents in the past. Only a few ships are equipped with the design.

- **TGZ MARK III**

These membrane-type containers were created by Technigas. The membrane is stainless steel, and the tanks have a 1.2mm waffle design to absorb thermal contraction as the tank cools.

- **GT96**

Gaztransport's design consists of main and secondary membranes composed of the Invar material, which has no thermal contraction. The insulation is constructed out of perlite-filled plywood boxes that are constantly flushed with nitrogen gas. By detecting hydrocarbon in the nitrogen, the integrity of both membranes is constantly checked.

3.9 Top Ten Oil and Gas Companies in India

Humans depend on the oil and gas business throughout their lives. We rely on them in a variety of ways; thus, the industry is in high demand, which drives the country's economy. It is one of India's eight key sectors, with a considerable effect on the economy's decision-making process. Because India's economy is essentially based on energy consumption, demand for oil and gas is expected to grow even more, making the industry comparatively favorable for business.
Various Indian oil and gas companies have contributed significantly to the country's fast economic growth. They also form business ties with various raw material suppliers and are one of the most important sources of employment for a large number of individuals.

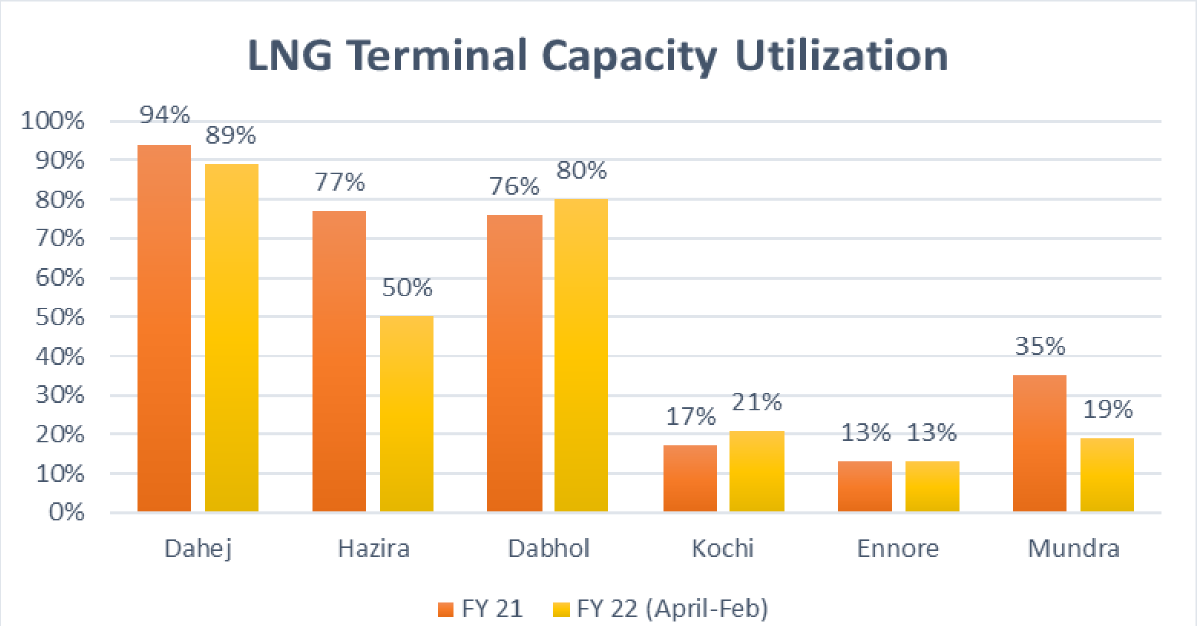
TABLE 4: LEADING OIL AND GAS COMPANIES IN INDIA

S. No.	COMPANY
1.	Indian Oil Corporation Limited
2.	Oil and Natural Gas Corporation
3.	Bharat Petroleum
4.	Gas Authority of India Limited
5.	Reliance Petroleum Limited
6.	Hindustan Petroleum
7.	Oil India
8.	Cairn India

9.	TATA Petrodyne Limited
10.	Essar Oil

Source: https://www.constructionworld.in/

3.10 Terminal Capacity Utilization in F.Y 2021 & F.Y. 2022



Source: https://www.igxindia.com/

Graph 1: Capacity Utilization of LNG Terminals in F.Y. 21 & 22

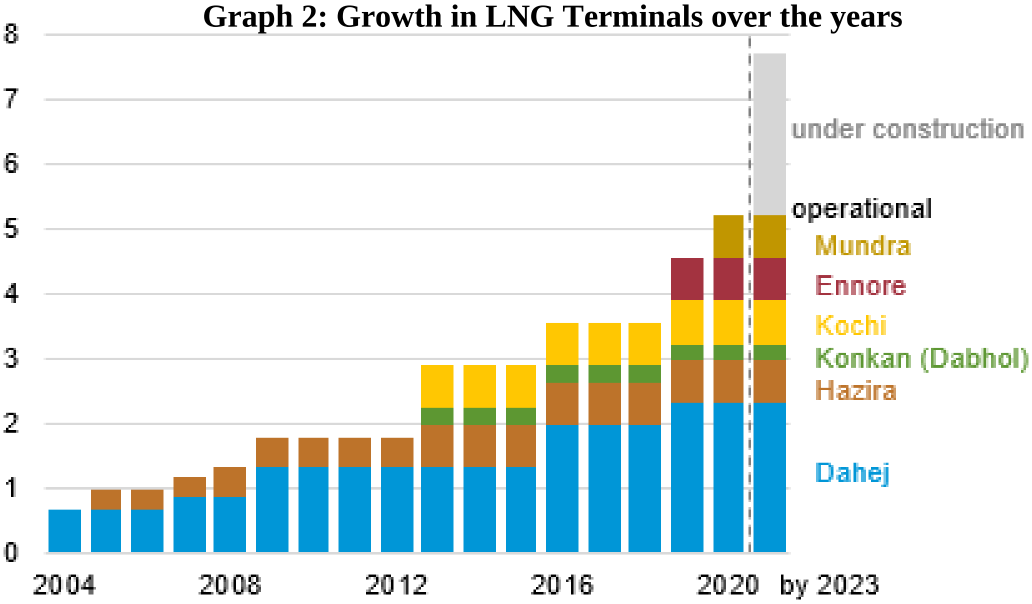
Except for one, India's LNG import ports are all along the Arabian Sea's west coast. Dahej (2.3 Bcf/d capacity) and Hazira (0.7 Bcf/d capacity) were the first two terminals to go live in 2004 and 2005, respectively. These two terminals are India's most heavily used LNG facilities, with approximately 100% capacity usage. The Konkan (Dabhol) LNG terminal (0.3 Bcf/d capacity), located south of Mumbai, and Kochi LNG (0.7 Bcf/d capacity), located near to the Kochi refinery in southern India, were both put into operation in 2013. In 2019, India's first LNG facility, Ennore LNG (0.7 Bcf/d), opened on the country's southeast coast, principally to service consumers in the Chennai area.

Mundra LNG, India's sixth LNG import facility, was launched in January 2020, with a notional import capacity of 0.7 billion cubic feet per day (Bcf/d). Mundra LNG is India's third LNG import facility, located near significant natural gas consumption areas and a well-developed pipeline network in India's westernmost state of Gujarat.

India's LNG import capacity is expected to rise by one-third over the upcoming years by 2023, with four terminals under development:

- Jaigarh LNG Floating Storage and Regasification Unit (FSRU) (0.5 Bcf/d capacity) (Maharashtra)
- Dhamra LNG (0.7 Bcf/d) (Odisha)
- Jafrabad FSRU (0.7 Bcf/d) (Gujarat)
- Chhara LNG (0.7 Bcf/d) (Gujarat)

Graph 2: Growth in LNG Terminals over the years



Source: https://www.eia.gov/

Western India, where the Dahej, Hazira, and Mundra terminals are located, has a well-developed natural gas infrastructure, but pipelines connecting coastal LNG import terminals to key demand areas farther interior are lacking in the southern and eastern parts of the nation. The timely completion of connecting pipes will determine the future expansion of India's LNG imports. Pipeline construction to carry natural gas to cities north and northeast of the Kochi terminal has been limited, limiting its use. Furthermore, land approvals for pipes linking the Ennore LNG terminal to cities north and south of Chennai must be obtained before development can commence. Meanwhile, the Ennore terminal serves a local refinery and Chennai city-gas users.

3.11 National Gas Grid

PNGRB awards organizations license to establish a City Gas Distribution (CGD) network (including PNG network) in a designated Geographical Area (GA) of the nation under the Petroleum and Natural Gas Regulatory Board (PNGRB) Act 2006. Compressed natural gas (CNG) is mostly utilized as an automobile fuel, whereas piped natural gas (PNG) is used in household, commercial, and industrial applications.

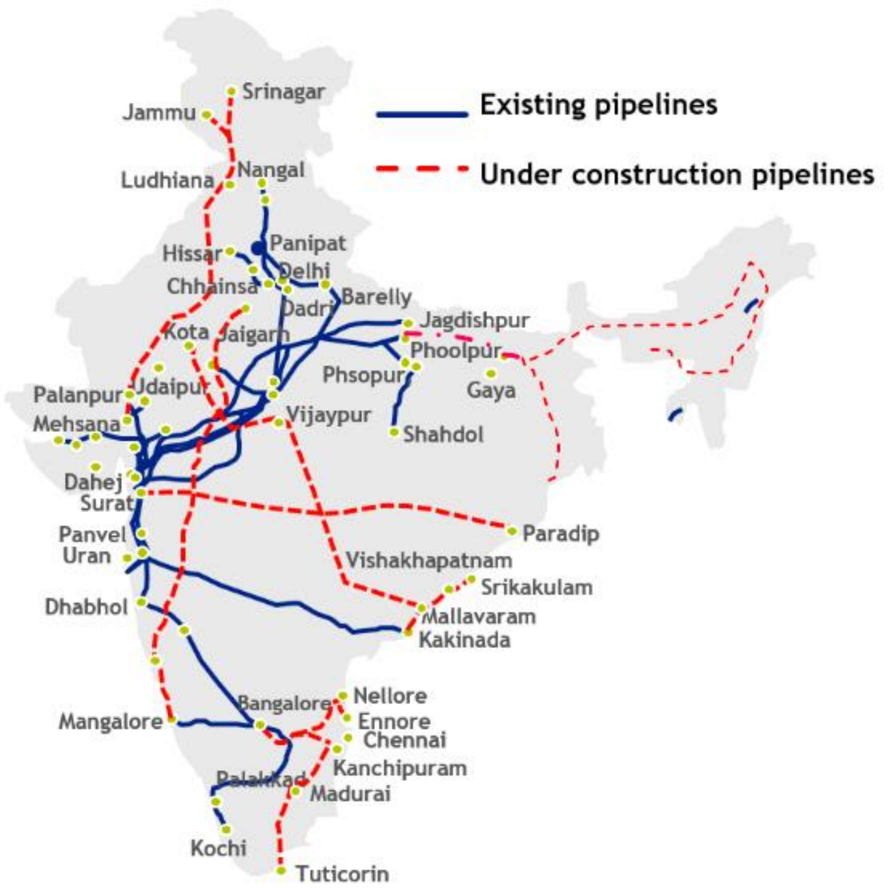


Fig. 11 Natural Gas Pipeline Distribution in India

Source: https://www.igxindia.com/

Gas accounts for only 6.2 percent of India's primary energy mix, compared to a global average of 24 percent. By 2030, the government wants to raise this percentage to 15%. The fertilizer, electricity, city gas distribution, and steel industries are likely to drive India's gas consumption. Over the next 25 years, India's energy consumption is predicted to expand at a rate of 4.2 percent each year.

According to the monthly production data provided by the ministry of petroleum and natural gas, India's gas output increased by 19.52 percent in June’21. Natural gas output in India is likely to rise. Reliance Industries Ltd and its partner BP are working on three deep-water gas projects in the KG D6 block off the coast of Andhra Pradesh, which are projected to generate 1 billion cubic feet of natural gas per day by 2023. In addition, the state-owned Oil and Natural Gas Corporation Ltd has begun producing gas from the KG-DWN-98/2 field.

India's petroleum regulator has approved a 33,764 km natural gas pipeline network for the country's gas grid as part of a push for cleaner fuel.

The PNGRB, for its part, has approved 232 geographical areas (GAs) as part of ten city gas distribution (CGD) bidding rounds that included over 400 districts in 27 states and union territories. Around 71 percent of India's population and 53 percent of the nation are covered by this. In addition, in the next 11th bid round, PNGRB aims to offer additional 44 GAs.

The Petroleum and Natural Gas Regulatory Board (PNGRB) approved a 33,764-kilometer natural gas pipeline network across the country on March 31, 2021, with the goal of creating a national gas grid and increasing natural gas supply across the country. This is in the context of India's drive to transition to a gas-based economy. Gas consumption in the nation is roughly 145 million standard cubic meters per day (MMSCMD).

According to the regulations, the authorized Natural Gas pipeline entity is entitled to install spur lines. 19,998 kilometers of natural gas pipeline (including sub-transmission and tie-in connectivity pipeline) are operating, while 15,369 kilometers are in different phases of development. Some of which are:

- Jagdishpur-Haldia/Bokaro-Dhamra Pipeline Project (JHBDPL) & Barauni-Guwahati Pipeline project (BGPL). (Indian states of Uttar Pradesh, Bihar, Jharkhand, Odisha, and West Bengal, 2265 km, GAIL)
- North East Region (NER) Gas Grid (A Joint Venture of IOCL, ONGC, GAIL, OIL and NRL, Indradhanush Gas Grid Limited (IGGL) has been entrusted to develop gas pipeline connectivity in all North Eastern states.)
- Kochi-Koottanad- Bangalore-Mangalore (Ph-II) Pipeline Project (KKBMPL) (South Indian states of Kerala, Tamil Nadu, Karnataka and the Union Territory of Puducherry, 1104 km, GAIL)
- Ennore-Thiruvallur-Bangaluru-Puducherry-Nagapattinum-Madurai-Tuticorin Natural gas pipeline (ETBPNMTPL) (States of Tamil Nadu, Karnataka & Andhra Pradesh, 1431 km, IOCL)

3.12 Demand Forecasting of LNG trade in India

The Power, Fertilizer, Industrial, and CGD industries are predicted to account for the majority of India's future natural gas demand increase. The power industry's demand for natural gas is likely to be fueled not just by a lack of domestic coal and the growing cost of its alternative, imported coal, but also by greater domestic gas supply and power sector reforms. The fertilizer sector is the only one that employs both chemical and thermal heat from gas in its production, and it continues to be a major contributor to the country's natural gas consumption. Increased emphasis on food security in India, as well as rising urea import prices, are likely to stimulate fertilizer demand.

Because the price of the alternate fuels (Naphtha/FO) used by industrial users is related to crude oil, the growing price of crude oil/ Naptha was one of the factors for increased gas demand from fertilizer units. It is also predicted to remain one of the drivers from industrial users. The

Government of India's focus on reducing subsidy burden is projected to remove demand from the country's fertilizer plants. In the CGD segment, the process of resolving environmental concerns is likely to stimulate natural gas demand from both industrial and compressed natural gas (CNG) customers. Natural gas is predicted to rise due to factors such as domestic gas supply, LNG imports, and the construction of necessary infrastructure.

3.11.1 Demand Drivers for Various Users

TABLE 5: SECTOR-WISE DEMAND DRIVERS

SECTOR	DEMAND DRIVER
Power Sector	• Rising cost of imported coal • Constrained domestic coal supply • Supply of domestic gas • Power sector reforms • Fast-growing economy
Fertilizer Sector	• Greater emphasis on Food Security • Increase in import price of Urea • Rising price of crude oil • Subsidy burden • Conducive Govt. Policy for new investment in urea manufacturing units
City Gas Distribution	• Environmental concerns • Subsidy burden • Enabling policy framework • Supply of domestic gas • Availability of affordable RLNG • Requisite infrastructure • GDP / Household income
Industrial User Segment	• Rising price of crude oil • Environmental concerns

In terms of demand sensitivity to natural gas prices, demand from the power and fertilizer sector is projected to remain extremely sensitive to the price at which these organizations are able to buy gas, owing to affordability difficulties among end users of basic food goods and energy. Other consuming sectors, on the other hand, are projected to be rather resistant to the price levels at which gas becomes accessible.

3.13 Major LNG Importing and Exporting Countries

Liquefied Natural Gas was the 14th most traded product in the world in 2020, with a total transaction of $99.6 billion dollars. Between 2019 and 2020, liquefied natural gas shipments fell by 31.2 percent, from $145 billion to $99.6 billion. Liquefied natural gas commerce accounts for 0.59 percent of global trade. LNG holds 4739th position in Product Complexity Index (PCI - The complexity and variety of the productive know-how necessary to make a product are ranked.)

3.12.1 Top Five LNG Importers

TABLE 6: TOP GLOBAL LNG IMPORTERS

S. No.	COUNTRY	IMPORT VALUE ($)
1	Japan	26.6 B
2	China	20.4 B
3	South Korea	14.2 B
4	India	7.26 B
5	Chinese Taipei	4.74 B

Source: https://oec.world/

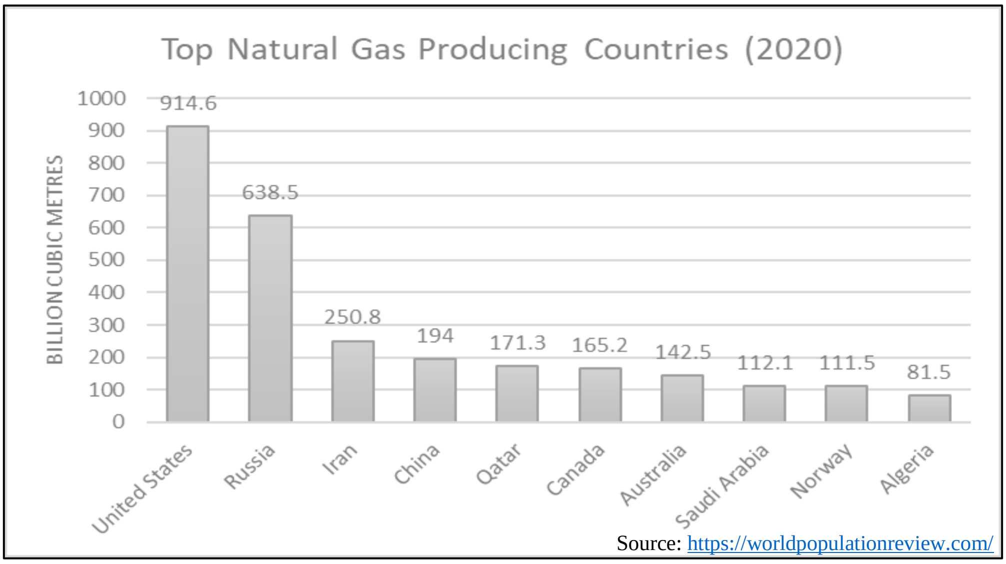
3.12.2. Top Five LNG Exporters

TABLE 7: TOP GLOBAL LNG EXPORTERS

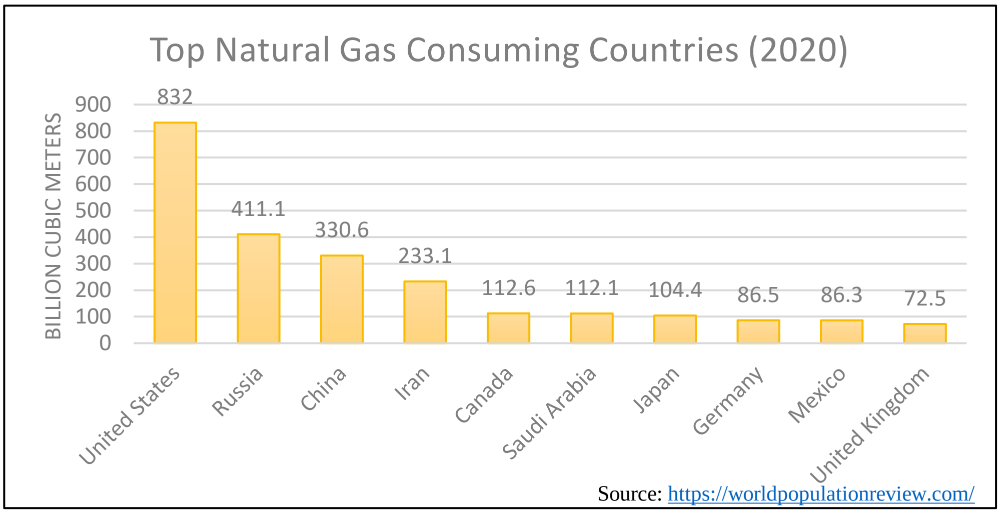
S. No.	COUNTRY	EXPORT VALUE ($)
1	Australia	25.7 B
2	Qatar	18.2 B
3	United States	13.2 B
4	Malaysia	7.30 B
5	Russia	6.80 B

Source: https://oec.world/

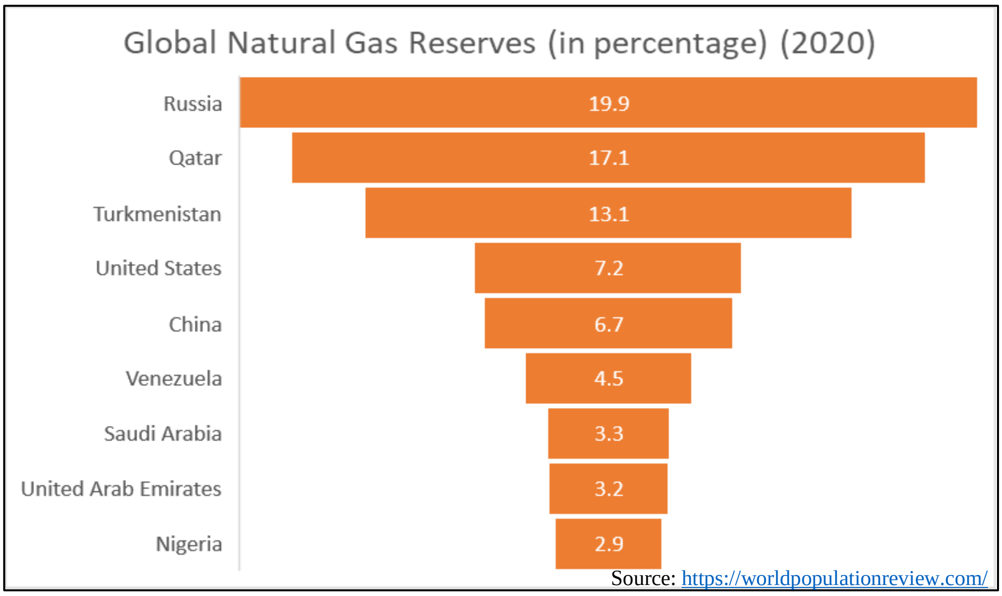
3.14 Global Production and Consumption of LNG



Graph 3: Natural Gas Producing Countries



Graph 4: Natural Gas Consuming Countries



Graph 5: Natural Gas Reserves around the world

Russia possesses the world's greatest natural gas reserves and exports more natural gas than any other country, with 238 billion cubic meters of gas expected to be sent in 2020. In Russia, natural gas for automobiles is heavily encouraged. Companies provide aftermarket kits, and some cars are built specifically to run on natural gas. By the end of 2020, Gazprom, the state-owned natural gas firm, was expected to have 500 fueling stations.

Iran has the second-largest natural gas reserves in the world. Iran is one of the world's most hydrocarbon-rich regions, with over 145 hydrocarbon fields and 297 oil and gas reservoirs identified to far, with the potential for more. Iran is now using only a small percentage of its gas reserves, making it one of the few countries capable of delivering much more natural gas in the future.

Qatar controls little over 13% of global natural gas reserves. The offshore North Field has the majority of the country's reserves. Qatar began drilling expansion in North Field in an effort to expand its natural gas exports and reclaim its position as the world's top liquefied natural gas exporter. It plans to increase output by 60%.

Natural gas reserves abound in the United States, with the largest concentrations in Texas, Oklahoma, and Louisiana. The United States has enough natural gas to last at least another 60 years or more, according to estimates. In addition to its domestic natural gas production, the United States imports natural gas through pipelines from Canada and Mexico.

Saudi Arabia possesses the world's fifth-largest natural gas reserves, which are primarily in the Persian Gulf. Saudi Arabia, the world's top crude oil exporter, is aiming to begin exporting natural gas as well. While the kingdom now relies on oil to generate electricity, it plans to move to natural gas for 70% of its power generation and renewable energy for 30%.

3.15 Impact of COVID-19

Over the years, humanity has witnessed some of the most dramatic episodes in the history of the global energy system, including the 1956 Suez Canal crisis, the 1973 oil embargo, which was quickly followed by the 1979 Iranian revolution, and, most recently, the Fukushima disaster in 2011.

All times of major global energy instability. All of this, however, pales in contrast to the events of 2020. Above all, the epidemic that swept the globe in 2020 was a humanitarian disaster. COVID-19 was estimated to have killed about four million individuals as of the beginning of July. The genuine figure is very certainly far higher, and it is continuing to climb.

The epidemic also resulted in significant economic losses. In 2020, global GDP fell by more than 3.5 percent, the biggest peacetime contraction since the Great Depression. According to the International Monetary Fund, the virus has pushed over 100 million people into poverty. And the pandemic's economic consequences – particularly for the world's poorest and least developed nations – are projected to last for many years after the virus has been contained. Long COVID comes in a variety of shapes and sizes.

The combination of the pandemic and measures to reduce its influence on the global energy grid resulted in unprecedented events and outcomes in contemporary peacetime.

2020 was a year unlike any other in terms of energy. First, we have been assaulted with daily reports of unparalleled changes and volatility. Standing back from the din, what occurred in the realm of energy last year, and how shocking was it?

The worldwide pandemic, on the other hand, was the mother of all stress tests. Engineers will tell you that how systems react under tremendous pressure may teach us a lot. What have we learned from the global energy system's response to the COVID-19 situation in that light?

Finally, all of this occurred against the backdrop of growing social and political pressure to expedite the transition to a net-zero energy system. COP26, possibly the most important UN climate meeting after Paris, was scheduled to take place in Glasgow, Scotland, last year. The meeting was eventually postponed until November 2021.

Worldwide energy consumption is expected to have decreased by 4.5 percent, while global carbon emissions from energy use are expected to have decreased by 6.3 percent.

By historical standards, they are the biggest reductions in both energy demand and carbon emissions since World War II. Indeed, last year's CO_2 emissions fell by nearly 2 Gt, bringing them back to levels last seen in 2011.

It's also worth noting that the carbon intensity of the energy mix – the average amount of carbon emitted per unit of energy consumed – decreased by 1.8 percent, one of the greatest drops in post-war history.

Natural gas, on the other hand, proved to be significantly more resilient. Gas demand is expected to drop by 2.3 percent (81 billion cubic meters) in 2020, comparable to the drop witnessed in 2009 following the financial crisis.

With the striking exception of China, where gas demand increased by nearly 7%, consumption declined in other areas. Sharp drops in gas prices aided natural gas's relative resilience, allowing gas generation to gain share in the US power market and hold its own in the EU.

CHAPTER IV
CRITICAL ANALYSIS

4.1 Energy Consumption in India

It is vital to describe current primary energy resources in India before describing the function of gas in the Indian energy picture. Non-commercial primary energy resources and commercial primary energy resources are the two types of primary energy resources, as discussed below.

4.1.1 Commercial Energy Resources

Commercial energy refers to energy sources that are offered on the market for a set price. Electricity, coal, and refined petroleum products are by far the most important commercial energy sources. In the modern world, commercial energy is the foundation of industrial, agricultural, transportation, and commercial growth. Commercialized fuels are the primary source of energy in industrialized countries, not just for economic production but also for numerous home functions.

Electricity, lignite, coal, oil, and natural gas, hydropower, nuclear resources are among examples.

4.1.2 Non- Commercial Energy Resources

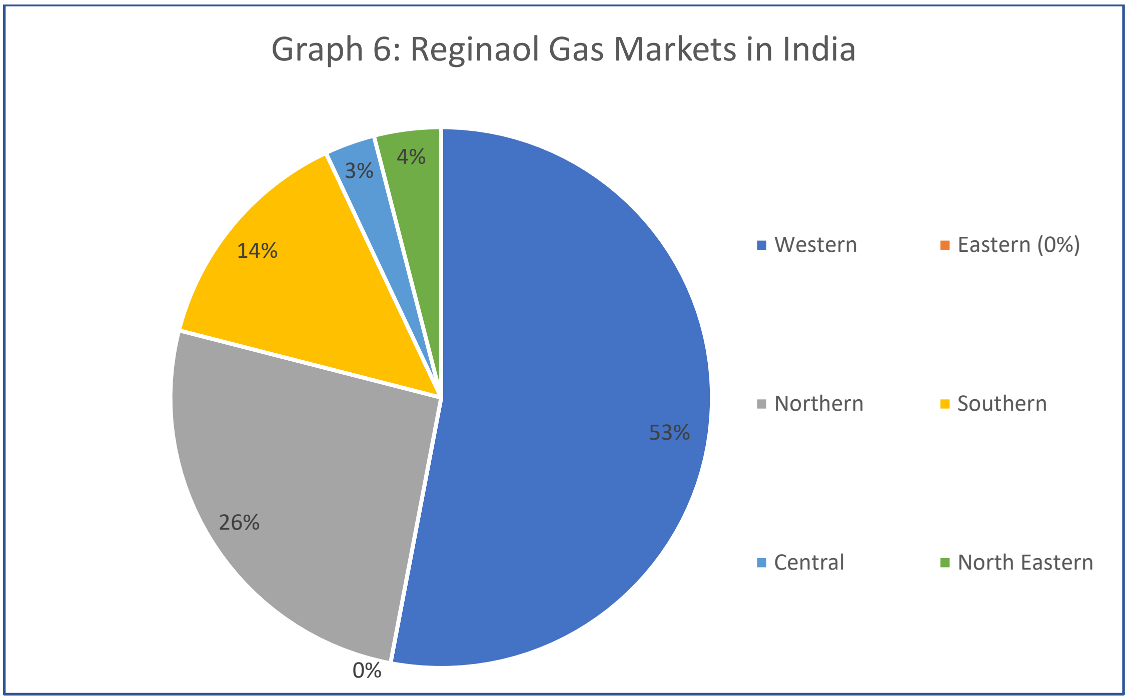
Non-commercial energy refers to energy sources that are not available for a fee on the commercial market. Fuels such as firewood, cow dung, and agricultural wastes, which are traditionally obtained and not purchased at a price, are examples of non-commercial energy sources. Traditional fuels are another name for them. In energy accounting, non-commercial energy is frequently overlooked.

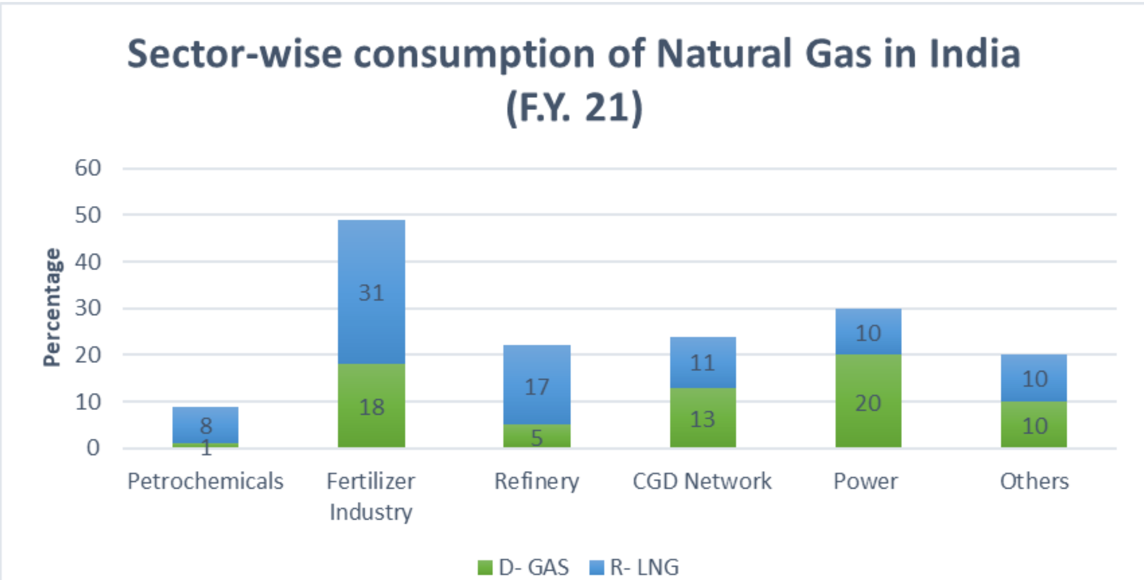
Animal power for transportation, threshing, raising water for irrigation, breaking sugarcane; sun energy for water heating, electricity generation, and drying grains, fish, and fruits; wind energy for lifting water and electricity generation.

Natural gas demand has risen dramatically in recent years as a result of increased gas availability, expansion of transmission and distribution infrastructure, cost savings from using natural gas instead of alternative fuels, and overall favorable economics of supplying gas at reasonable prices to end consumers. Switching to natural gas for energy has grown easier for the power, fertilizer, and CGD industries, as well as industrial and commercial institutions.

In the foreseeable future, India's natural gas consumption is likely to be anchored by the power and fertilizer industries. However, with increased gas availability, increasing demand for natural gas is projected from the industrial (process and power generation - cogeneration) and residential sectors in the future.

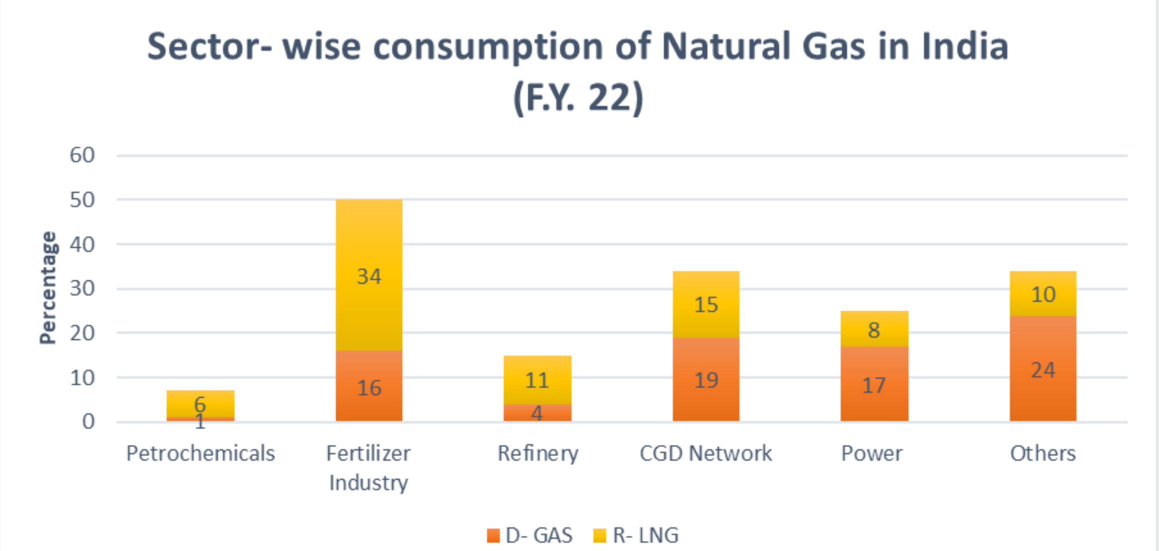
Northern, Western, Central, Southern, Eastern, and North-Eastern markets are the six primary regional natural gas markets in India. Out of them, the Western market consumes the most natural gas, accounting for more than half of the country's overall gas consumption. The Northern market is next, accounting for about a quarter of total consumption. Among all the gas markets in the country, the Eastern market has the lowest usage.





Source: https://www.igxindia.com/

Graph 7: Consumption of Natural Gas in India in F.Y. 21



Source: https://www.igxindia.com/

Graph 8: Consumption of Natural Gas in India in F.Y. 22

Natural gas markets are now restricted to states where gas deposits have been discovered. Gujarat, Maharashtra, Northern markets, Andhra Pradesh, and other states that are closer to the gas source or have pipeline infrastructure (HVJ pipeline) have benefited from increased gas availability and local gas market growth. Due to poor gas availability and inadequate pipeline infrastructure, other states such as Punjab, Haryana, Jharkhand, Uttarakhand, Karnataka, Kerala, Bihar, Chhattisgarh, and others have been unable to reap the advantages of gas.

TABLE 8: REGION-WISE GAS INFRASTRUCTURE

Region	States with infrastructure and consuming gas	States lacking pipeline infrastructure
Western	Gujarat, Maharashtra	Goa
Northern	Delhi, Uttar Pradesh, Haryana, Rajasthan	Punjab, J&K, Himachal Pradesh, Uttarakhand
Central	Madhya Pradesh	Chhattisgarh
Southern	Tamil Nadu, Andhra Pradesh	Kerala, Karnataka
North Eastern	Assam, Tripura	Meghalaya, Sikkim, Arunachal Pradesh, Mizoram, Manipur, Nagaland
Eastern	N/A	Bihar, West Bengal, Odisha, Jharkhand

Source: Petroleum Planning and Analysis Cell

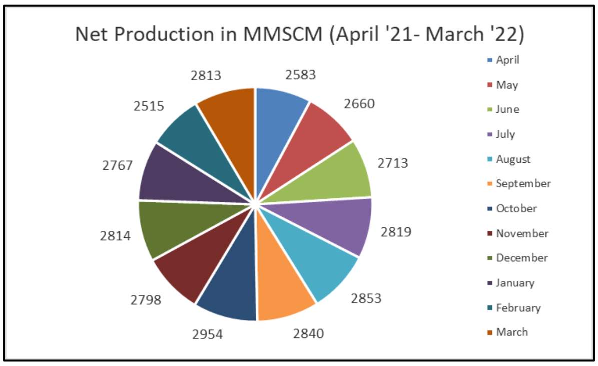
4.2 Role of Natural Gas in the Energy Scenario of India

India has a lot of room for a greener fuel. The following paragraphs address the role that natural gas or liquefied natural gas can play in the Indian energy environment.

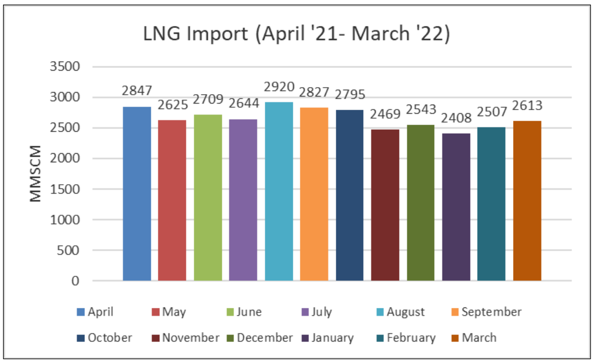
Natural gas is usually the most cost-effective energy source for business. Natural gas is a clean, safe fuel that is found in most equipment. This translates to lower maintenance costs owing to clean burning, lower liability due to its safety, and a greater choice of equipment acquisition due to natural gas's widespread use. Another factor that affects economics is stability. A plant's value is greatly enhanced by a consistent supply of high-quality natural gas, independent of weather, war, embargo, or other supply disruptions. Stability also entails price stability.

Natural gas costs are at an all-time low and are projected to stay that way for many years. The reason for this is that worldwide supply much outnumbers demand. Because natural gas burns clean, it is simple for a company to comply with state rules and air pollution legislation. It lowers the costs of expensive chimney cleaning machines and lowers the maintenance costs of all connected equipment.

4.3 Production and Consumption of Natural Gas in India



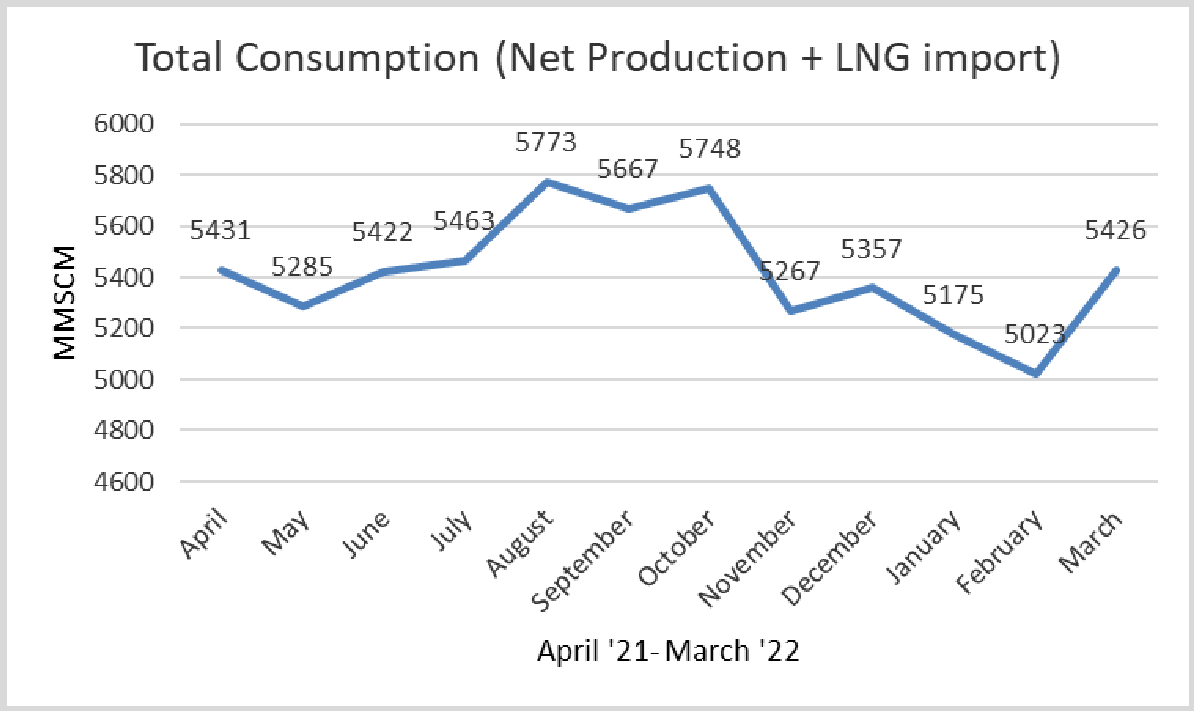
Graph 9: Production of Natural Gas in F.Y. 21



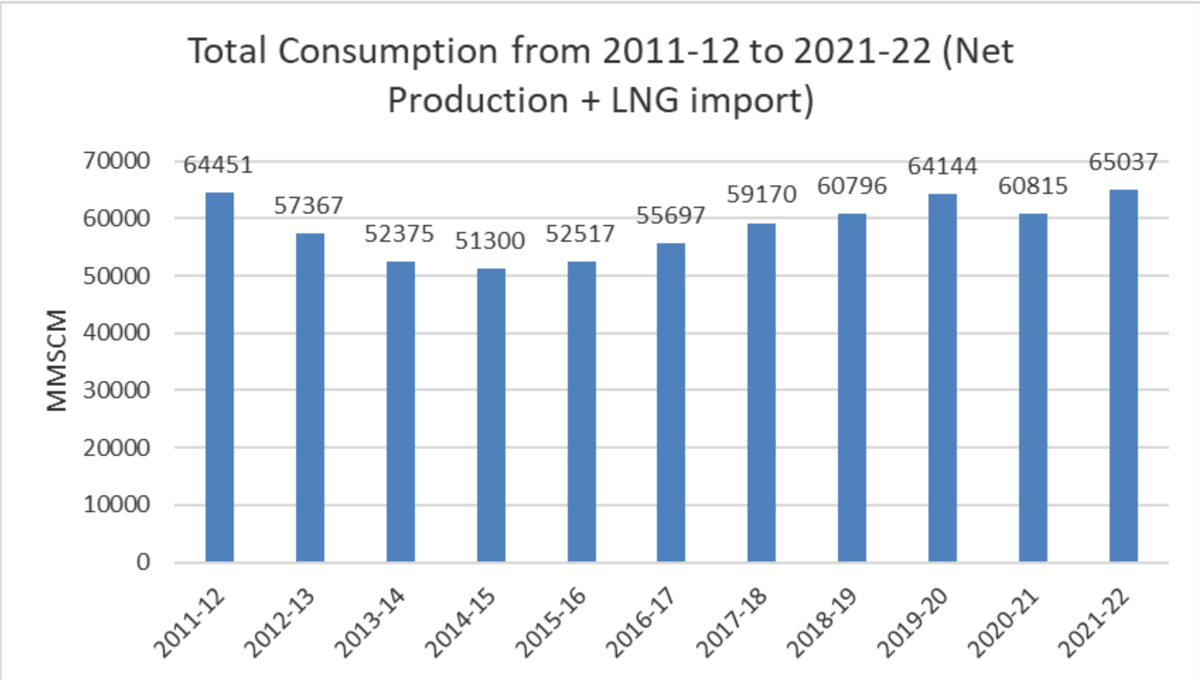
Graph 10: LNG Imports in F.Y. 21

The net production of natural gas rose from 2583 MMSCM in April'21 to 2813 MMSCM in March'22, showing an 8.9% increase in the production of natural gas in the financial year 2021, while generally also showing an increasing trend month by month for the year.

Similarly, import of liquified natural gas in the financial year 2021 showed a steady trend implying that demand for LNG in India has been increasing. The total consumption went from 5431 MMSCM in April'21 to 5426 MMSCM in March'22, indicating a steady annual demand.

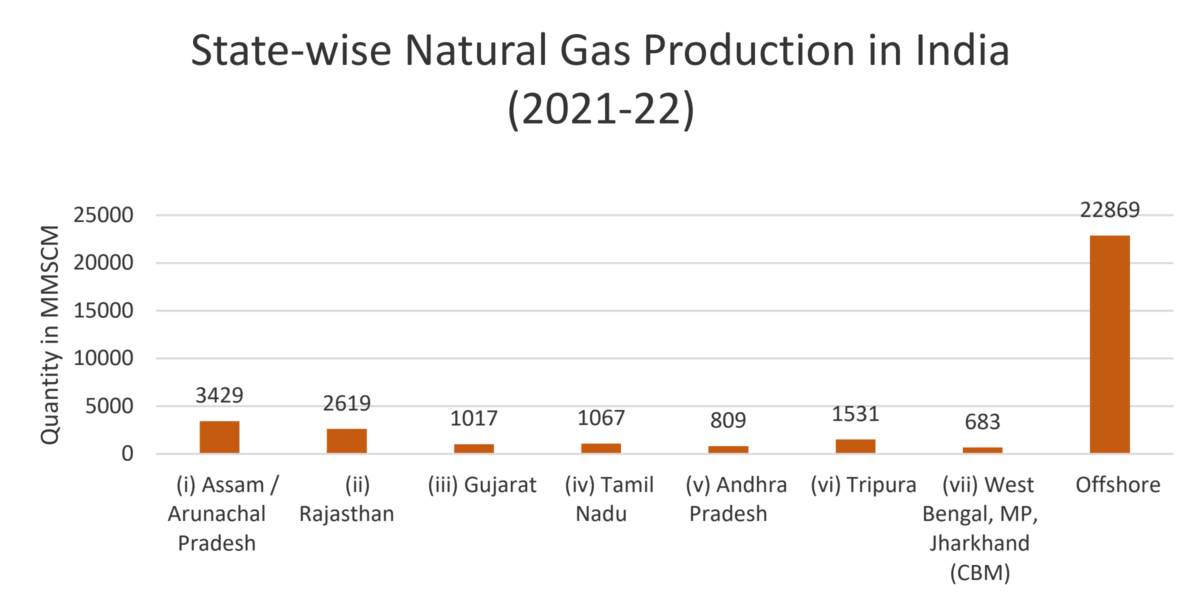


Graph 11: Total Consumption of Natural Gas in F.Y. 21



Graph 12: Consumption of Natural Gas from 2011 to 2021

Though, consumption of natural gas has merely increased by 0.91% from 2011 to 2021 but over the period of 10 years the annual growth rates have fluctuated showing a maximum increase of 6.9% in 2021 and a steep decline of 10.99% in 2012.



Graph 13: State-wise Natural Gas Production in India in F.Y. 21

4.4 Network of Gas Pipelines in India

GAIL, RGTIL/RGPL, and GSPL are the three biggest pipeline companies in India now involved in natural gas transmission. GAIL operates 11411 km of trunk pipelines in India, accounting for 70% of the country's pipeline network. The HVJ, DVPL, DUPL/DPPL, Dadri Bawana-Nangal, and Dabhol-Bengaluru trunk pipelines are used to evacuate both local and imported RLNG. GAIL also manages regional gas pipeline systems in Maharashtra, the K.G. Basin, the Cauvery Basin, and Gujarat. RGTIL and RGPL, which operate the East-West Pipeline (EWPL) to evacuate gas from the KG-D6 field in Andhra Pradesh and the Shadol-Phulpur Pipeline, respectively, operate 1784 km of pipes (about 11% of the pan India network). GSPL is mostly focused on Gujarat, with around 2692 km of gas pipes (almost 16% of the total).

TABLE 9: SPREAD OF PIPELINE NETWORK

S. no.	Transporter	Length in KM	Percentage share
1	GAIL	11411	69.9%
2	RGTIL / RGPL	1784	10.9%
3	GSPL	2692	16.5%
4	AGCL/DNPL	297	1.8%
5	IOCL	140	0.9%
	Total	**16324**	**100.0%**

Source: https://www.ppac.gov.in

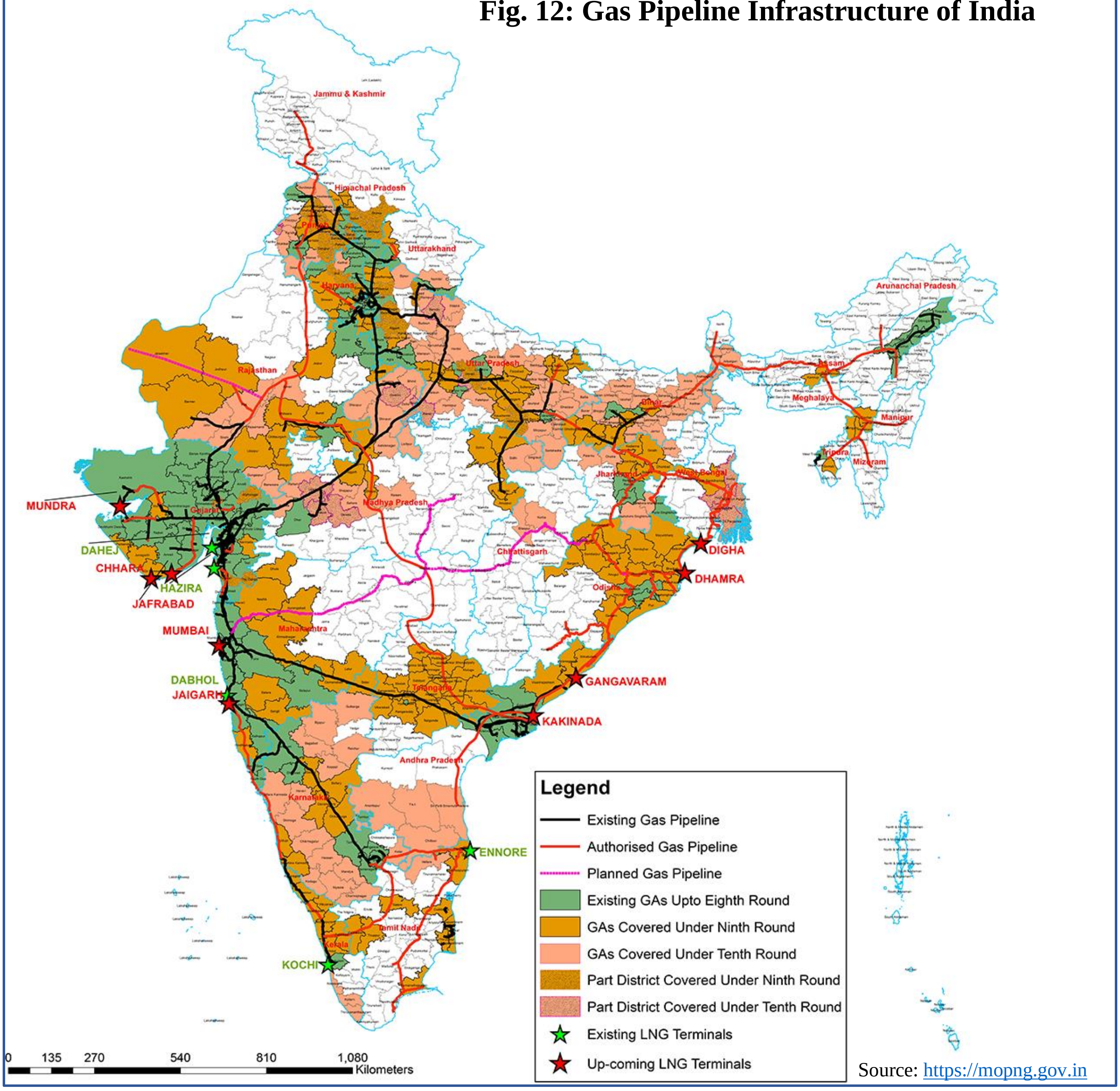
KG-D6, Mumbai offshore, Cambay Basin, Ravva Offshore, KG Basin, Cauvery Basin, and LNG imports are the main sources of natural gas.

TABLE 10: DETAILS OF EXISTING PIPELING NETWORK IN INDIA

Gas pipeline network as on 01.04.2019						
Network/Region	**Entity**	**Length (Kms)**	**Design capacity (mmscmd)**	**Pipeline size**	**Average flow 2018-19 (P) (mmscmd)**	**Percentage capacity utilisation in 2018-19 (P)**
Hazira-Vijaipur-Jagdishpur Pipeline/Gas rehabilitation and expansion project pipeline/Dahej-Vijaipur Pipeline & spur/ Vijaipur-Dadri Pipeline	GAIL	4554	53	36"	29.5	56%
DVPL-GREP upgradation (DVPL-II & VDPL)	GAIL	1385	54	48"	35.9	67%
Chhainsa-Jhajjar-Hissar Pipeline (CJPL) including spur lines *	GAIL	310	5	36"/16"	1.0	20%
Dahej-Uran-Panvel Pipeline (DUPL/ DPPL) including spur lines	GAIL	928	20	30"/18"	13.9	70%
Dadri- Bawana-Nangal Pipeline (DBPL)	GAIL	852	31	36"/30"/24"/18"	5.5	18%
Dabhol-Bengaluru Pipeline (Including spur)	GAIL	1116	16	36"/4"	1.3	8%
Kochi-Koottanad-Bengaluru-Mangalore (Phase-1)	GAIL	48	6	16"/4"	2.3	38%
Tripura (Agartala)	GAIL	60	2	12"	1.3	55%
Gujarat	GAIL	685	9	24"/16"/12"	4.4	49%
Rajasthan	GAIL	151	2	12"	1.4	57%
Mumbai (Uran-Thal-Usar & Trombay-RCF)	GAIL	131	7	26"	6.4	91%
KG Basin	GAIL	884	16	18"	5.4	34%
Cauvery Basin	GAIL	306	9	18"	3.3	38%
East- West Pipeline	RGTIL	1480	67	48"	19.4	29%
Shahdol-Phulpur Pipeline	RGPL	304	4	16"	0.9	26%
Gujarat State Petronet Limited (GSPL) network	GSPL	2692	43	Assorted	34.6	80%
Assam network^	AGCL, DNPL	297	3	Assorted	1.9	69%
Dadri-Panipat	IOCL	140	10	30"/10"	5.0	53%
Total		**16324**	**320**			

Source: https://www.ppac.gov.in

Fig. 12: Gas Pipeline Infrastructure of India

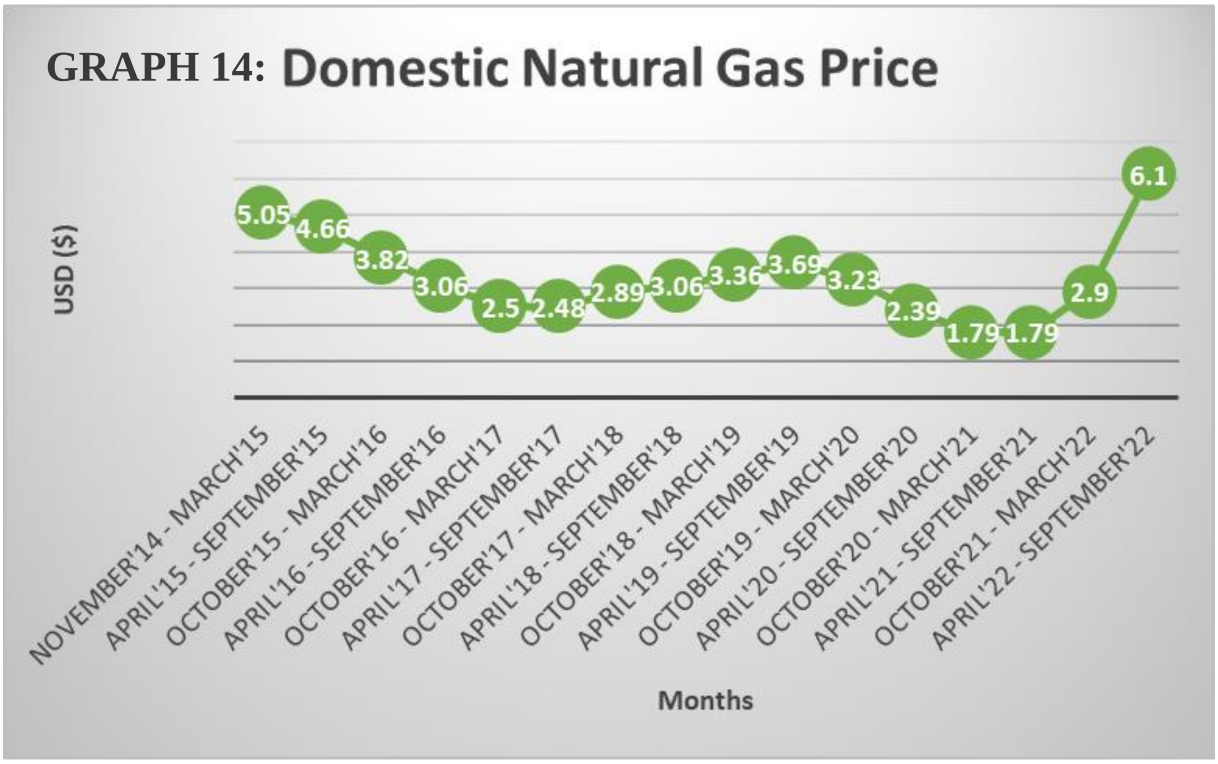


Source: https://mopng.gov.in

4.5 Influence of Gas Pricing on Trade

The Domestic Natural Gas pricing is in accordance with 'New Domestic Natural Gas Pricing Guidelines' issued by Ministry of Petroleum and Natural Gas, Government of India, for respective periods of time, based on Gross Calorific Value.

Natural gas could theoretically absorb nearly all of the fuel oil market in industry and power generation, as well as the whole gas oil market in industry and the residential/commercial sectors. In reality, however, the price of gas relative to competing fuels and government regulations determine the technological demand for gas.



With the exception of sales to utilities or big industrial clients, which are typically negotiated independently, the price of bulk natural gas is nearly always established by long-term contracts with producers, while end-use natural gas sales are normally controlled or regulated by governments. Almost all governments manage and regulate electricity pricing, and there are still many cases when natural gas prices are set by governments to assist the attainment of specific regional development or social goals unrelated to supply costs.

4.6 Cost Structure of LNG Transportation

The cost of LNG transportation is a critical factor in the project's overall feasibility. The cost of building LNG tankers is so high that they may be the single most expensive item in the overall project's budget. The three main components of shipping LNG are:

1. Direct operating cost: crew, insurance, maintenance, store and lubes and administration costs
2. Voyage cost: port charges and cost of boil off gas and fuel oil used
3. Capital cost of the ship

4.7 Comparison between F.Y. 2021 & F.Y. 2022

- Overall domestic gas output climbed by 24%, with PVT. /JVs contributing 195 percent of the growth.

- LNG imports decreased by 6%.
- Domestic gas use in the power sector decreased by 14%, while CGD usage increased by 44%.
- Switching to alternate fuels reduced gas usage by 30% in the refinery and petrochemical industries.
- Overall CGD gas consumption increased by ~37%

CHAPTER V
CONCLUSION

Natural gas is a fossil fuel and it is used for heating and cooking at homes, for providing hot water in homes and for all residential and commercial cooking. Natural gas is also used for electricity generation, and for manufacturing chemicals, plastics, fertilizers, and other products In 2020, primary energy usage declined by 4.5 percent, the most since 1945. Oil was the major driver of the drop in energy use, accounting for about three-quarters of the net decrease, while natural gas and coal also witnessed large drops. Despite a drop in overall energy consumption, wind, solar, and hydroelectricity all climbed.

The United States, India, and Russia were the countries with the greatest reductions in energy use. China saw the highest rise (2.1%), making it one of just a few countries where energy consumption increased last year.

Natural gas prices have fallen to multi-year lows: in 2020, the US Henry Hub averaged $1.99/MMBTU, the lowest since 1995, while Asian LNG prices (Japan Korea Marker) fell to their lowest level ever ($4.39/MMBTU).

Natural gas usage declined by 81 billion cubic meters (BCM), or 2.3 percent, in the first quarter of this year. Despite this, gas's percentage of primary energy continued to grow, hitting a new high of 24.7 percent. Russia (-33 BCM) and the United States (-17 BCM) led the declines in gas consumption, with China (22 BCM) and Iran (10 BCM) providing the most rises. Inter-regional gas commerce fell by 5.3 percent, with a 54 billion cubic meters (10.9 percent) decline in pipeline trade accounting for the whole drop.

While natural gas's proportion of India's primary energy mix has remained relatively stable in recent years, at approximately 6%, overall energy demand has increased fast, with major swings in natural gas consumption in various sectors of the economy. Natural gas use in industry has surged tenfold since 2010, despite a 50 percent growth in overall energy use in the sector. As a result, natural gas's proportion in the sector has risen from less than 2% to approximately 10%.

Similarly, natural gas utilization in construction has quadrupled in the last decade, albeit from a low foundation. However, a decrease in the usage of natural gas for electricity generation has somewhat countered these increases. The pressures that caused this drop are still present: Due to a dearth of inexpensive natural gas, approximately 60% of India's natural gas-based power production capacity is under severe financial strain and is working at extremely low capacity.

India has declared that it wants to expand natural gas's portion in its primary energy mix to

15% by 2030, up from 6% in 2019. The government has taken a number of steps to promote this goal, including increasing domestic production, facilitating imports, and encouraging demand. HELP offers for price and marketing flexibility for gas generated from deep water, ultra-deep water, and other challenging sources, allowing for increased production. All other fields' gas prices are set every six months using a formula based on hub prices in other nations, including as the United States, Canada, the United Kingdom, and the Russian Federation. The Indian Gas Exchange (IGX), a natural gas trading platform, would be created by the government in 2020. However, the relatively low level of gas prices in recent years has worked as a deterrent to major investments in domestic production.

India's gas demand has exceeded local supply, resulting in a growing reliance on imported LNG. Natural gas imports have increased from 20% of India's total gas consumption in 2010 to 50% now. India has six LNG facilities to enable these imports.

Despite certain infrastructural limitations, India currently has a 17,000 km pipeline network to deliver gas to points of consumption, and it plans to greatly expand this grid. The Petroleum and Natural Gas Regulatory Board, India's downstream regulator, is in charge of supervising this growth as well as regulating pricing for users of this infrastructure.

India has ambitious ambitions for city gas distribution (CGD) networks to serve families, business institutions, and industrial within cities, in addition to its long-distance pipeline network. CGD networks are now in 18 states, and consecutive bid rounds have given CGD licences with the goal of reaching 70% of all homes by 2030.

Demand destruction has been visible in India for months, and among the major importers, India has witnessed the largest drop in LNG imports in percentage terms so far this year. Refinery LNG demand has been cut in half as customers move to oil as a captive fuel, but domestic gas consumption has increased somewhat. This appears to have had minimal impact on operations, with average refinery capacity utilisation greater than the same period last year and at or over 100% on average. The usage of LNG has more than halved as domestic gas supply has become more dependable, despite a third reduction in gas demand from the power industry.

As a result, monthly gas-fired generation has decreased by around 1TWh. However, because natural gas accounts for less than 2% of total electricity output, other sources - a mix of coal, nuclear, and renewables - have been able to make up the difference. The annual rise in electricity consumption, which is around 3%, has also been examined. Coal shortages are more likely to threaten supply security this summer than gas shortages.

The supply of gas to other sectors has fared better. Industries have benefited from the growth of eastern offshore gas, which has offset the impact of LNG reductions in several industrial clusters. Fertilizer and city gas distribution are the most robust industries in terms of LNG, since they are best positioned to pass on increasing costs through pooling and subsidy arrangements.

5.1 Challenges in Future

The surge in local gas production has helped to offset the impact of decreased LNG supply thus far. Domestic output is expected to expand by 4% in 2022, according to ICIS, but most of the ramp-up had already occurred by May 2021.

ONGC, the state-owned oil and gas company, has been unable to reach its production objectives for months, and the start-up of gas production in its eastern offshore projects has been postponed until May 2023. This means that expanding domestic supplies will not be able to meet LNG demand until December 2022, when Reliance Industries begins production at the MJ field.

Domestic gas prices are also growing, now at $6.1/MMBtu and expected to approach double digits by October 2022, when global gas indicators begin to factor into the pricing calculation. The price cap for deep water gas, which is compared to competing fuels, has also risen, currently standing at $9.92/MMBtu.

Longer term, the price may encourage domestic gas development, but for consumers, it means that inexpensive gas is becoming scarce.

In the ICIS 24-month prediction horizon, the LNG market has limited supply growth potential, thus demand response will have to perform most of the heavy lifting.

Indian LNG consumption is expected to stay stable until 2022, and potentially into the following year, according to ICIS. With the start-up of HURL's Gorakhpur fertilizer factory anticipated to boost gas consumption higher by the monsoon planting season, fertilizer and city gas distribution might defy the trend. However, the government would face a greater fertilizer subsidy cost, and natural gas's position in the energy transition will be seriously harmed across critical industries.

With the utilisation rates of terminals Jaigarh, Jafrabad, and Dhamra unknown under present market circumstances, the profitability of future LNG import infrastructure projects might potentially be jeopardised.

In India, the use of gas as a transition fuel is primarily motivated by the need to combat air pollution. However, as the world's focus shifts to supply security, the window of opportunity for gas to play a large role in India is closing.

REFERENCES

https://www.ppac.gov.in/content/154_1_PipelineandCGDStructure.aspx

https://mopng.gov.in/en/natural-gas/about-the-division

http://naturalgas.org/overview/background/

https://petronetlng.in/Dahej_LNG_Terminal.php

https://www.hydrocarbons-technology.com/projects/haziralngterminalguj/

https://www.hydrocarbons-technology.com/projects/dabhollngterminalmah/#:~:text=Ratnagiri%20Gas%20and%20Power%20(RGP,mechanically%20completed%20by%20December%202010.

https://petronetlng.in/kochi-terminal.php

https://www.bv.com/projects/ennore-lng-terminal-black-veatch-completes-design-commissioning-lng-regasification

https://www.indianoillng.com/importance-of-terminal/

https://energy.economictimes.indiatimes.com/news/oil-and-gas/gail-arm-to-invest-rs-3000-crore-in-dabhol-lng-terminal-to-double-capacity/63573727

https://www.hydrocarbons-technology.com/projects/kochi-lng-terminal/

https://cameronlng.com/wp-content/uploads/2018/10/Natural-Gas-and-the-Liquefaction-Process-CLNG.pdf

https://beeindia.gov.in/sites/default/files/1Ch1.pdf

https://www.elengy.com/en/lng/what-is-lng.html#:~:text=Liquefaction%20as%20an%20economical%20transport%20and%20storage%20method&text=To%20enable%20maritime%20transport%2C%20the,Liquefied%20Natural%20Gas%20(LNG).

http://petroleum.nic.in/sites/default/files/ipngstat_0.pdf

https://www.livemint.com/industry/energy/india-lng-demand-journey-to-be-shaky-slow-due-to-infrastructure-limits-1552619774804.html

https://corporate.cyrilamarchandblogs.com/2018/12/lng-transport-fuel-india-heavy-vehicles/

https://informaconnect.com/10-challenges-facing-lng/

https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

https://www.igxindia.com/

https://www.igxindia.com/wp-content/uploads/2022/05/Gas%20Connect%20-%20IGX%20-%20May%202022.pdf

https://oec.world/en/profile/hs/natural-gas-liquefied

https://www.researchgate.net/publication/276177861_The_Research_about_Storage_and_Transportat

ion_of_Natural_Gas_Based_on_LNG_Technology
https://www.researchgate.net/publication/322307406_Impact_of_Using_Liquefied_Natural_Gas_for_Transportation_in_the_City_of_Cochin_A_Review
https://www.naturalgasworld.com/indias-gas-infrastructure-challenge-lng-condensed-71572
https://www.intechopen.com/online-first/79999
https://www.mdpi.com/1996-1073/15/8/2750/htm
https://www.ceew.in/publications/small-scale-lng-expanding-natural-gas-access-india
https://www.constructionworld.in/energy-infrastructure/oil-and-gas/top-10-oil-and-gas-companies-in-india/32052
http://www.gasprocessingnews.com/news/india%E2%80%99s-sixth-lng-import-terminal-comes-online.aspx
https://www.indianoillng.com/importance-of-terminal/
https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng.html
https://www.maritimeoptima.com/blogdata/different-type-and-sizes-of-liquefied-natural-gas-lng-carriers
https://en.wikipedia.org/wiki/LNG_carrier
https://www.elgas.com.au/blog/493-what-is-lng-liquefied-natural-gas-methane/
https://worldpopulationreview.com/country-rankings/natural-gas-by-country
https://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2020/02_27/#itn-tabs-0
https://gastopowerjournal.com/projectsafinance/item/11315-india-s-7th-fsru-to-start-up-early-2021-covering-power-sector-demand
https://www.livemint.com/
https://www.nsenergybusiness.com/projects/jagdishpur-haldia-and-bokaro-dhamra-pipeline-jhbdpl/
https://iggl.co.in/
https://s3-us-west-2.amazonaws.com/visionresources/infographics/7b2ed-north-east-gas-grid-project.pdf
https://www.nsenergybusiness.com/projects/kochi-koottanad-bangalore-mangalore-pipeline-project/
https://puducherry-dt.gov.in/document/drdm-petroleum-and-natural-gas-pipeline-projects-right-of-user-for-laying-pipeline-by-iocl-fixing-of-compensation-for-right-of-user-and-crop-compensation-under-the-petrol/
https://www.gem.wiki/Ennore-Tuticorn-Bengalaru_Gas_Pipeline
https://puducherry-dt.gov.in/document/drdm-petroleum-and-natural-gas-pipeline-projects-right-of-user-for-laying-pipeline-by-iocl-fixing-of-compensation-for-right-of-user-and-crop-compensation-under-the-petrol/