Analysis of Potential and Feasibility of LNG as a Marine Fuel

Final Year Project Report submitted in partial fulfillment of the Requirement for the Award of the degree of

MBA (Energy Trading)

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Certificate of Declaration

This is to hereby state that the intention of this report is very original in every sense of the terms and conditions and it carries a sense of honour and belief and that no shortcuts have been taken and I remained both meticulous and caring during the prevalence of this research work. I have put in my best to keep this work as informative and precise as possible.

It may be also stated here that during the preparation of this report some help has been taken from a scope of professionally shared information & knowledge, a comprehensive description of which has been mention in the references chapter of this report.

Dated: 21st April, 2014

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This to certify that the Mr. Kashish Khanna, student of University of Petroleum and Energy Studies, Dehradun pursuing MBA in Energy Trading has successfully completed his dissertation project. As a part of his curriculum, the project report entitled "Analysis of Potential and Feasibility of LNG as a Marine Fuel" submitted by the student to the undersigned is an authentic record of his original work which he has carried out under my supervision and guidance. This study has not been submitted anywhere else for degree purpose.

I wish him all the very best for his future endeavors.

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ABSTRACT

The restrictions imposed by International Marine Organization (IMO) on emissions will come into force in 2015 in the prescribed ECA's (Emission Control Areas) and that for the rest of world by 2020. In order to comply with the said regulations some amendments are to be made in the conventional business system. There are a number of solutions proposed, however, LNG has the possibility to overcome the compliance of emission restrictions in order to keep intacta substantial share of the world marine fuel market: as the technology is proven (around 45 ships are successfully running on LNG as a fuel), thereby complying not only the emission restriction but also the economics. However, there is a need to determine the uncertainties associated with the usage and thereby determining the solutions for those uncertainties is required, in order to prove the potential of LNG as a marine fuel.

There is an utter need of heavy investments in all the steps of the value chain, but the maritime industry follows the classical chicken and egg dilemma, which makes it hard to determine the long term source from suppliers or owners or charterers. An efficient solution to the problem lies with meeting the demand with the supplies followed by the optimum investments in the infrastructure, so as to have an efficient market and an effective value chain.

Another area to look upon is the development of regulations, standards and code of conduct, in order to have an equation of safety (HSE management) and the day to day conduct of the supplies required to meet the demand of the LNG industry, so as to have an efficient overall development of the LNG Bunker industry with the optimum care taken of the responsibilities towards the environment and safe practices for the maritime fleet across the world.

The LNG production across the world equates the world bunker potential; Consequently, the question arises of its availability on the potential ports on the most traversed transit routes, and a standard pricing mechanism, so as to assess the overall feasibility of the shift to LNG, hence a question to the existing LNG market's capability to accommodate LNG as a marine fuel is there.

There is hence a focus shift seen, towards the emission reduction in order to minimize the impacts of air pollution on the environment, which is driven by regulations as a mandate and the stakeholder's expectation on a stretch.

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1. INTRODUCTION

The Modern day Global Economy is heavily dependent on the Import and Export of commodities and goods between countries across the world. To help move such volumes of cargo at an economical rate, transportation by sea is the most preferred mode of transport. In the last few decades,the demand for vessels, for cargo and product transportation has increased ten times and so has the vessel movement on a global scale.

Due to this the demand of ***Bunker Fuels***, as generally referred to be (Intermediate Fuel Oil and Marine Gas Oil) has increased significantly. Bunker fuels that are also known as Marine Fuel include Intermediate Fuel Oil (IFO), Marine Gas (MGO) and Marine Diesel Oil (MDO). IFO is similar to Gasoline used for cars, used to run the Ship's engine which drives for propulsion, and MGO is used to run the generators to produce electricity on a vessel.

Bunkering is the term used in the shipping industry to explain the selling and transferring of fuel (IFO, MGO, MDO, Lubes) to Ships or Marine Vessels. It generally includes supplying fuel from one ship, Tank Farms through pipelines or Tank Trucks to a Ship/ Marine Vessel involved in transportation ofoil,people, cargo or container service.

The prices of Bunker fuel havedire impacts on the global freight level and the economic profitability of shipping companies. Consequently, shipping companies always look to identify the potential bunkering locations for their vessels. Presently, the globalbunker market for bunkers is estimated to have a potential of 200 million tons (approx.) in size.

Bunker costs calls for almost 45-55% of voyage expenses and as the price of crude oil and increases as time passes, this percentage has increased. Due to the relentlessly rising price of oil and ever-increasing marine environmental protection awareness, the Bunkering Industry, hasdevelopedinto a highly focused shipboard operation in terms of regulatory compliance, and quality and quantity assurance.

Bunker fuel Oil is technically any type of fuel oil used aboard ships. Fuel oil is a fraction obtained from petroleum distillation, either as a distillate or as a residue. Fuel oil is any liquid petroleum product that is consumed in a furnace or boiler for the generation of heat or used in an engine for the generation of power. The term fuel oil is also used sense to refer only to the heaviest commercial fuel that can be obtained from crude oil, and is heavier than gasoline and naphtha. The heavy fuel oil are extracted and processed from a refinery bottoms or residues after all other fractions have been extracted from a crude oil feedstock.

1.1. BUNKER FUEL

There are ***three major types*** of marine fuel: ***distillate fuel, residual fuel***, and a ***combination of the two*** to create a fuel type known as ***"intermediate" fuel oil (IFO)***. Distillate and residual fuels are blended into various combinations to derive the different grades of marine fuel oil. The list below states the major marine fuel grades and their colloquial industry names. Distillate fuels are morecostly than intermediates, and residual fuels are the Cheapest.

FUEL TYPE	FUEL GRADES	COMMON INDUSTRY NAME
DISTILLATE	DMX, DMA, DMB, DMC	Gas Oil or Marine Gas Oil
INTERMEDIATE	IFO 180 380	Marine Diesel Fuel or Intermediate Fuel Oil (IFO)
RESIDUAL	RMA-RML	Fuel oil or Residual Fuel Oil

TABLE 1. MARINE FUEL TYPES

Distillates and/or residual fuel oil stocks are blended with blending components or cutter stocks to achieve internationally accepted product specifications provided by the 1987 (revised in 1996) International Standard, the ISO 8217, which gives the guidelines for the specification of fuel grades for use in marine diesel engines. Marine fuel grades carry three letters: "D" or "R" indicate the "distillate fuel" as compared to "residual fuel." The second "M" signifies "marine fuel" use. The third letter designates the individual grade. Distillate marine (DM) fuels have three grades from A to C. Residual marine (RM) fuels have 15 grades depicted by letters A through H, K, and L. For example, RME-35 stands for "residual marine fuelE at a maximum viscosity (at 100° C) of 35 centistokes.(RTI International, 2008)

Marine fuel traders, Marine fuel testing service experts and Commercial marine fuel supply services Providers all are of the opinion that DMA grade of fuel is usedas a fuel for tugboats, fishing boats, crew boats, drilling rigs, and ferry boats. Ocean faring vessels that take residual fuel oil bunkers also take distillate fuels for use in running their generators for generating electricity on board and sometimes for use in port. The commonly used fuels are DMC, IFO-180 and IFO-380, depending on the specific engines in service. DMB is infrequently specified, and is not available in all ports. Where it is not available, DMA is supplied, sometimes in a barge that has transported DMC or IFO (hence, a "dirty" cargo holds that would contaminate DMA). (RTI International, 2008)

MARINE GAS OIL (MGO)

The blending of Light Cycle Oil with a distillate oil to produce one of the highest marine fuel grades Marine gas is the resultant, which is costly due to its lighter fraction and better quality fuel than diesel fuel. MGO is a fuel best suited for faster-moving engines (Spreutels and Vermeire, 2001). (RTI International, 2008)

MARINE DISTILLATE OIL (MDO)

A combination of kerosene, light, and heavy gas oil fractions, MDO's or DMA and DMB as they are technically referred to are typically used in small- to medium-sized marine vessels. DMC is heavier fuel oil and may sometimes be referred to as an intermediate fuel oil because it can be blended with residual fuel. MDO is manufactured by blending DMC with 10% to 15% residual fuel (Spreutels and Vermeire, 2001). MDO is more expensive than the more common intermediate fuel types. (RTI International, 2008)

INTERMEDIATE FUEL OIL (IFO)

Residual marine fuel grade G (RMG-35) is one of the most common residual fuels used in transoceanic ships. More commonly known as IFO380, this residual marine fuel is manufactured at the refinery and contains visbroken residue, HCO, and LCO (Spreutels and Vermeire, 2001). IFO380 typically has a high sulfur content that approaches 5%. IFO180 is another common IFO. IFO180 has a lower viscosity and metals content but maintains the same sulfur content as IFO380.(RTI International, 2008)

1.2. BUNKER FUEL QUALITY

Bunker quality is reflected by factors such as the flash point, pour point, energy content, sulphur, vanadium, aluminum, silicon, used lubricant oil, water contents, viscosity and presence of sediments in bunkers (International Organization for Standardization, 2005). Failing to consider such factors leads to a series of operational problems. This below table depicts all the parameters of Marine fuel Oil as per fuel quality standards for distillate marine fuels used worldwide in Bunkering Industry.

Although the market for the MGO and MDO is very less but still ships needs these fuels. In India the bunker fuel which is produced by the old Indian refineries is straight run fuel which having less amount of sulphur. Such kind of fuel is considered good for the life of ship engines. 85 % of the total bunker sales and market is IFO 380 CST. India refineries did not use to produce IFO 180 CST, but now have begun producing 180 CST which consists of 10 % of total bunker sales and market. Following are the standards set by the ISO for 180 CST and 380 CST.

All the Bunker fuel's sold worldwide are sold with compliances to ISO 8217:2010 specs. ***(Refer to Annexure I for ISO 8217:2010 specs)***. The International Maritime Organization or IMO as it is referred to have set guidelines for Marine Pollution (MARPOL) emissions of CO and SO_Xcaused the burning of bunker fuel and the effects of it on the environment. All fuels sold have to also comply with MARPOL annex VI. ***(Refer to Annexure II for MARPOL)***

1.3. BUNKER FUEL QUALITY ISSUES

The quality of Bunker fuel issues are a major concern for not only Ship Owners, but is also a source of concern for the bunker supplier. Any disparity in the quality of the bunker fuel gives rise to claims that are a burden for the supplier, as they not only have to pay for the damages caused to the ship's engines but also tend to lose their reputation as suppliers. As bunkers are the residue from refining activities, the quality of bunkers from advance configuration refiners is compromised because such refiners are able to extract a greater quantity of clean petroleum products, hence leaving behind residual bunkers with poorer quality. The Blending processprovides for more opportunity in terms of quality discrepancies as compared to importing bunkers in the packaged and finished form.The bunker Fuel quality is also affected by frauds and negligence on part of the parties involved.

Bunker quality problems could be alleviated by implementing strict monitoring systems, international standards and practices as well as improving technical support such as testing labs, equipment and well-trained bunker specialists.

Market Transparency of this industry also plays an important role in the degree of corruption and collusion in the bunkering market has been has been plagued by malpractice. This affects ship operators' confidence in the port of bunkering. These dishonest practices lead to unethical acts of bribery among various parties including surveyors, chief engineers and barge operators. This results in discrepancies in bunker quantity and quality, hampering the bunker operations and adds costs to ship operators and managers. Market transparency is affected by the characteristics of the bunker market. A cut throat competition among suppliers may encourage unscrupulous behaviors in the pursuit of higher profits as compared to cases of monopolistic market.

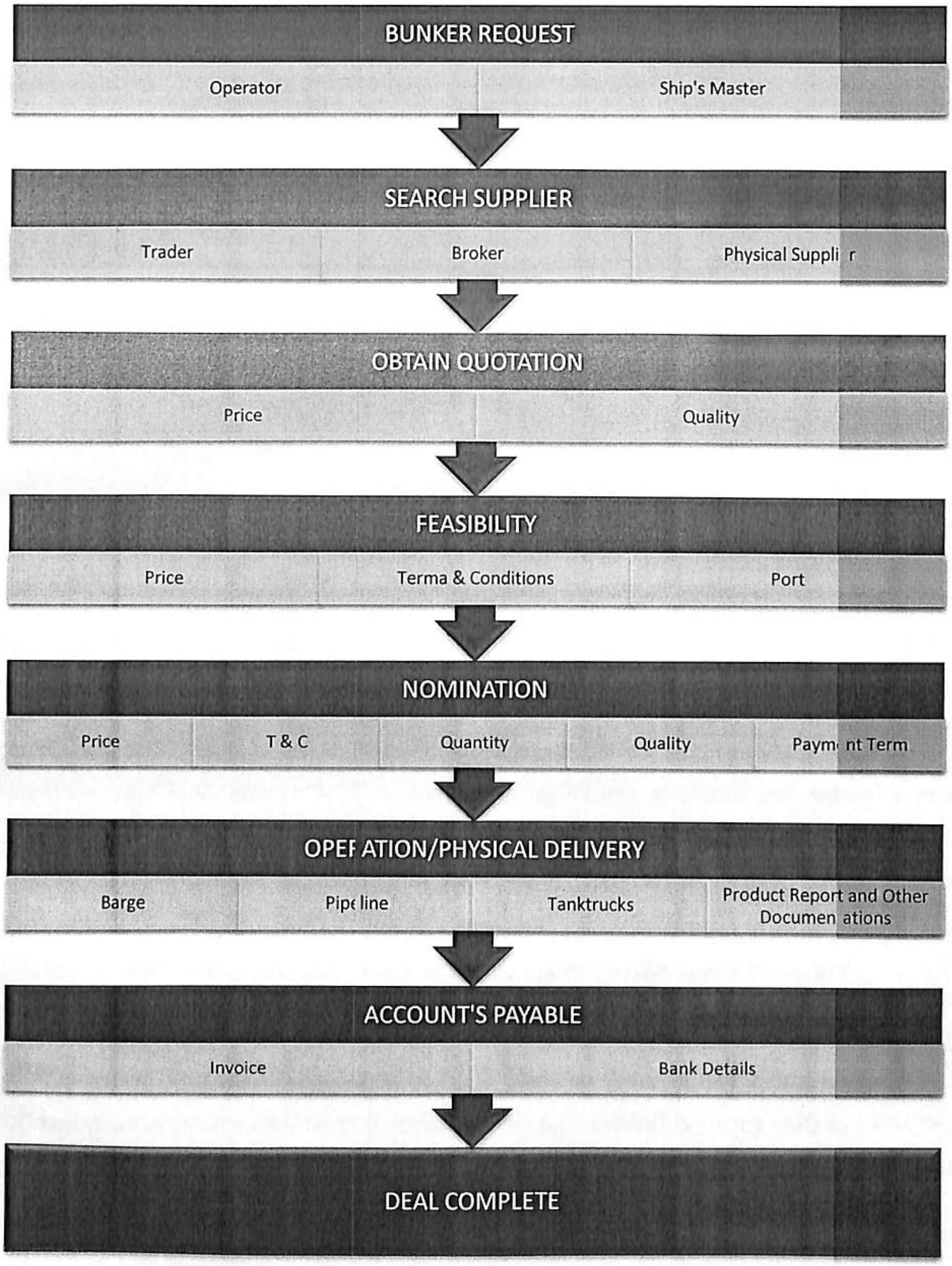

FIGURE 1.BUNKER PROCESS FLOW

1.4. CONTEXT OF STUDY

The restrictions imposed by International Marine Organization (IMO) on emissions will come into force in 2015 in the prescribed ECA's (Emission Control Areas) and that for the rest of world by 2020. In order to comply with the said regulations some amendments are to be made in the conventional business system. There are a number of solutions proposed, however, LNG has the possibility to overcome the compliance of emission restrictions in order to keep intact a substantial share of the world marine fuel market: as the technology is proven (around 45 ships are successfully running on LNG as a fuel), thereby complying not only the emission restriction but also the economics. However, there is a need to determine the uncertainties associated with the usage and thereby determining the solutions for those uncertainties is required, in order to prove the potential of LNG as a marine fuel.

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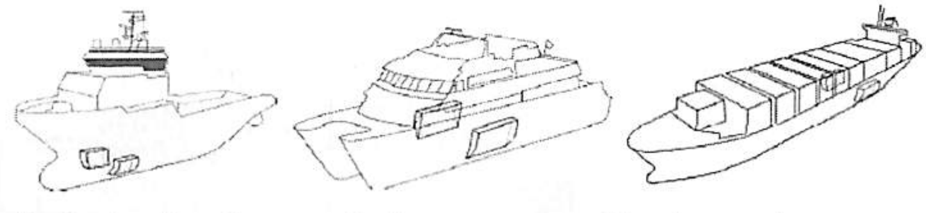
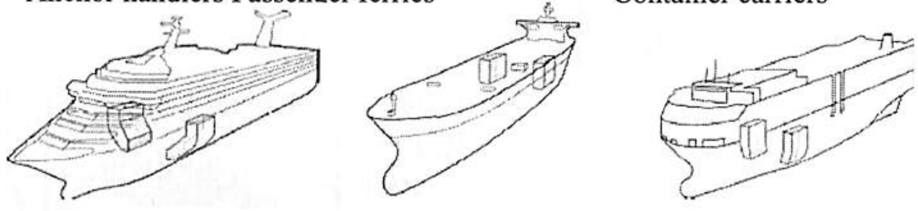


Anchor handlers Passenger ferries Container carriers



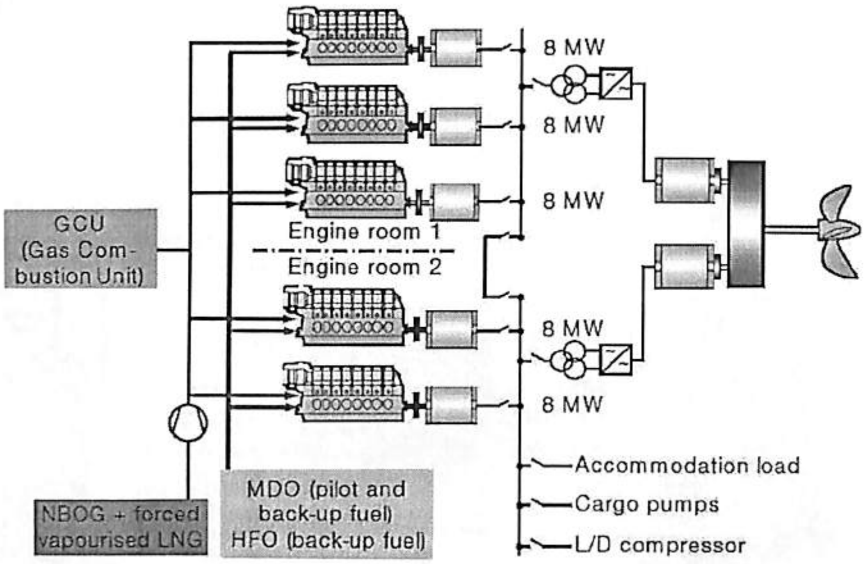
Cruise ships Oil Tankers Ro-Ro vessels

2. LITERATURE REVIEW

2.1. POSSIBILITIES FOR USING LNG AS A BUNKER

Till 2000 it was the utilization process only of the LNG vaporization (boil-off) from cargo tanks. At present it may be a marine fuel and replace the heavy fuel oils. There is no problem to prepare the gas turbines and boilers (for steam turbines) for burning natural gas. It affects continuous combustion - this is an advantage for these engines.

By reason of efficiency it may mainly try to use LNG as a marine fuel in diesel engines -two and four stroke. The propositions are dual fuel (DF) or three fuel (TF) engines. The engines may work on heavy fuel oils, if necessary on marine diesel oils (during manoeuvres or low loads) and of course on natural gas. There are self-ignition diesel engines. In the case the two stroke diesel engine works on natural gas it is needed to inject a pilot dose of liquid fuel (more often 1% of marine diesel oil) for the facilitation of self-ignition the fuel-air mixture. The natural gas is injected to the cylinder under pressure about 25-35 MPa (it is a problem to use high pressure compressors). In the case the four stroke diesel engines the natural gas is passing to the air inlet channel under pressure about 0.5-0.6 MPa (more convenient pressure). The pilot dose of MDO or HFO is needed too. The dual fuel engines are not sensitive to gas quality and the load.



The thermodynamic cycle of engine work is Sabathe-Seiliger's cycle independently on used fuel. Even in the case of delayed injection (for the restriction of NO_x emissions) the engines mayproduce the NO_x emissions below the level of tier 2, but it is impossible to fulfil the level of tier 3 without the purification exhaust gases process It is needed SCR (selective catalytic reactor) for NO_x reduction to meet IMO tier 3. It will be possible if the engines work on Otto's thermodynamic cycle. It means that the engines ought to be the spark ignition engines, not used in marine industry before year 2000. It is obligatory to build another type of engines.

Here we meet a problem with the fulfilment of low NOx emissions with correct and efficient work of spark engines .

The problem is increasing when the load of the spark engine is changing. The operating window every narrow and the knocking area is jointing with misfiring area during great engine loads about 2.2-2.4 MPa of mean effective pressure (BMEP). It happens the misfiring cycles or knocking cycles (by reason of the fuel self-ignition in the other moments of thermodynamic cycle). It disturbs the correct work of engine, resulting in the increasing loads of all engine mechanisms and being the reason of quick engine malfunction or damage. The problem has been tried to solve by many marine engine manufacturers. At first it was tried to intensify the power of the spark by conventional spark plug, the next was tried the laser ignition.

The problem hasn't been solved properly till today. On the other hand it was become realized the probes for improving the fuel injection process. For example the Wartsila built in 2009 an experimental spray combustion chamber for testing the injection process.

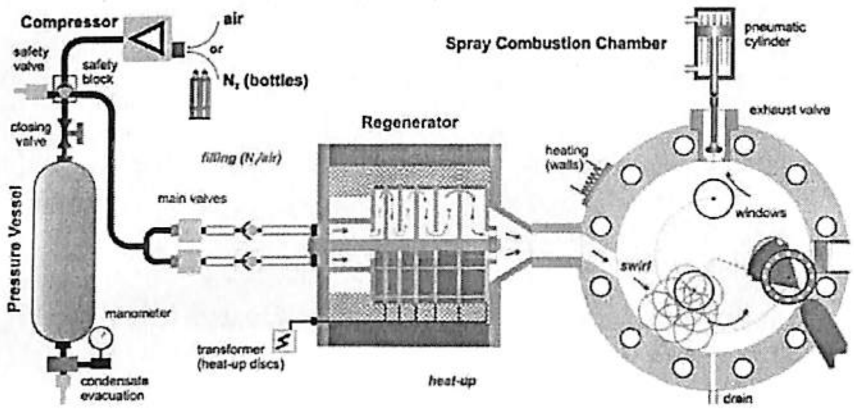
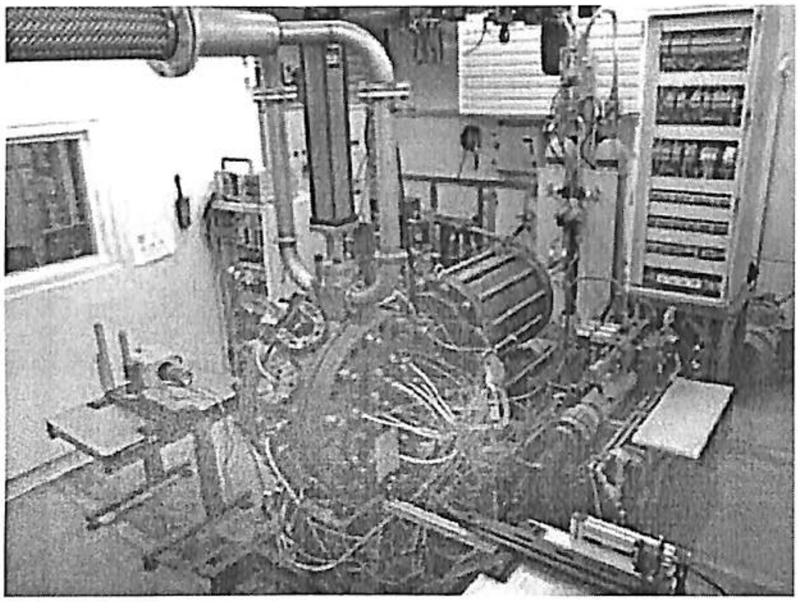


FIGURE 2. SETUP EXPERIMENTAL SSC TEST FACILITY

The changing requirements resulting from recent developments in the marine industry (environmental regulations as well as fuel quality trends) make the more thorough optimization of combustion on large marine engines indispensible. For this purpose, appropriate tools are needed, both for supporting the development by means of sufficiently accurate simulations and for experimentally studying the effect of key parameters. The spray combustion chamber takes a key role in this context - by providing reference data for the validation of simulation tools at relevant conditions and by allowing a direct verification of the effect of some design features.

2.2. HOW ECONOMICALLY COMPETITIVE IS LNG OVER HFO

The price of LNG depends for many years on HFO price, but often is cheaper. Taken into account the LHV of fuels and theirs prices the cost of LNG is about 60% of HFO. On gas carriers the cost of boil-off gas is decreasing due to savings of reliquefaction process. Natural gas prices (including LNG) has been reduced the last two years due to the introduction of shale gas in the US market. This is a reason that LNG has improved its competitiveness to HFO, especially on ECA's areas where it is needed exhaust gas cleaning.



The basic question is what will be the price of HFO in the future. We must remember the middle of 2008 when the price of HFO IFO380 was over 1000 $ per metric ton. In the middle of 2011 is about 650 $ like in 2007 and first half-year 2008. It may be seen the increasing price of MDO and MGO fuels. Later the next step was the rise of HFO price. In my opinion the price of LNG will be more stable than HFO, because depends on the industry price. It must be remembered about LNG storage problems and cost of that and some needed safety equipment. On a long stay (due to the shipyard) the fuel tanks must be emptied because the fuel vaporization.

On the other hand LNG is very pure fuel. The operational costs of engines are decreasing. The engines are in the better technical states. The number of emergency situations and failures is decreasing. This is money too! In my opinion LNG will be competitive with HFO taking into account only price during the next 20 years, later it will be still better. Taking into account all other parameters the LNG competitiveness is better.

Several companies in the shipping industry, meanwhile, have revealed plans to develop gas-fuelled merchant ships. The reason is what to do now in the perspective of 2016 year and the IMO requirements. There is no problem with fulfilment the tier 3 by LNG as a fuel. LNG is available on the wide world. It is possible to built small barges for small scale distribution by dedicated ships is available, especially in ports where are existing LNG storage infrastructure. Storage technology for ships is available and needs further development. Gas engine technology for ships' main propulsion and gensets is available for all types of piston engines. For existing ships this is a problem how prepare them for tier 3. The engine replacing is only the one way, but expensive and not economical. The greater problem concerns ships on ECAs and SECAs areas.

LNG has the potential to be economical competitive to HFO. The future will show the real possibilities to replace HFO as a marine fuel on ships by gaseous fuels, especially LNG.

3. OBJECTIVES

Objectives of the Research:

1. To determine alternative approaches to meeting IMO Annex VI requirements and their comparative economics.
2. To estimate the potential demand, availability & cost for LNG as a marine fuel.
3. To study the technology required to implement LNG as a marine fuel.
4. To analyze variables that prevent the use of LNG as a marine fuel.

4. RESEARCH METHODOLGY

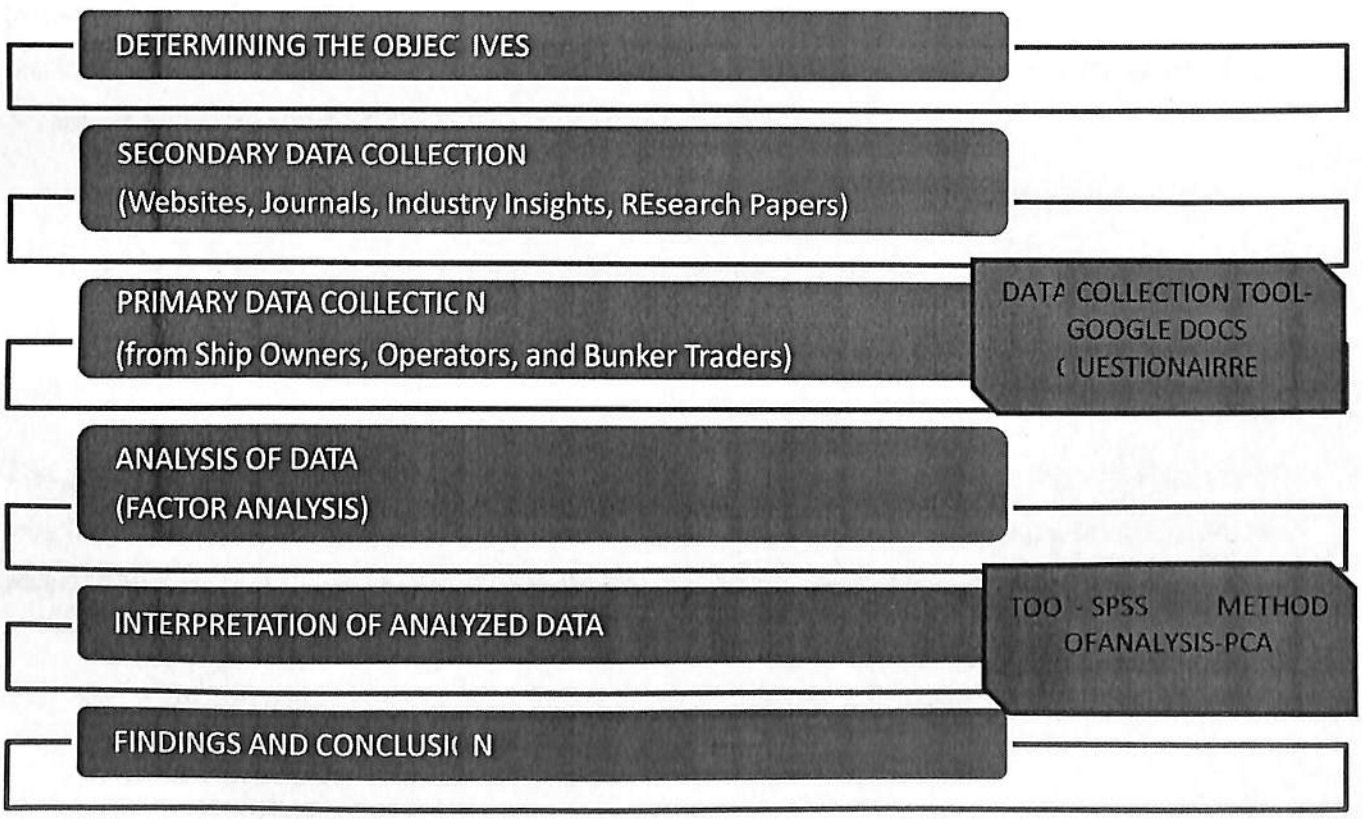
The research methodology adopted for the research is descriptive and analytical in nature.

Descriptive Research: Descriptive Research Method describes the research of statistics. It is logical and primarily focuses on numeric data.

Analytical Research: The research also uses analytical research by the use of various regression tools to understand the impact of various factors affecting the crude oil prices.

4.1. DATA COLLECTION

For the completion of the research, the data would be collected majorly through the secondary sources like journals, research papers, and internet. Further a questionnaire would be used for collecting the primary data, by making use of the information got from the secondary research. Further the responses will be put under factor analysis in order to determine the broad variables that facilitate the first Objective.



5. RESEARCH AND FINDINGS

5.1. MARINE FUELS AND SULPHUR RESTRICTION

The most widely used marine fuels as of now are the Heavy Fuel Oils (IFO) and Distillate fuel (MDO) which are marked by high sulphur content varying from .5 to 2% depending on the port location.

5.1.1. MARINE BUNKER FUELS

At present there are three basic types of bunker (marine fuel) available in the market:

- Residual fuel oil –This is the fuel obtained at the heaviest fraction in the crude oil refining process. It is traditionally used on a large scale as a marine fuel and is high on sulphur content, as compared to the other types.
- Distillate fuel oils - – This is the fuel obtained at the lighter fraction in the crude oil refining process. It is not used on a large scale as a marine fuel, owing to its high price; hence is used in electricity generation purpose only in the large vessels, and is lowest on sulphur content, as compared to the other types.
- Intermediate fuel oils (IFO) - these are the mixture of residual oils and distillate fuel oils.

MGO is generally used as a term used for all low-sulphur fuels, owing to the negligible price difference that exists between different types of low-sulphur fuels like MGO, MDO etc. and the high sulphur fuels like HFO and IFO.

The global demand for marine fuels was estimated to be around 245 Mnt in 2013 (IEA, 2013) of which HFO accounts for more than 75%. However, the demand for intermediate and distillate fuel oils was more concentrated around Emmission Control Areas and was otherwise negligible.

5.1.2. STRICTER SULPHUR CONTENT LIMITS IN MARINE FUELS

The environmental concerns has led the International Maritime Organization(IMO) to adopt measures preventing air pollution caused by ships through the MARPOL Annex VI.

MARPOL's Annex VI includes a cap of 3.5% on global sulphur content of marine fuels (bunker) in order to reduce from 2012, the sulphur dioxide emission which in itself is a harmful pollutant.

It also outlines the emmissions to be reduced to 0.5% by 2020, However it is envisaged that depending on the outcomes of the further investigation done on the availability of low sulphur fuel by IMO could be deferred to 1st January, 2025. For this the reports of investigation of availability of Low sulphur fuel will be taken into account in 2018.

Provided that the onshore industries have started cutting emmissions, emission from the ships are more significantly becoming a part of the total emissions. MARPOL Annex VI report estimates that shipping emissions account for around 2-4% of global CO_2 emissions, 4-8% of SO_x global emissions and around 10-20% of NO_x global emissions.

Regulation-13 of MARPOL Annex VI categorize the following tiers according to the limitation of NO_x and Sox emissions :

* Tier 1: for engines of the ships constructed between 1st January 1990 and 1st January 2000 with displacement per cylinder over 90dm3 and for engines of ships constructed between 1st January 2000 and 1st January 2010 with the target for retrofitting of existing engines of power over 5MW.

* Tier 2: is considerably about 20% below of the level of Tier 1, and is for the ship engines constructed between 1st January 2011 and 1st January 2016.

* Tier 3:: is considerably about 80% below of the level of Tier 1 and is for the engines of ship with their propulsion power over 750KW for vessels constructed from 1st January 2016.

Implementation schedule for MARPOL annex VI is shown in figure 3:

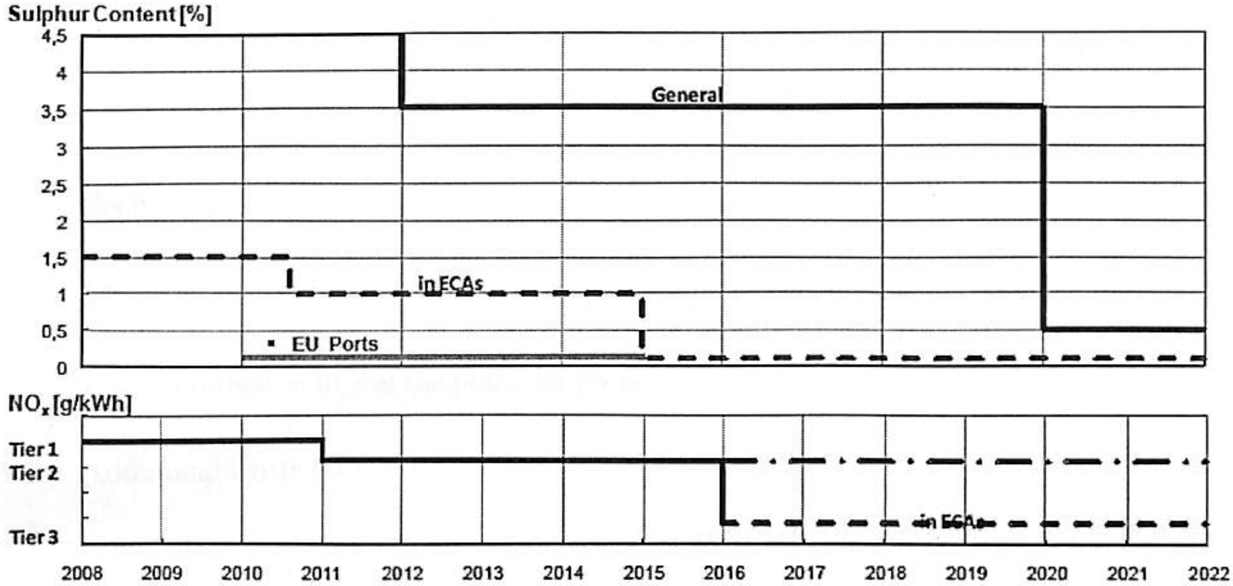


FIGURE 3. IMPLEMENTATION OF MARPOL ANNEX VI SCHEDULE

The obligations are meant to be in force after 2015 for Tier 2 in all the areas, tier 3 after 2015 only in ECA's, and another tier 4 for the onshore installations.

LNG is prospected to reduce nearly 100% SOx and particulate emissions, 80-85% of NOx emissions and around 20% of CO2 emissions as compared to high sulphur residual marine fuels that are presently used.

LNG can serve as an alternate complying to the tier 3 NOx and SOx emission standards set by MARPOL and that to without any other installation required additionally to treat the exhaust gases.

According to Det Norske Vetitas (DNV), there exist three possible solutions for ECA's said emission standard compliance after 2015 when the limits of SOx emission falls to 0.1%, they are:

* Low sulphur Fuels

* Scrubbers for exhaust gas purification

* LNG as a propulsion Fuel

The shift however, to the potential replacement bunker LNG is being widely discussed within the shipping industry. Although there are several merits, it poses lot of challenges as well that are related to:

* Technological Compliance to the existing fleet.
* LNG market and its availability in the potentially traversed routes.
* Lack of infrastructure at the potential ports.
* Additional Costs for retrofits and overhauls.

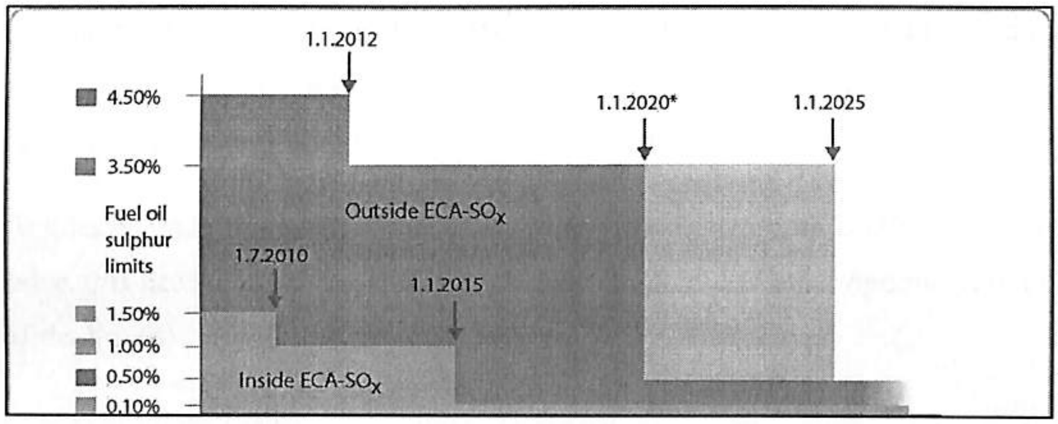


FIGURE 4. SULPHUR LIMITS ENFORCEMENT WITH RESPECTIVE TIMELINES

Since 2005 the following are the number of ECA's (Emission Control Areas) that have been implemented, with more stringent limits to be followed. The current emission limits of 1% reduces to 0.1% by 2015.

Current and Confirmed ECA's	Entry into force*
Baltic Sea (SOx)	19th May, 2005
North Sea (SOx)	22nd November, 2006
North America, US including Canadian Coast upto 200 Nautical Miles	1st August, 2011

US Caribbean Sea covering Puerto Rica and US Virgin Islands ECA	1st January, 2013
***Stricter limits for fuel oil Sulphur content to be applied one year after the date of entry into force**	

TABLE 2. CURRENT AND CONFIRMED ECA'S

5.1.3. COMPLIANCE WITH THE SULPHUR LIMITS

In order to comply with the sulphur emission limits, the use of low sulphur distillates seems to be relatively easy. However, the current production of distillate fuel would not be sufficient if the world wide fleet switches on it as a fuel option by 2020. According to a recent report (Outlook for Marine Bunkers and Fuel Oil 2030) Meech,2011, in order to meet the anticipated demand for distillates as a bunker fuel, refinery industry would need to produce extra 4-4.5 million barrels per day of MDO and MGO, on the imposition of the IMO global sulphur limits by 2020.

Besides availability, another concerning factor associated with Distillates as an option is its high price, this has led to the consideration being transferred to other options available for compliance of the limits.

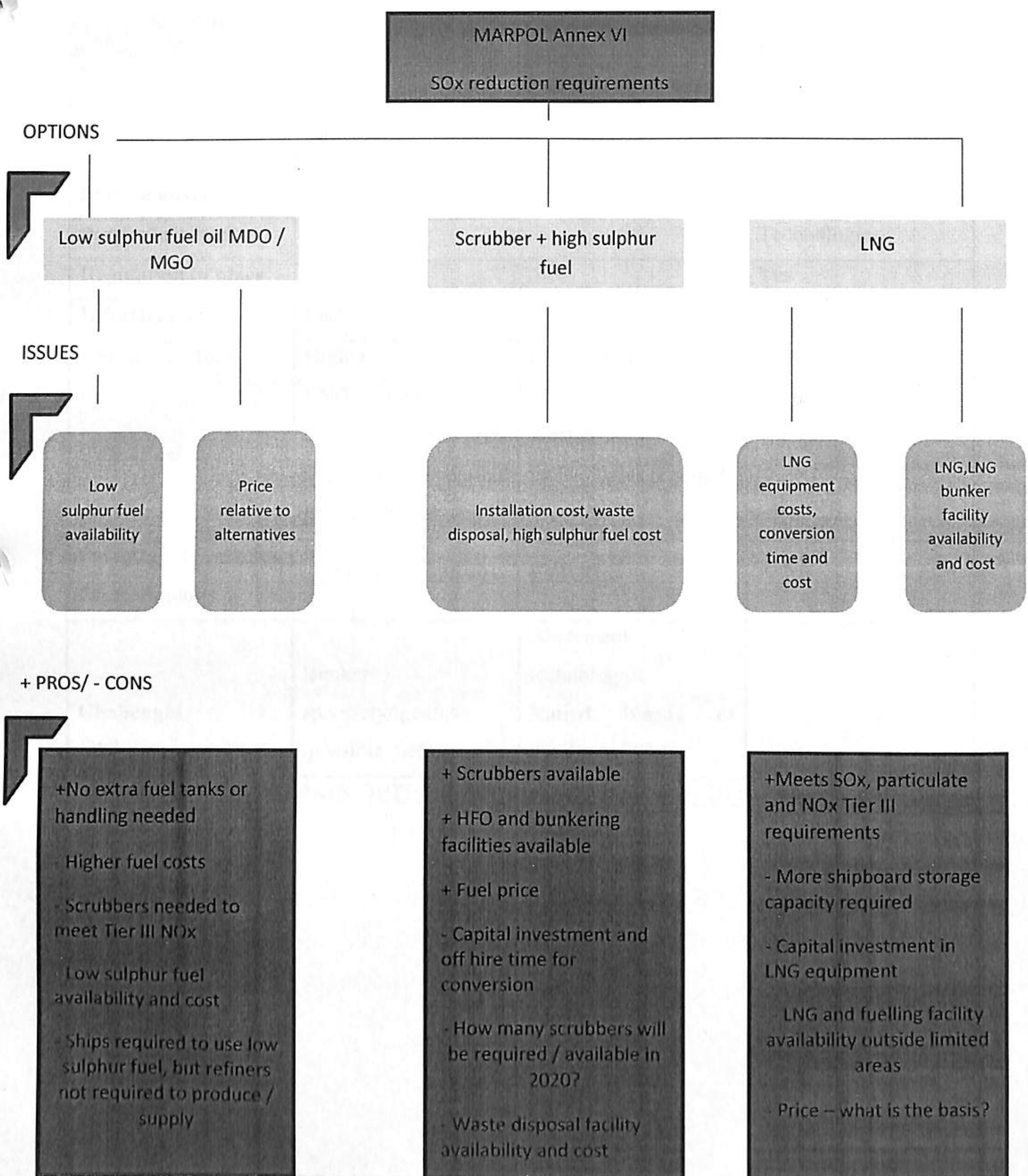


FIGURE 5. PROS AND CONS OF ALTERNATIVES

Compliance option	LNG	HFO	MDO/MGO
CO_2 removal	10-20%	Abatement technologies	No
SOx removal	100%		MDO: <2%; MGO: 0.01 -1%
NOx removal	Up to 80-90%		Abatement Technologies
Particulate matter	98 -100%		
Regulation in place	Developing	Yes	Yes
Infrastructure	Early stages	Yes	Yes
Cultural factors	Higher	Established	Established
Cost of use	LNG storage tank size; LNG fuel price uncertain; possible loss of cargo space	Abatement technologies required	
Potential to stretch the technology	Further CO_2 reduction	End of cycle	
Challenges /differences	Bunker space/cryogenics /possible methane slip	Abatement technologies Varied blends of distillates 2020	

TABLE 3. THREE MAIN OPTIONS FOR COMPLIANCE AND CORRESPONDING EMISSION REDUCTION

5.2. LNG SUPPLY PRESENT AND FUTURE

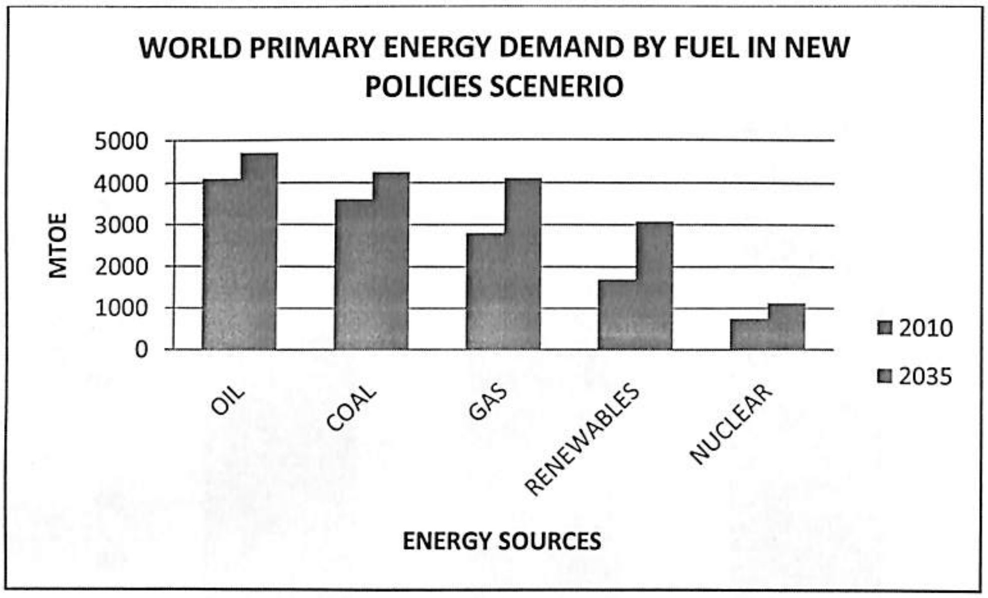


FIGURE 6.GAS COMPETING WITH OTHER PRIMARY ENERGY SOURCES (Source WEO REPORT 2012)

According to the WEO Gas Scenerio-2012, World Primary energy demand will increase by 37% between 2010 and 2035. Global natural gas share of energy demand mix as primary energy is expected to rise to 22% between 2010 and 2035, competing with coal at 23%.

5.2.1. WORLD NATURAL GAS RESERVES

Natural Gas reserves are abundant in the world, however the reserves are so technologically intensive that there exists problems pertaining to its harvest and transportation to the required consumption regions. The global reserves of Natural Gas grew by approximately 21% from 2002 amounting to approximately 187.3 Trillion Cu. M. at the end of 2013.

During 2010, the natural gas trade across the world grew by approximately 10.5 %, driven by strong growth in LNG shipments. Besides pipeline and other modes, around 30.5% of gas trade was dominated by LNG cargoes.

The figures of BP statistical Review Report 2013 shows that if the Natural Gas is consumed at the prevailing rate, than the unconventional gas reserves could last for over 250 years, to be precise.

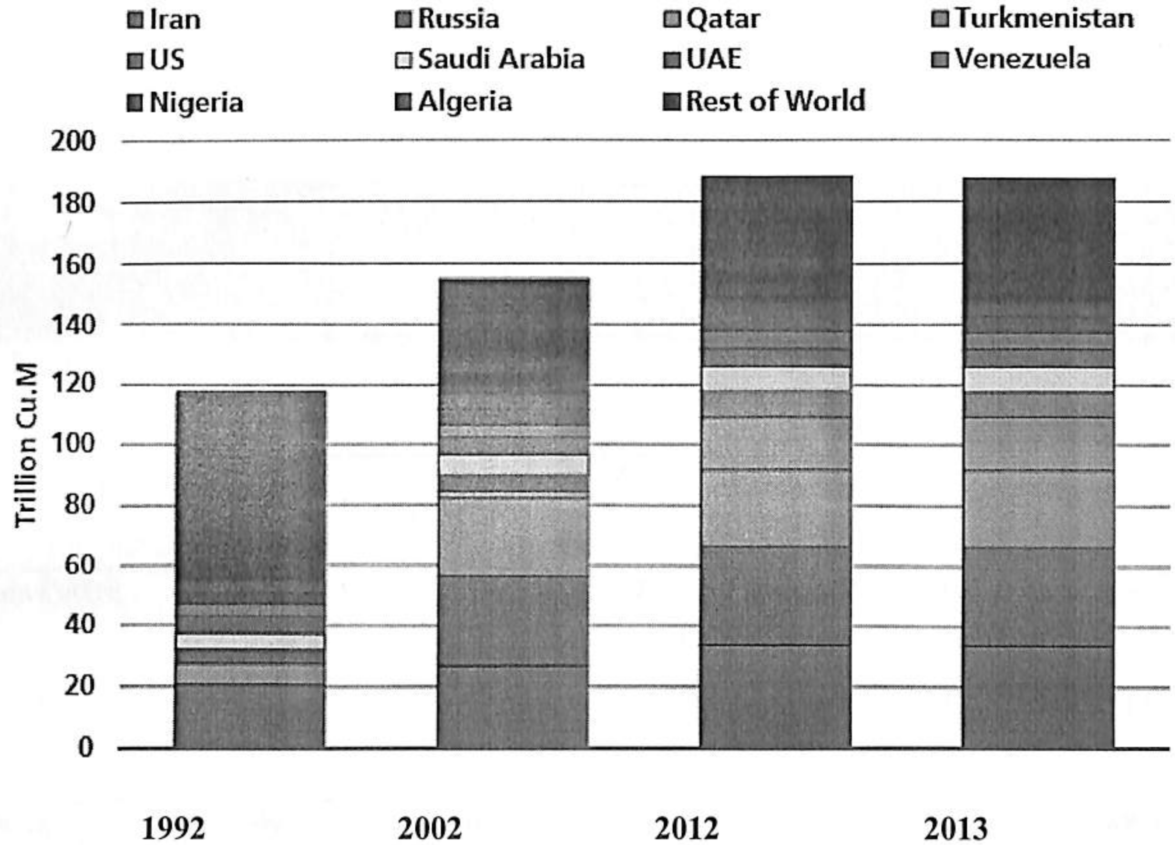


FIGURE 7. GROWTH IN WORLD NATURAL GAS RESERVES FOR TOP 10 COUNTRIES (SOURCE BP STATS 2013)

5.3. AVAILABILITY OF NATURAL GAS

5.3.1. CONVENTIONAL AND UNCONVENTIONAL NATURAL GAS RESERVES

The table below illustrates region wise, technically recoverable natural gas resources, they are categorized by the types viz. Conventional and Non Conventional for the year 2013 in Trillion Cubic Meters (TCM). Asia Pacific Controls around 28.7% (94 TCM) of unconventional gas, followed by OECD America i.e. Canada, Chile, Mexico, and United States, with up to 67 TCM representing 20.4 % of the unconventional gas resources.

The remaining resources comprise of proven reserve, reserves growth and undiscovered resources. The resource estimates for CBM in Eastern Europe/ Eurasia replaces a figure given in the WEO-2012, which includes a "gas-in-place" estimate for Russia, instead for technically recoverable resources. Unconventional gas resources that are richly endowed with conventional gas, such as Eurasia and Middle East are often poorly known or could be much larger than prospected

REGION	CONVENTIONAL	UNCONVENTIONAL				TOTAL
		Tight Gas	Shale Gas	CBM	Sub Total	(TCM)
E. Europe/ Eurasia	144	11	12	20	44	187
Middle East	125	9	4	-	12	137
Asia Pacific	43	21	57	16	94	137
OECD Americas	47	11	47	9	67	114
Africa	49	10	30	0	40	88
Latin America	32	15	35	-	48	80
OECD Europe	24	4	16	2	22	46
WORLD	**462**	**81**	**200**	**47**	**328**	**790**

TABLE 4. REGION WISE CONVENTIONAL AND UNCONVENTIONAL RESERVES

(SOURCE IEA 12, WEO REPORT 13)

5.3.2. UNCONVENTIONAL RESOURCES AND SHALE GAS RESERVES AVAILABILITY

The unconventional gas reserves around the world are up to 328 trillion cubic meters (TCM) out of the total proven reserves of Natural gas i.e. 790 TCM, as per the World Energy Outlook Report of 2013.

Since 2000 there has been a boom in the shale gas production in the United States, which has subsequently boosted the overall gas supplies across the world. This has subsequently driven down the prices, if the anticipated need to import LNG into North America is removed.

This has disconnected the North America Natural Gas prices from the global prices. As there exists a wide price differentials with other gas markets around the world, As at March 2014:

Region/ Market	Spot gas price ($/MBtu)
Henry Hub	4.75
United Kingdom	9.04
Mediterranean LNG	14.9
North East Asian LNG	18.2

TABLE 5. REGION WISE SPOT PRICES (SOURCE: HENRY HUB, EIA, ICE, REUTERS.)

However, the domestic prices are expected to increase as the North American gas exports market increases.

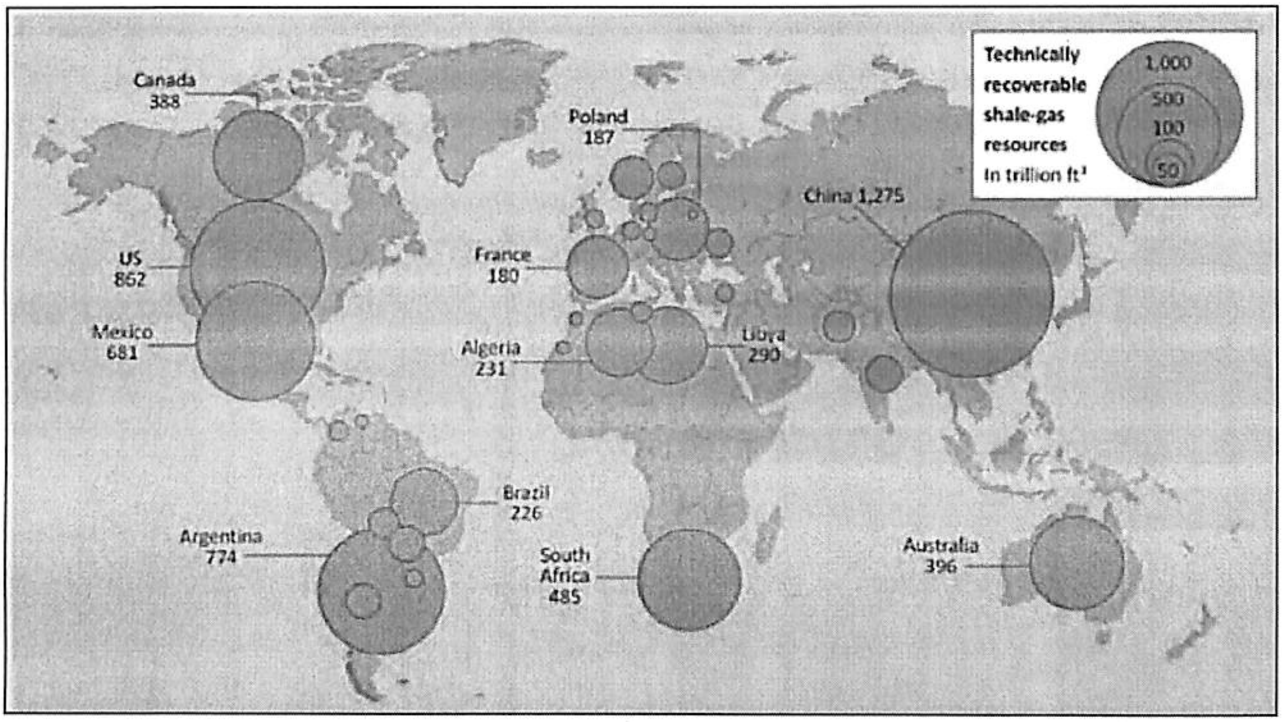


FIGURE 8. GLOBAL SHALE GAS RESERVES IN TCF (SOURCE: ARGUS)

The above figure shows the global shale gas reserves in Trillion Cubic feet. The figure shows that USA and Latin America leads the shale reserves with around 2000 TCF of shale followed by Asia Pacific, Africa, Eurasia, Middle East and OECD Europe.

5.4. LNG AND BUNKERING

In shipping industry up till now the use of LNG has been in the transportation of the product in the LNG carriers to local natural gas demand as well as for the long term supply contracts, from its production source to the demand areas across the world. The scale of LNG transportation is wide owing to the demand that comes from Gas fired power plants, household gas requirement, CNG for vehicles etc.

International LNG shipments of 330 BCM (ve) accounts for nearly 10-12% of overall global natural gas consumption, perhaps natural gas accounts for about 25% of the total global energy use. The trade is done with the help of 376 tankers, powered by heavy 35-40 MW engines, carrying nearly 120,000-200,000 CM of LNG respectively.

Most of these vessels are run on Fuel Oil or Distillates, but there are few vessels that use the LNG which they carry for the propulsion purpose. LNG vessels represent 4 % of total maritime fleet worldwide, and the fleet size is growing in response to the shooting demand of LNG.

The IMO's GHG (Green House Gas Study) 2009, the use of LNG in maritime is taking a steep turn inroad owing to the emission reduction compliance, especially in the regulatory bound areas where the refueling infrastructure shortcomings are minimum.

Bit Viking is the largest LNG powered vessel with a 25000 MT product tanker that is used in Norway. Norway and Sweden have been pioneers in the use of LNG as a marine fuel. With a wide fleet of Passenger/ Crew Supply vessels, Patrol Vessels, Ferries, and Platform supply vessels.

The first LNG fueled inland barge entered into service in November, 2011 where it sailed and operated in Mass and Rhine rivers. The current problem hindering the development is the unavailability of Small scale LNG supplies, infrastructure and lack of vision.

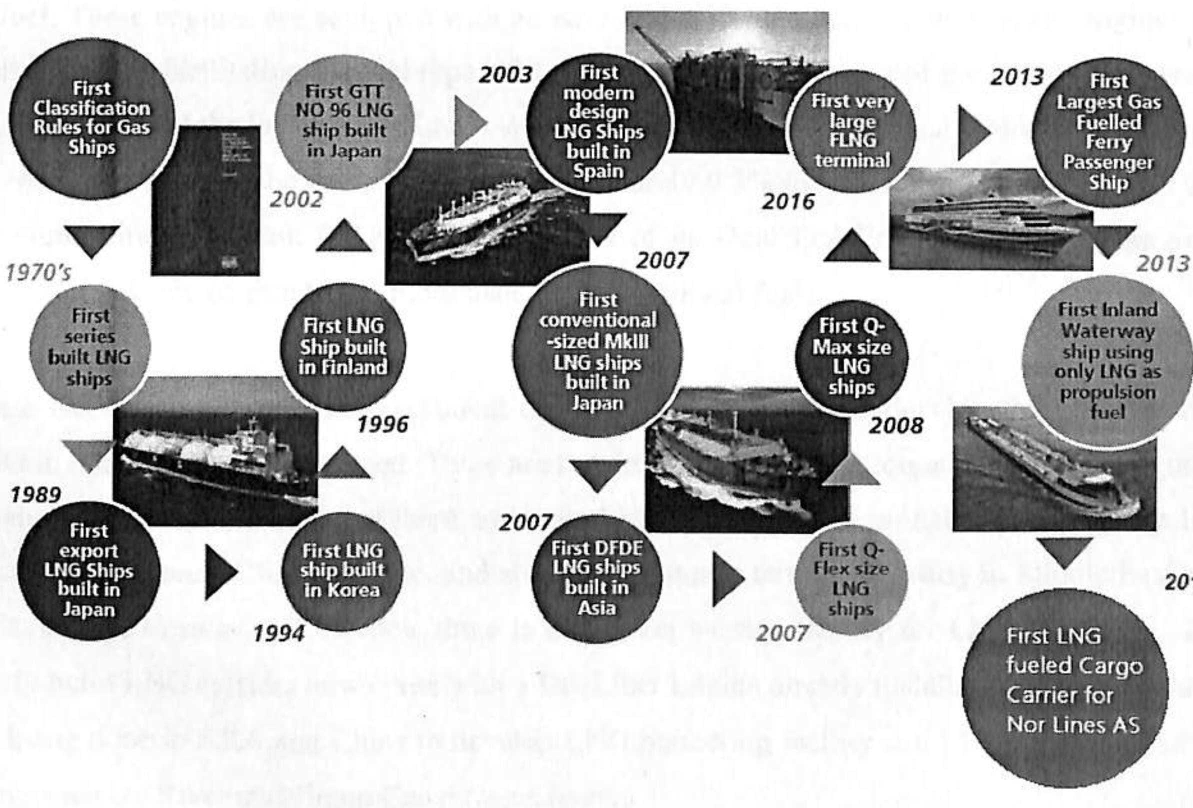


FIGURE 9. UNPARALLELED LIST OF LNG TECHNOLOGY

Around **29 LNG ships** were only operational in 2012 and large number of them were ordered. Among the deliveries there are several ro-rovessels, LNG powers general cargo ships, etc for use in North Sea and Baltic Sea. Also there are commitments in North America of putting **2-5 LNG fueled container vessels in operation by TOTE (Totem Ocean Trailer Express)** for two separate routes i.e. between Washington and Alaska and between Puerto Rico and Florida), with a capacity of 3000 TFE (Twenty foot equivalent) units. These will hence be the first LNG powered containerized vessels and will be in operation from 2015 or 2016.

Rolls-Royce, MAN and Wartsila have developed different LNG ignition technologies for marine applications. In order to reduce the efficiency loss during combustion, Spark-ignited lean engines are invented, so as to mix air prior to combustion as the fuel enters the combustion chamber. The efficiency of these **Spark-ignition, lean burn and Miller-cycle Engines** is 48 % more than comparable diesel engines. This has led RR to sell 500 engines on those technologies so far.

Another technology gaining attraction these days are the **Dual fuel engines**, which makes use of fuel oil as a pilot fuel to facilitate the ignition's first cycle, so as to use LNG as a primary source of fuel. These engines are equipped with an easy fuel shift automatic system. These engines are well suited for facilitating the fuel type shift, while traversing in or out of the ECA's and also to take advantage of the low price of LNG. Wartsila claims of selling 330 dual fueled engines so far for 90 vessels, and so the energy consumption is barely 0.5% more than MDO and 5% less that the conventional fuel oil. MAN however claims of its Dual fuel Engines providing the peak thermal efficiency of about 50% more than the conventional fuels.

There has been an enormous investment done in the recent past to develop the infrastructure LNG in order to meet the demand. There are hundreds of LNG liquation and regasification units all around the world. As of now there are around 89 LNG import Terminals in 29 countries like Japan, South Korea, UK, Spain, etc. and around 104 Import terminals mostly in Middle East and Asia. Except Norway and Sweden, there is no bunker storage facility for LNG as of now. The newly build LNG carriers now come with a Dual fuel Engine already installed. However, studies are being done in ARA and China to develop LNG bunkering facility and LNG powered vessels along Yangtze River and Grand Canal respectively.

There are several ambitious plans proposed and under operation by different countries. Example EU has a plan to deploy 139 LNG fueling facilities for inland and seagoing vessels by 2020-2025. China has a vision of the development of "green port" in 12 years down the line.

The following are the three main suppliers that have been the pioneers in providing LNG as a Bunker along the coast of Norway:

- **Gasnor in mid Norway:** Owned by Royal Dutch Shell, Statoil and Total. Has facilities for LNG Production at Bergen(120,000 tons/ year) and Karmoy(20,000 tons/ year).

- **Skangass in Southern Norway:** Owned by Lyse Energie, a Norwegian Utility. Has a liquefaction unit in Stavanger(300,000 tons/year).

- **Barents Naturgass in Nothern Norway:** A bunker terminal with a throughput of 4.2 million ton/ year and sources LNG from Statoil's Snohvit Plant.

In Sweden, Linde (a subsidiary of AGA Gas) has established Sweden's first Regasification (Import) terminal at Nynashamn in the year 2011. This has extended bunkering facilities into the Baltic Sea as well. AGA Gas can source LNG from its co-owned LNG unit at Tjeldbergodden (150,000 tons/ year) situated in mid Norway or from Skangass.

Further the port authorities of Rotterdam (Netherlands) and Antwerp (Belgium) are deployed on the research of the feasibility of break bulk terminals that can source bunker for Rhine barges or other small vessels, using the nearby LNG import Terminals as a source. For this LNG terminals of UK are also interested for supplying as a source, provided the managing of break bulk facilities are done independently and also the additional traffic doesn't bother the large LNG tankers.

Rotterdam is also keeping abreast with the research, by commissioning Linde (Germany) to carry out a study citing the best suitable location to setup LNG Bunkering terminal. Outside Europe, Bunkering options are also observed in Canada. The Canadian State run Societe des Traversiers du Qubec (Quebic Ferries) placed an order in October 2011, for two small and one large LNG fueled ferries to be operated in St. Lawrence River, and is expected to be delivered by 2014.

Argentina State will be delivered with a passenger catamaran that is LNG fueled by the end of this year and will operate on River Plate crossing Uruguay. Although the present regulatory scenario demands certain areas of North America and North Europe to use LNG fueled vessels, the development will pick the pace if the port, owners, and operators are ready to invest infrastructures and retrofits respectively, with an additional promotion incentive from the respective state government as is the case with Norway.

<table>
<tr><th colspan="2">State of Development (a)</th></tr>
<tr><td>LNG-Powered Vessels</td><td>Around 376 operating LNG carriers.
108 additional orders for 2013-2016.
Out of which, around 30 ferries, Platform Supply Vessel, Merchant Ships, Coast Patrol etc.; operational in Norway, about 25 additional orders from Canada, Finland, Norway, Sweden, USA.
2 chemical tankers in Norway and Sweden respectively
2-5 container ships in USA for 2015-16</td></tr>
<tr><td>LNG import-export terminals (b)</td><td>89 Import Terminals in 29 countries
<table><tr><td>Japan</td><td>27</td></tr><tr><td>Europe</td><td>23</td></tr><tr><td>North America</td><td>15</td></tr><tr><td>China</td><td>6</td></tr></table>
104 liquefaction facilities in 18 countries (48% in Qatar, Malaysia & Indonesia)
A number of import and export facilities are planned and</td></tr>
</table>

	are in construction.
LNG port refueling bunkers (b)	• Small scale bunkering facility available in Norway and Sweden. • Small Scale Facilities Planned for Finland, Netherlands, Canada & USA. • EU plan for 139 bunkering facilities at major maritime and inland ports by 2020-2025.
(a) All numbers are approximate owing to conflicting reports on completed projects/ deliveries and uncertainties about planned and in-construction projects and deliveries. (b) In addition there are hundreds of fueling facilities that provide LNG on road vehicles and nonmarine uses.	

5.5. LNG CARRIER MARKET

Since the nuclear plant disaster in March, 2011 in Japan, the demand for LNG has increased because of various governmental policies change, in order to give preference to natural gas as a preferred energy source.

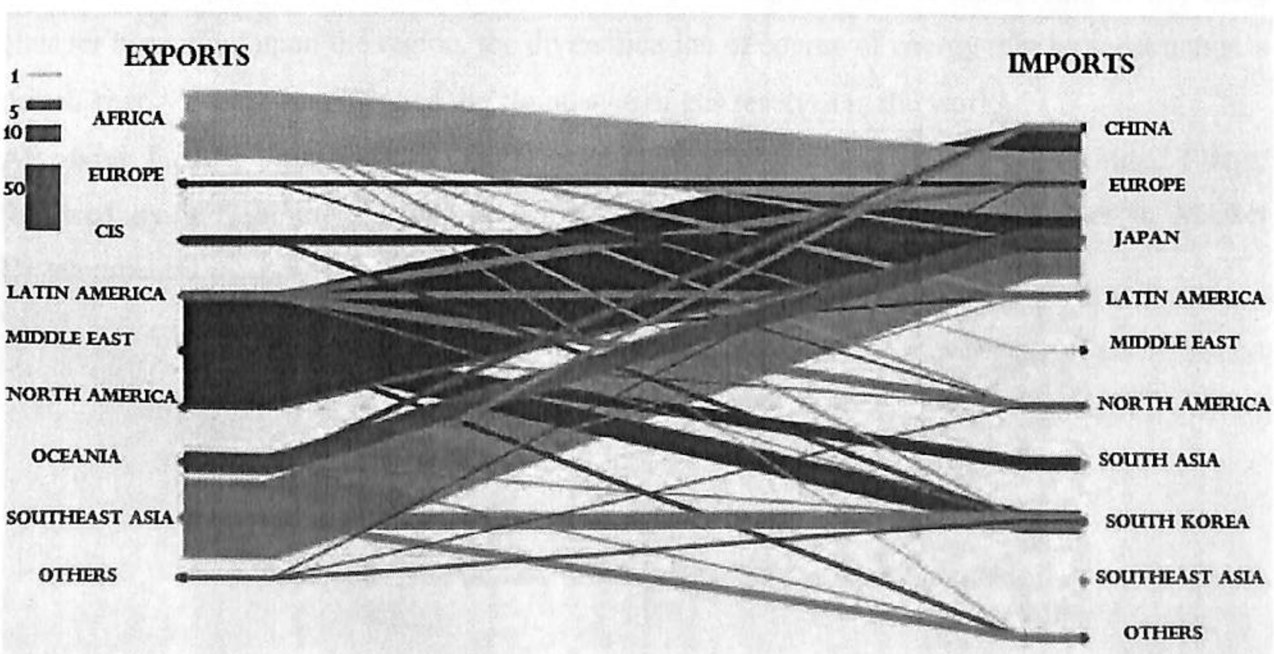


FIGURE 10. LNG SEABORNE TRADE 2010 (MILLION TONES) (SOURCE: UNIVERSITY OF STRATHCLYDE, GLASGOW)

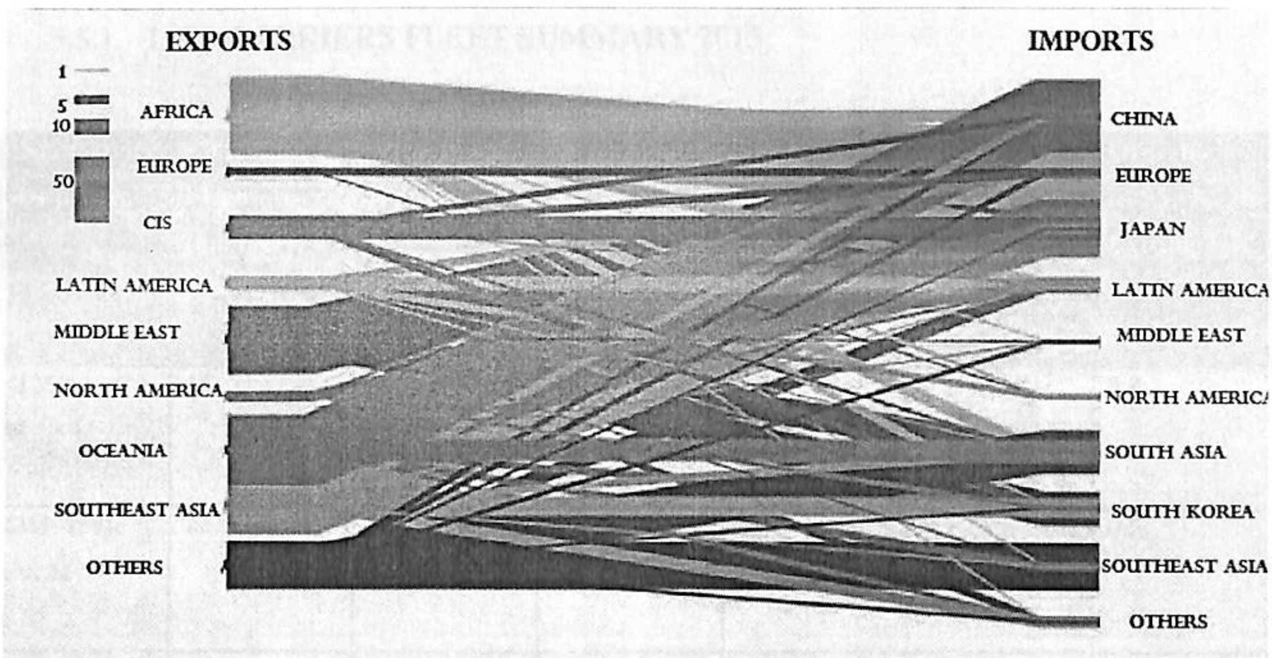


FIGURE 11. LNG SEABORNE TRADE 2030 (MILLION TONES) (SOURCE: UNIVERSITY OF STRATHCLYDE, GLASGOW)

The global natural gas demand is expected to increase at a greater pace in future owing to the environmental characteristics, the prices of LNG as compared to Oil prices, and is relatively cheaper depending upon the region, the diversification of source of energy mix by most nation's driven energy security policy, and the abundance of gas reserves in the world.

All above factors, backed by the development of unconventional shale gas in United States, followed by the commercial export if made possible, will act as a key driver in Market Developments.

5.5.1. LNG CARRIERS FLEET SUMMARY 2013

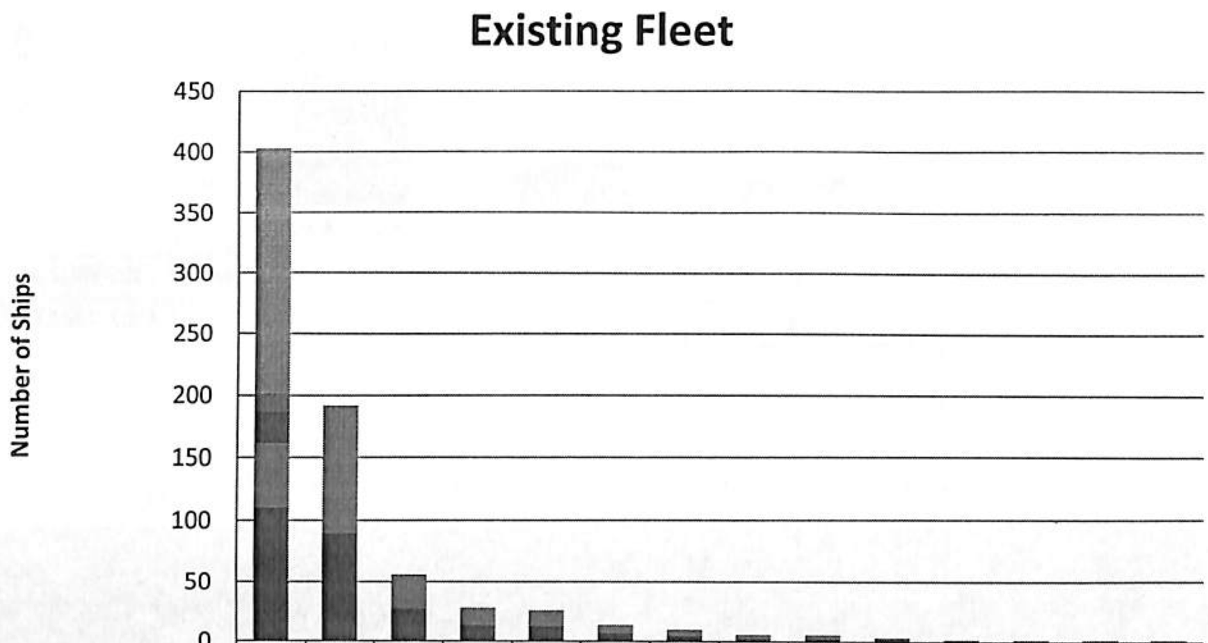
LNG Carrier Size profile	Existing Fleet (number)	Orderbook (number)	Orderbook as a % of Existing Fleet (number)	Existing Fleet (mCu.M)	Orderbook (mCu.M)	Orderbook as a % of Existing Fleet (mCu.M)
<125k Cu. M	45	9	20	2.1	0.2	9.8
125k-150k Cu. M	227	1	0.4	31.4	0.1	0.5
150k-180k Cu. M	59	95	16.1	9.4	15.4	163.9
180k-200k Cu. M		3	0		0.5	0.0
200k-250k Cu. M	31		0	6.5		0.0
250k+ Cu. M	14		0	3.6		0.0
Grand Total	**376**	**108**	**28.7**	**53.1**	**16.3**	**30.8**

Average Sea Borne LNG Demand/ year 2013-25: 386.3 Mnt or 516 BCM or 834.9 mCu. M/yr

Average Seaborne LNG Trade Demand Growth CAGR 2013-25: 5.69 % CAGR

TABLE 6. LNG CARRIERS AND ORDERED (SOURCE IHS FAIRPLAY 2013)

5.5.2. GLOBAL LNG CARRIERS BY COUNTRY OF BUILD

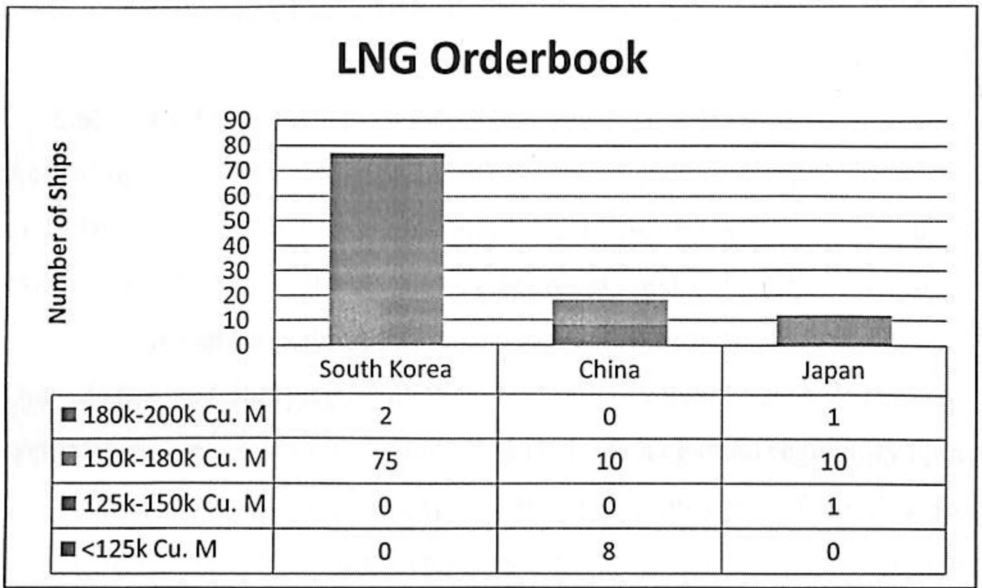


	South Korea	Japan	France	China	USA	Spain	Finland	Norway	Sweden	Germany	Italy	Belgium	Netherlands	Poland
Total	201	96	28	14	13	7	5	3	3	2	1	1	1	1
250k + Cu. M	15	0	1	0	0	0	0	0	0	1	1	0	0	0
200k-250k Cu. M	26	0	0	0	0	0	0	0	0	0	0	1	0	1
150k-180k Cu. M	51	6	0	0	0	0	0	0	0	0	0	0	1	0
125k-150k Cu. M	108	72	15	6	13	7	5	0	3	1	0	0	0	0
<125k Cu. M	2	18	12	8	0	0	0	3	0	0	0	0	0	0

FIGURE 12. LNG EXISTING FLEET COUNTRY WISE (SOURCE IHS FAIRPLAY 2013)

The existing fleet of LNG carriers from all across the world sums up to 376, the cumulative capacity of which amounts to around 53.1 m Cu. M. The total number of ordered/ undelivered LNG ships is 109, the cumulative capacity of which is around 14.4 m Cu. M.

Most of the ordered vessels are being constructed or will be constructed in Korea; i.e. 77 ships (71.3% of the total ordered vessels.) and 18 are being constructed in China Shipyard, and 13 in Japan.



	South Korea	China	Japan
180k-200k Cu. M	2	0	1
150k-180k Cu. M	75	10	10
125k-150k Cu. M	0	0	1
<125k Cu. M	0	8	0

FIGURE 13. LNG ORDERED FLEET (SOURCE IHS FAIRPLAY 2013)

LPG Carrier Size Profile	Existing Fleet (number)	Orderbook (number)	Orderbook as a % of Existing Fleet (number)	Existing Fleet (m Cu. M)	Orderbook (m Cu. M)	Orderbook as a % of existing fleet (m Cu. M)
<6k Cu. M	741	32	4.3	2.0	0.1	6.0
6k-22k Cu. M	238	37	15.5	2.4	0.4	17.4
22k-40k Cu. M	99	17	17.2	3.0	0.6	19.4
40k-60k Cu. M	18		0.0	1.0		0.0
60k+ Cu. M	155	25	16.1	12.3	2.0	16.5

Grand Total	**1251**	**111**	**8.9**	**20.7**	**3.1**	**15.2**

TABLE 7. LPG CARRIERS AND ORDERED (SOURCE IHS FAIRPLAY 2013)

5.6. ECONOMIES OF LNG EXPORTS

According to the forecast done by WEO 2012 report, the exports by North America could reach to 35 BCM and 40 BCM by 2020 and 2035 respectively. The potential of the expected US LNG export capacity lies in the regulatory approvals and only if the price differential with respect to other regions can be maintained.

Out of the several proposed LNG export terminals in US, i.e. 15 LNG export licenses applications, only Cheniere Sabine Pass project has gained regulatory approval (Annex 1).

The WEO report 2012 also expects the gas prices in US to rise from an average of US $2.10/MBTU in 2012 to approximately US $5.50/MBTU by 2020, this however is attributed to the domestic supply and demand dynamics.

A study into the macroeconomics impacts of US LNG exports, commissioned by Department of Energy was completed in December 2012, which concluded that the largest increase expected to range between US $0.22/Mcf to US $1.1/Mcf over a continuous 5 years of LNG exploration growth period.

Furthermore, US domestic gas/ LNG pricing is expected to remain competitively priced as compared with other regional exporting locations, provided the exploration of the unconventional/ shale resources continue as per expected exploitation forecast numbers.

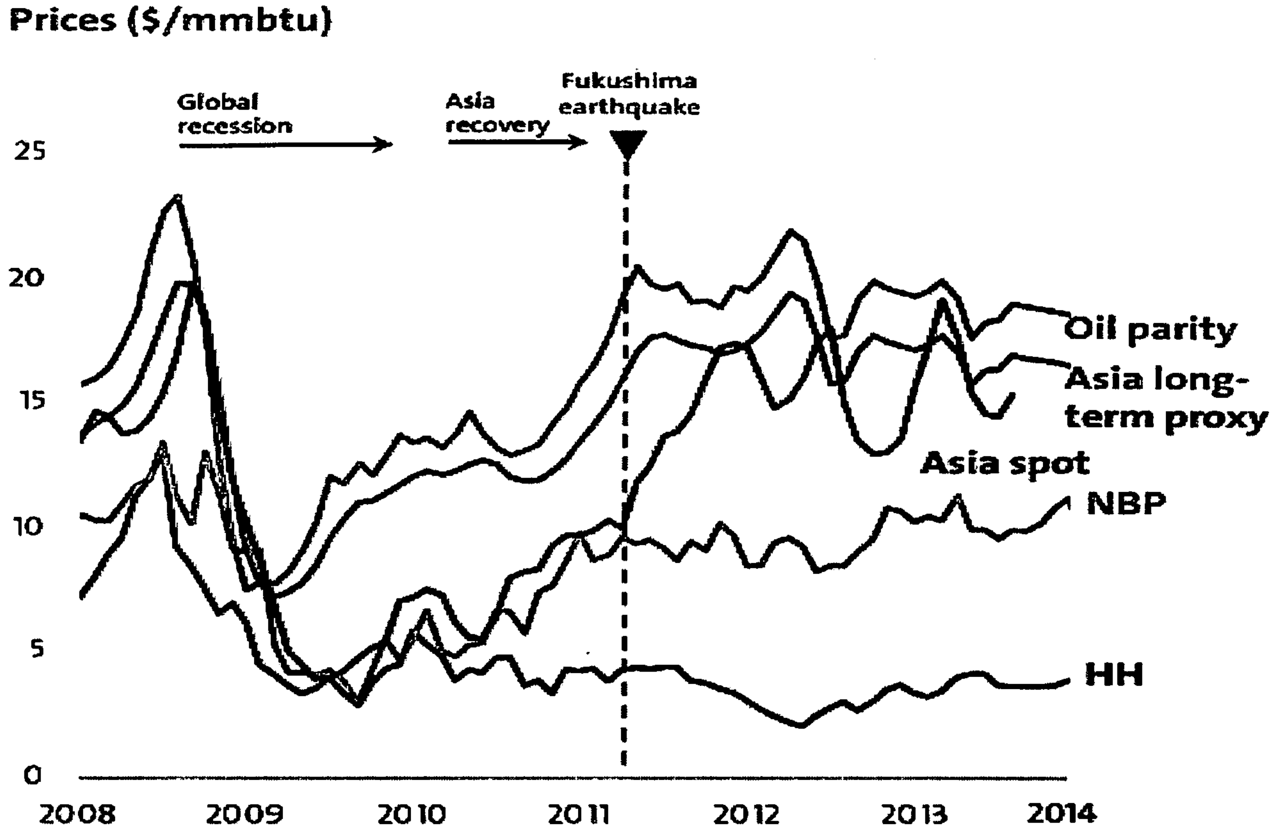


FIGURE 14. ASIAN SPOT PRICES COMPARISON WITH NBP AND HH (SOURCE B-G GROUP REPORT 12)

The graph shows that Asian Spot Prices have varied between European prices NBP and Oil Parity. Asian Long term proxy has been observed at upper resistance level, and the trend is expected to continue.

Asia Long term proxy= 14.85% **JCC** + 0.50 Oil Parity.

Where JCC is the Japanese Average Crude Price.

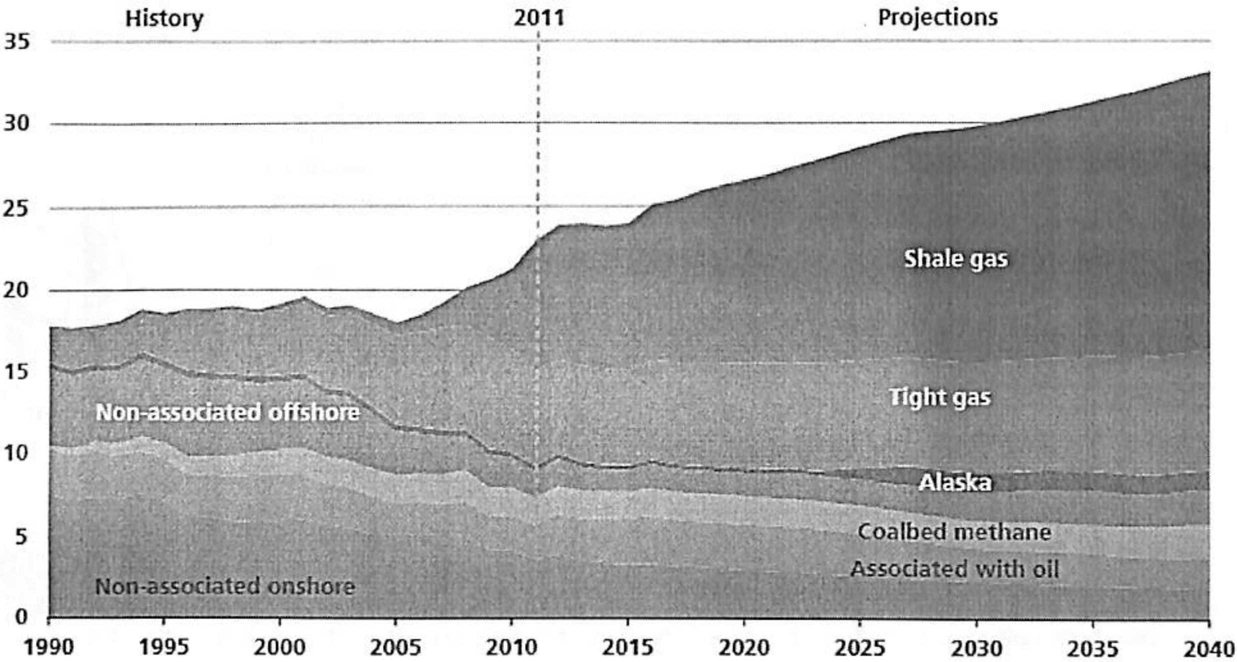


FIGURE 15. US NATURAL GAS PRODUCTION TCF (SOURCE EIA, 2013)

The EIA, Annual Energy Outlook Report 2013 shows the projection for dry Natural gas production for US to rise from around 24 TCF in 2014 to 33 TCF by 2040, the major contribution of which comes from Shale gas, however other Non-associated sources shows a decline over the coming years.

The chart below shows the expected significant decrease in LNG imports to US, commencing from 2012, with up to -52% drop in imports from 9.9BCM in 2011 to 4.7 BCM during 2012, further these reductions are expected up to 2017 with imports to further stabilize at 1.3 BCM per year until 2020 and further decline later on.

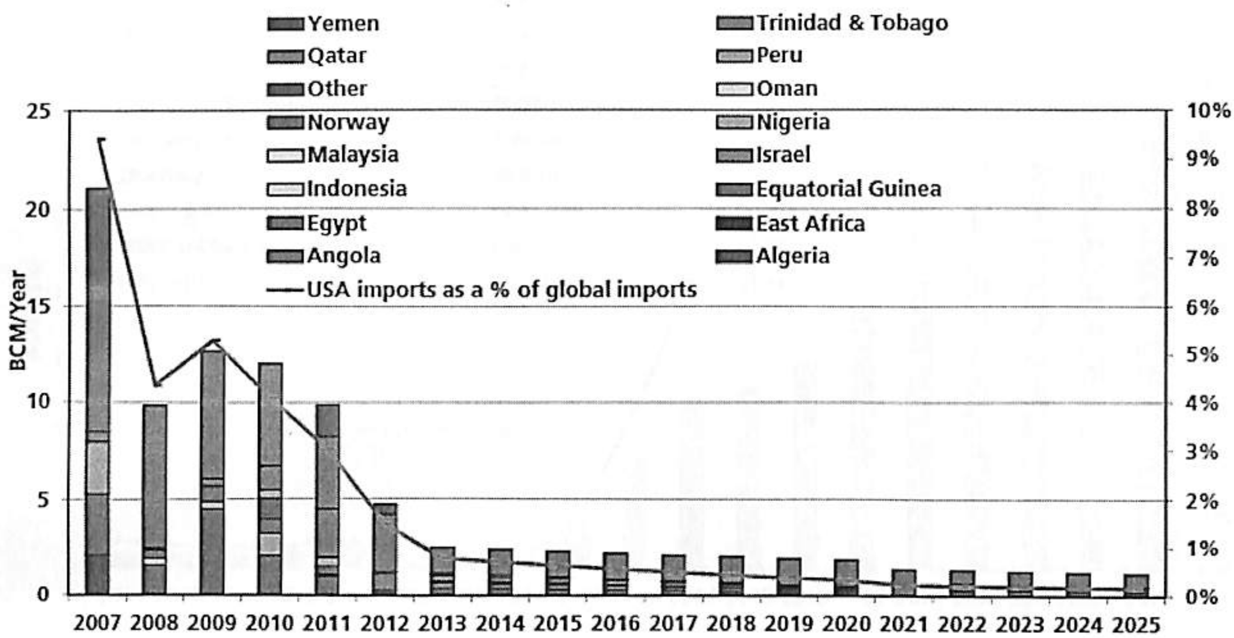


FIGURE 16. US LNG IMPORT FORECAST BY COUNTRY OF ORIGIN (SOURCE MSI LTD., LNG MODEL 2013)

However the exports from US are expected to increase owing to the realization of high exploitation rate coming from the non-associated sources of gas in the coming years. This makes US a potential source of LNG supply in the coming years, with its exports raising to Japan, Europe, PRC and UK, covering the ECA's of the present and the near future. On the other hand US is expected to attain self-sufficiency for Natural gas in the coming years owing to the decline in imports and better exploitation of resources.

The figure below demonstrates the expected increase in LNG export cargo from US commencing from 2015, with over 50 % of exports are expected to be procured by Japanese Importers. Up to 70 % are destined to Asian Market.

US LNG imports are Expected to reach up to 30 BCM by 2025, representing up to 8% of global LNG exports.

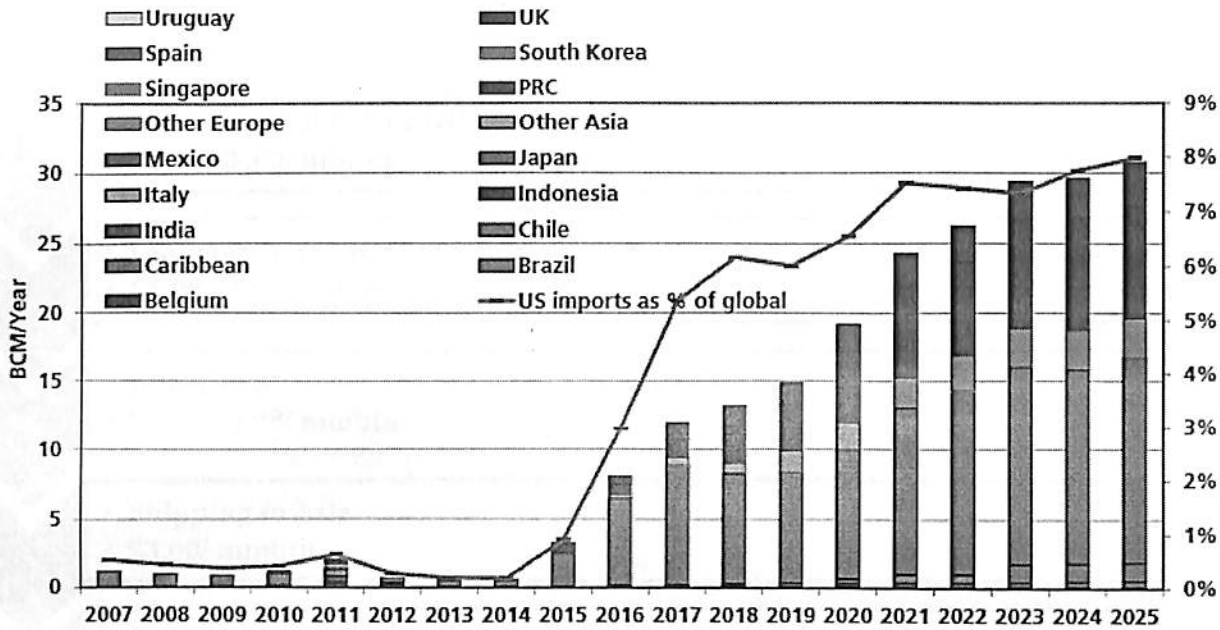


FIGURE 17. US LNG EXPORT FORECAST BY COUNTRY OF ORIGIN (SOURCE MSI LTD., LNG MODEL 2013)

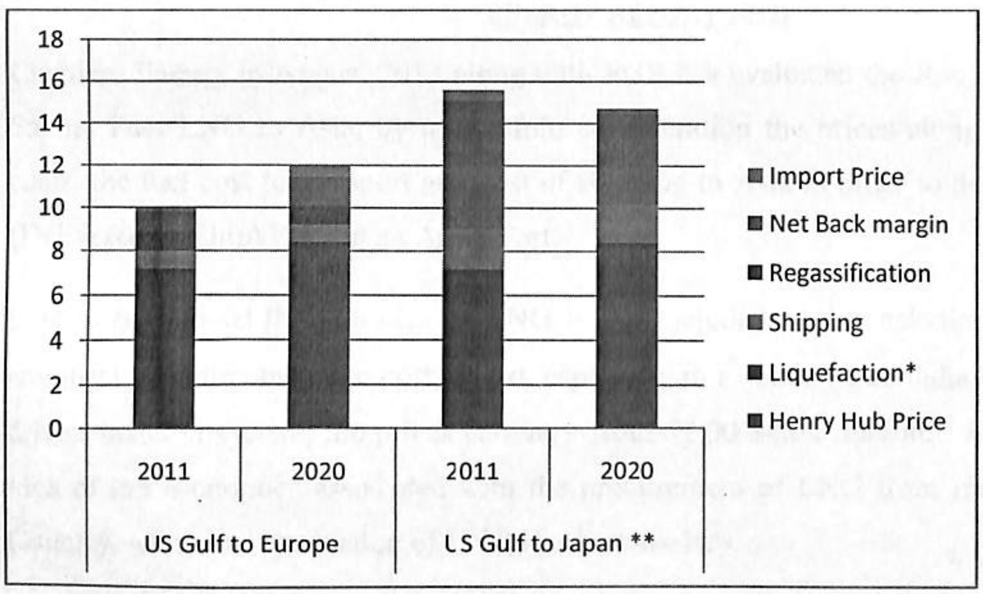


FIGURE 18. INDICATIVE ECONOMICS OF LNG EXPORTS FROM US (SOURCE LLOYD'S REGISTER 2013)

5.6.1. ECONOMICS OF US LNG EXPORTS

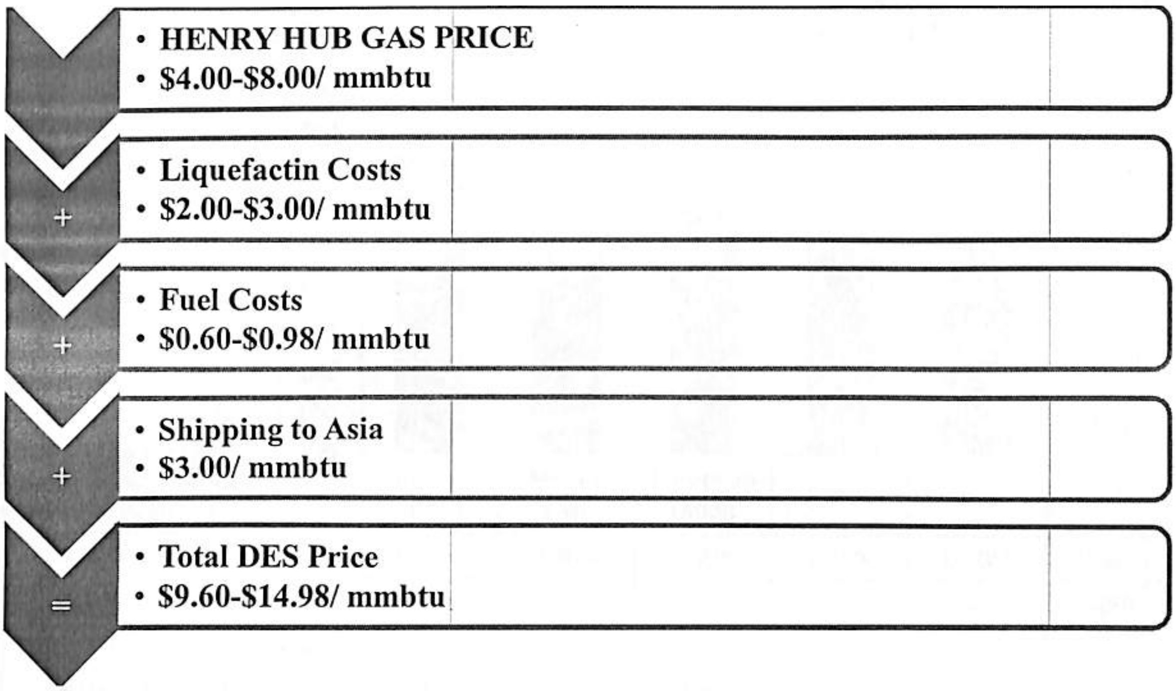
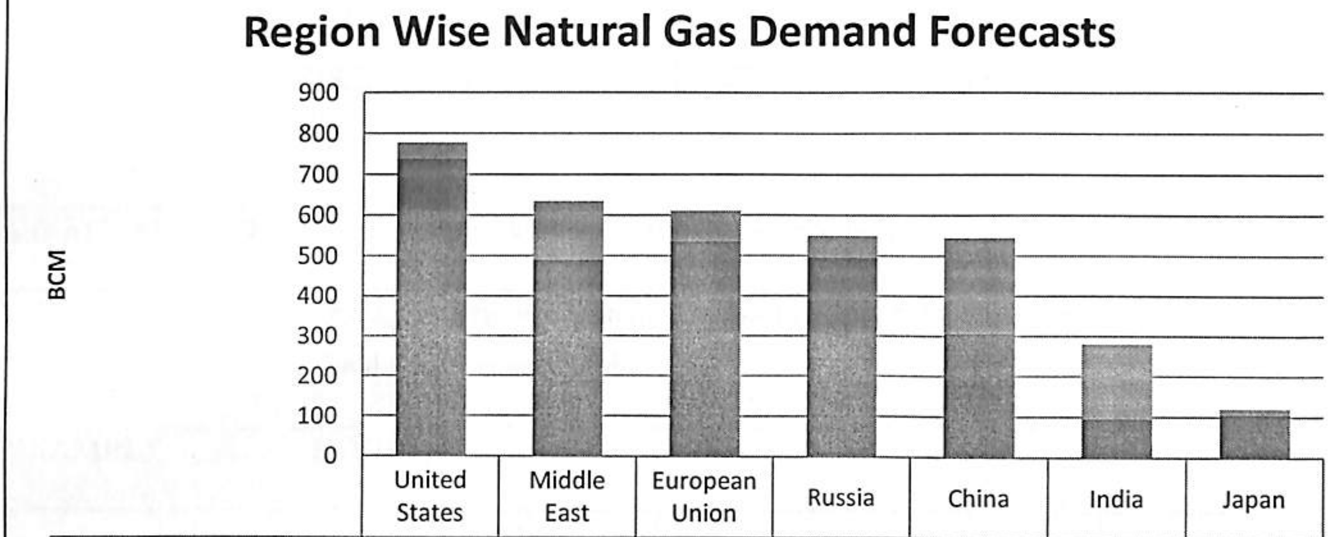


FIGURE 19. SABINE PASS LNG: RANGE OF DES PRICE TO ASIA (SOURCE CHENIERE ENERGY REPORT 2012)

Cheniere Energy in August 2012 along with FGE has evaluated the Range of DES Prices from Sabine Pass LNG to Asia, by taking into consideration the prices along with the liquefaction costs, the fuel cost to transport and cost of shipping to Asia in order to determine the total DES (Delivered ex Ship) Price at an Asian Port.

It is to be noticed that the cost of LNG is not included in this calculation, as it varies from country to country and from port to port, especially in a country like India where there exist state driven taxation system, the prices can vary from $2.00-$4.00/ mmbtu . Hence this gives a fair idea of the economics associated with the procurement of LNG from Henry Hub in an Asian Country, where the production of LNG is otherwise less.

5.6.2. NATURAL GAS DEMAND FORECAST



	United States	Middle East	European Union	Russia	China	India	Japan
CAGR	0.50%	2.10%	0.60%	0.70%	6.60%	4.20%	0.70%
Demand growth by 2035	40	145	75	55	240	185	15
Demand Growth by 2020	53	115	5	25	200	30	10
Demand in 2010	685	375	530	470	105	65	95

FIGURE 20 NATURAL GAS DEMAND FORECAST (SOURCE IEA REPORT 2012)

According to IEA World Energy Outlook Report 2012 for the above given non-OECD countries, India and China lead the growth for the demand of Natural Gas by 2035, with their CAGR (Compounded Annual Growth Rates being 6.6% and 4.2% respectively.

5.7. LNG CONTAINMENT SYSTEMS

The following are the different types of containment systems used for storage of LNG in large carriers, the advantages and disadvantages of the following are given along with:

MOSS TYPE	
ADVANTAGES	Less chance of any damage caused due to mis-operation.
	Has two barriers, Inner (Primary Barrier) i.e. fully gas tight.

	Secondary barrier that is visible on the outer periphery.
	There exists no barrier with respect to the volume limits.
	There is an easier access to repair with no problems associated with respect to entry.
DISADVANTAGES	These systems are the most expensive to build
	Owing to their sizes, there is additional fees associated with entry to suez canal which is very high.
EXAMPLE	KOGAS, HHI

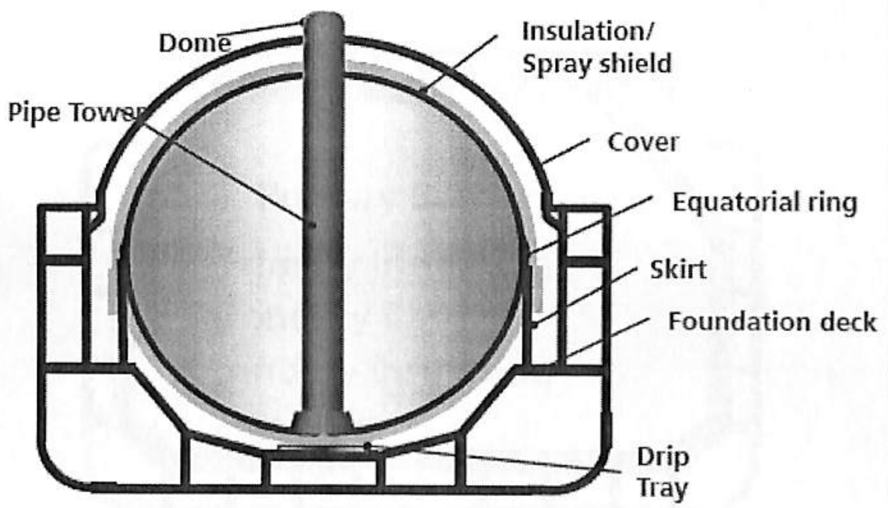


FIGURE 21. MOSS CONTAINMENT SYSTEM

MEMBRANE TYPE	
ADVANTAGES	There exists a cool-down rate limit, with a better Intra tank temperature monitoring system.

	The size and location of tank on the deck is of such kind, that provides better visibility from bridge during propulsion.
	The implementation of these systems does not cause the size of the vessel to be bulky.
	Such systems are manufactured by almost every company, that is into manufacturing of containment tank, and also provides in-service advice.
DISADVANTAGE	There is a problem with respect to the integrity of system owing to the difference in the quality of gas demanded by different sub-contractors.
EXAMPLE	GTT NO.96, GTT MARK III, GTT CS1

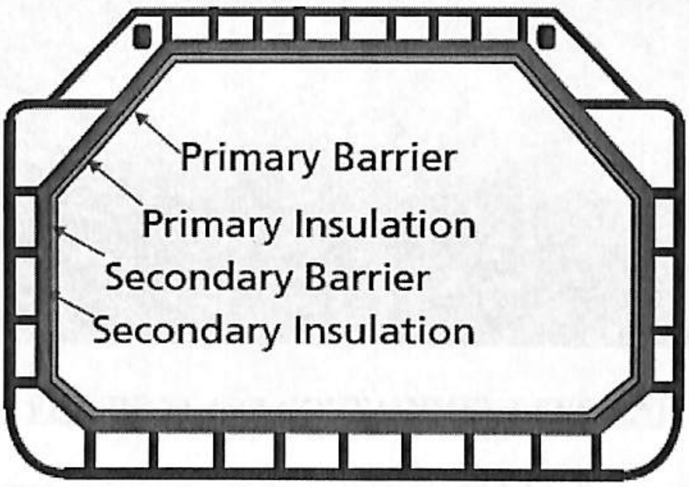


FIGURE 22. MEMBRANE CONTAINMENT SYSTEM

SPB	
ADVANTAGES	Same features as that of Moss Containment System
	Additional feature of good visibility from bridge, which is not present in Moss Containment System
	Keeps the deck area flat which is potentially beneficial for floating LNG

DISADVANTAGES	Only two small aluminium tank ships exist as of now, so there is the absence of In-service experience.
	It costs more than Membrane Containment System, owing to higher Suez Canal Fees.
EXAMPLE	IHI SPB

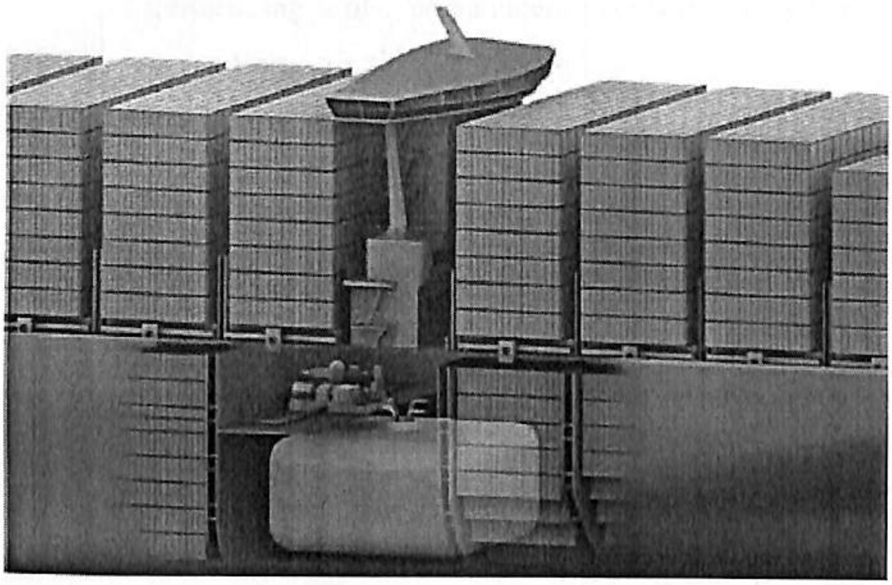


FIGURE 23. SPB CONTAINMENT SYSTEM

The following is the comparison done on the advantages and disadvantages of LNG containment System for small LNG carriers

	MEMBRANE	**TYPE C**
ADVANTAGES	There exists a cool-down rate limit, with a better Intra tank temperature monitoring system.	Type C has been proven to be the most robust design available as a containment system at present.
	The size and location of tank on the deck is of such kind,	This system is leakage free as here the leaks are possible only from the

	thatprovides better visibility from bridge during propulsion.	valves.
	The implementation of these systems does not cause the size of the vessel to be bulky.	It has an efficient system to control the boil off emissions.
	Such systems are manufactured by almost every company, that is into manufacturing of containment tank, and also provides in-service advice.	The installation of Type C system is the simplest as compared to other containment system.
DISADVANTAGE	There is a problem with respect to the integrity of system owing to the difference in the quality of gas demanded by different sub-contractors.	These containment systems are there for low volumes. Hence the benefits cannot be realized if there is a need of carrying large volumes.
EXAMPLE	GTT NO.96, GTT MARK III, GTT CS1	

The design to in-service survey done by Lloyd's has shown that moss ships have a good service record, but structural problems have been observed in the tank cover reinforcement structure. However, due to improved analysis procedures SDA (Structure Data Analysis) and FDA (Foundation Data Analysis) the problems have been solved for more recent designs.

The foundation deck reinforcement structure has however, not shown any major structural problems like cracks or buckling. But any if there occurs any major problems, they can become catastrophic. Therefore, the potentially affected regions must be carefully surveyed for cracking and buckling i.e. skirt support structure and midship cargo hold structure.

There is a need of continuing structural integrity to be confirmed to prevent any damage to narrow deck strip which is subject to high stresses on Moss Ships.

The problem with the structural configuration of Moss Ships is the complexity of structural Configuration, and with this is associated a risk of fatigue cracking in the ballast tanks and its double structure despite of the comprehensive analysis.

5.7.1. SPB TANKS (TYPE B)

Type B independent tanks with flattened top can also be constructed, they are also called as "prismatic" or they can be of spherical type even. However, the need to have spherical tanks for maintaining the vapour pressure is not mandatory here. Such type of containment tanks are often termed as Self-supporting prismatic. The benefits associated with such tanks are that, they maximize the ship hull's volumetric efficiency.

It has also a geometric benefit associated i.e. the prismatic type B tank's entire storage can be placed beneath the flat upper deck.

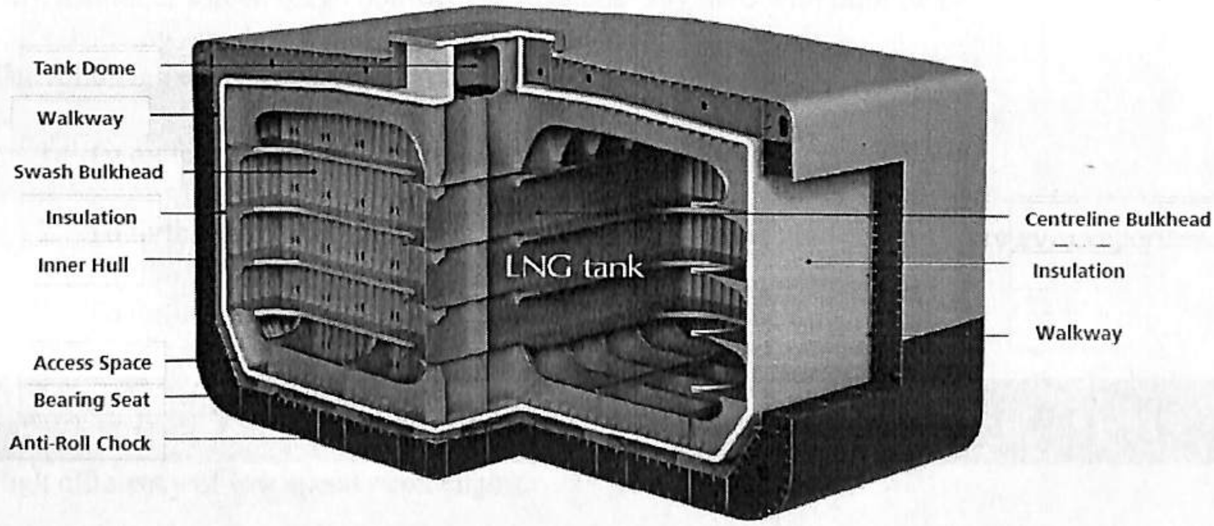


FIGURE 24. SCHEMATIC ARRANGEMENT OF TYPE B TANKS

Viability of prismatic tanks for liquefied gas can be established on the basis of service experience of LPG carriers, using low carbon steel. However, low temperature carbon steel is not suitable for LNG carriers, hence aluminium is used instead. But there is a need to ensure the integrity and fatigue strength.

The yield stress of Steel tanks is around 235 N/mm2 whereas for aluminium it is nearly half i.e. 125 N/mm2. Fatigue strength of Steel tanks is around 100 FAT and for that of aluminium is less than half i.e. 40 FAT. There is a need to reduce stress concentrations and to control the construction quality such as welding and alignment control.

5.7.2. TYPE C TANKS

Another type of tank is Type C independent tank, which is also referred to as a pressure vessel, is a type of tank that meets pressure vessel criteria. Such tanks may be vertically or horizontally mounted and can be of various shapes i.e. Cylindrical, spherical or bi-lobe. However, such arrangement compensate with the efficient utilization of hull volume.

5.8. DUAL FUEL ENGINES TECHNOLOGY

The propulsion plant of Low speed Diesel Engine with Dual Fuel (ME-GI) engine is designed to burn natural or forced cargo boil-off gas in almost any ratio with pilot fuel.

The following are the three methods of achieving this:

1. To route the boil off gas to a high pressure compressor.
2. To further reliquefy (pressurize) LNG before vaporizing it in a high pressure vaporizer.
3. To further compress CNG by using a high pressure compressor.

ADVANTAGES	CONSIDERATIONS
High efficiency of low speed main engine	New engine
Fuel flexibility	Abatement technology to meet Sox / NOx Tier III restrictions
Environmental Friendly- less CO2 Sox compliant, less Particulate matter	High pressure gas into Engine Room
Reduced Risk for Methane slip	

ME- GI Slow Speed Diesel Engines are commercially available and have an advantage of retrofitting in existing slow speed engines. It has comparable low fuel consumption and has low running costs. However, as compared to other systems has higher vibration and higher noise levels.

ME-GI Engines use pressurized gas, which is compressed separately from engine and then injected into the combustion cylinder only after combustion has started by a pilot oil injection. There is no risk of pre-ignition knocking of the gas during compression. An ME-GI engine is therefore, an ME engine with an additional rail gas loop, pressurized at 250 bar.

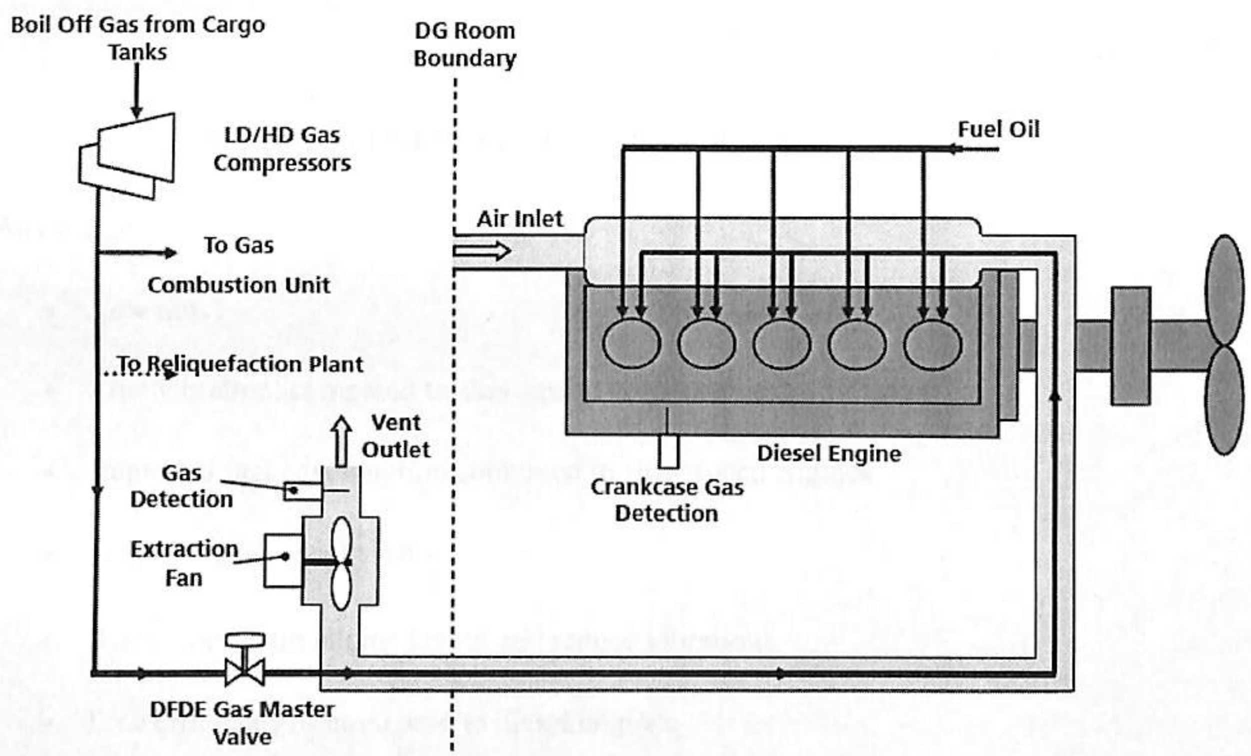


FIGURE 25. DUAL FUEL ENGINE TOPOLOGY

5.8.1. FUEL/ GAS INJECTORS

Dual fuel operation requires valves for both the injection of pilot fuel and gas fuel. The valves are of separate type and two valves are fitted for gas injection and two for pilot fuel.

The media i.e. required for both the types of fuel and gas operations are :

- Fuel oil Supply
- High-pressure gas supply
- Sealing oil supply
- Control oil supply for activation of gas injection valves.

5.8.2. DUAL FUEL WITH ELECTRIC PROPUSION

Advantages:

- Low noise
- Low vibration, compared to slow speed engines
- Improved fuel consumption compared to slow speed engines
- Low power to weight ratio
- Allows optimum engine layout and reduce vibrations
- Low efficiency as compared to diesel engines

5.8.3. DUAL FUEL ENGINE OPERATING MODE

MODE	FUEL AND INJECTION
Gas Operating Mode	Gas Fuel With Pilot Fuel Injection
Diesel Operating Mode	Conventional jerk-pump diesel fuel injection

	with pilot fuel injection
Back up Operating Mode	Conventional jerk-pump diesel fuel injection

5.8.4. DF ENGINE SAFETY

- Double wall pipework
- Flame Arresters fitted to gas Inlet Manifold
- Gas safety checks and purging are performed automatically when changing fuel modes
- Exhaust Gas Temperatures and Deviations of Cylinders are monitored
- Gas Pressure and Control Air Pressure Monitoring
- Crankcase Oil Mist Detection
- Pressure Sensor inside Crankcase
- Bearing Temperature Sensors (alarm 100 degree celcius, shutdown at 120 degree celcius)

5.8.5. RECENT DEVELOPMENTS WITH STEAM PROPULSION PLANT

- Mitsubishi UST System
- Kawasaki Advanced Reheat System

5.8.6. DUAL FUEL ENGINES

	COMBUSTION CYCLE	TYPE	RATING per Cylinder (kW)	Experience

MAN DIESEL	2 stroke Diesel	ME-GI S60/65/70 2 x 7S60 ME-GI	2380/2870/3270 (5 to 8 cyl)	Yes1
WARTSILA	2 stroke Diesel	RTX5		(No)
MAN DIESEL	4-Stroke Diesel/Otto	51/60DF	975 (6 to 18 cyl)	Yes
WARTSILA	4-stroke Diesel/Otto	50DF 3x12V/1x9L	975 (6 to 18 cyl)	Yes
MAK	4-stroke Diesel /Otto	43/32		Yes/No
AUX ENGINES	4-stroke	20DF		Yes/No

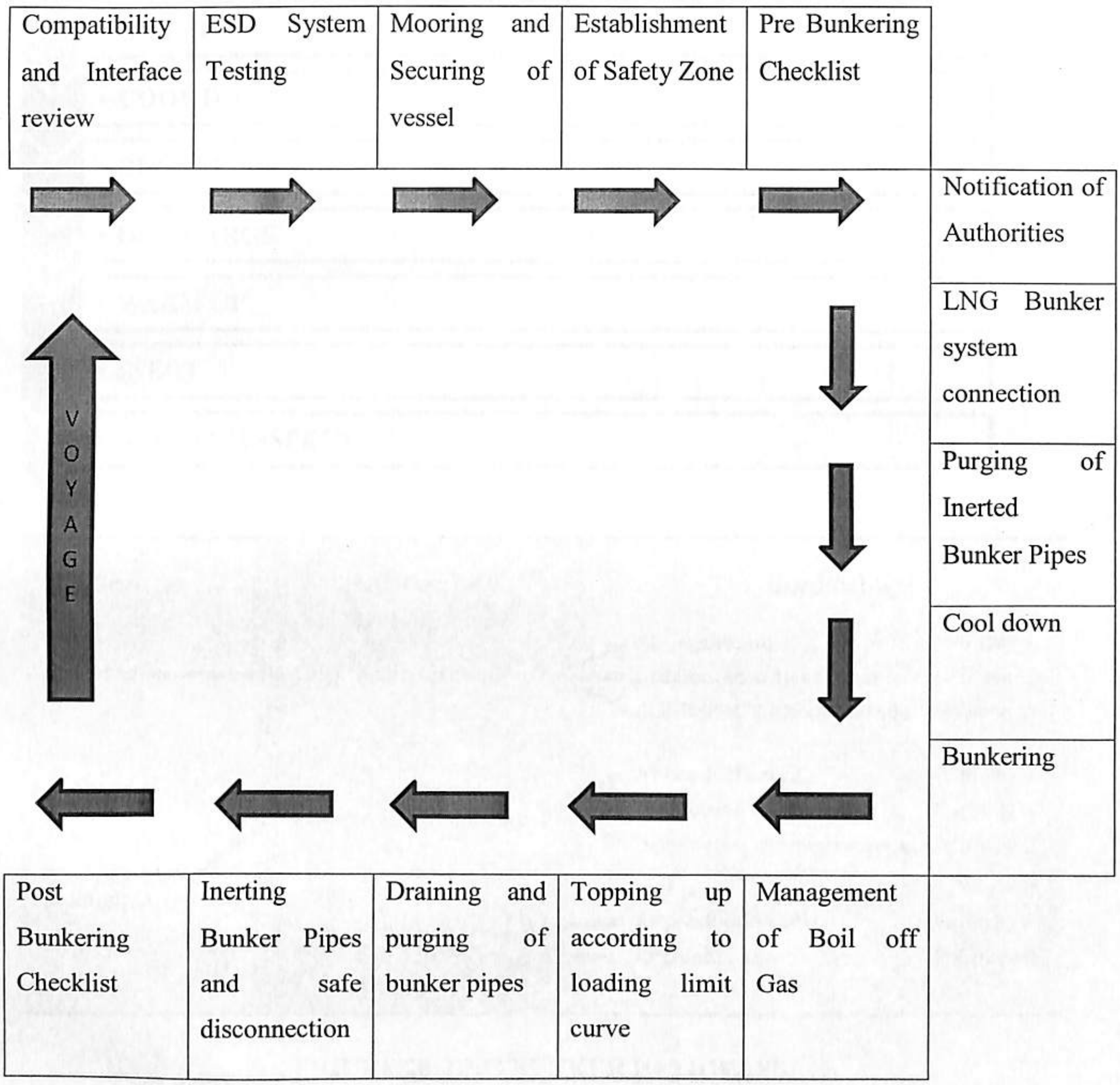
TABLE 8. TYPES OF DF ENGINES

5.8.6.1. Two Stroke versus DE (4 stroke)

	2 Stroke	DE
Gas Pressure	250-300 Bar	4-6 Bar
Combustion principle/ cycle	Diesel	Otto
Pilot %	5%	1-5%
Min Load on Gas	15-20%	10-15%
Methane Slip	No	2-8%
Knocking Risk	No	Yes
Methane Number	N/A	Min 80
Risk of leakage gas into exhaust System	No	Yes

TABLE 9. TWO STROKE V/S DE ENGINES

5.9. LNG BUNKERING PROCESS



5.9.1. LNG STORAGE TANK LOADING AND EMPTYING

- INERT
- GAS UP
- COOL DOWN
- BUNKER
- DISCHARGE
- WARM UP
- INERT
- AERATE/ INSPECT

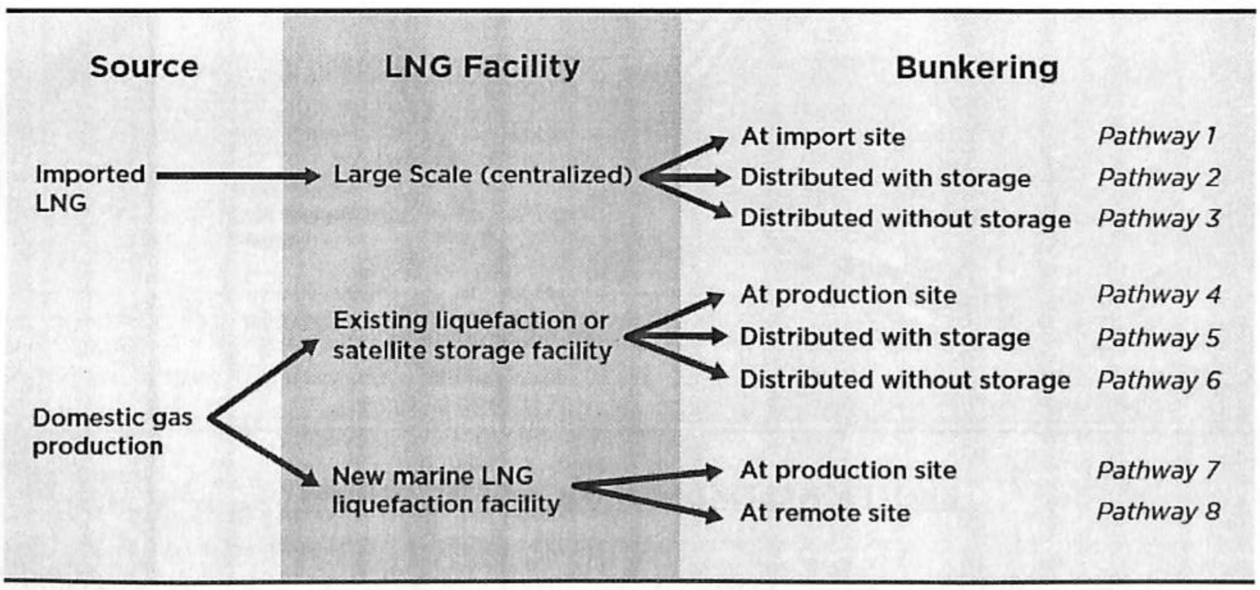


FIGURE 26. LNG BUNKER PATHWAYS

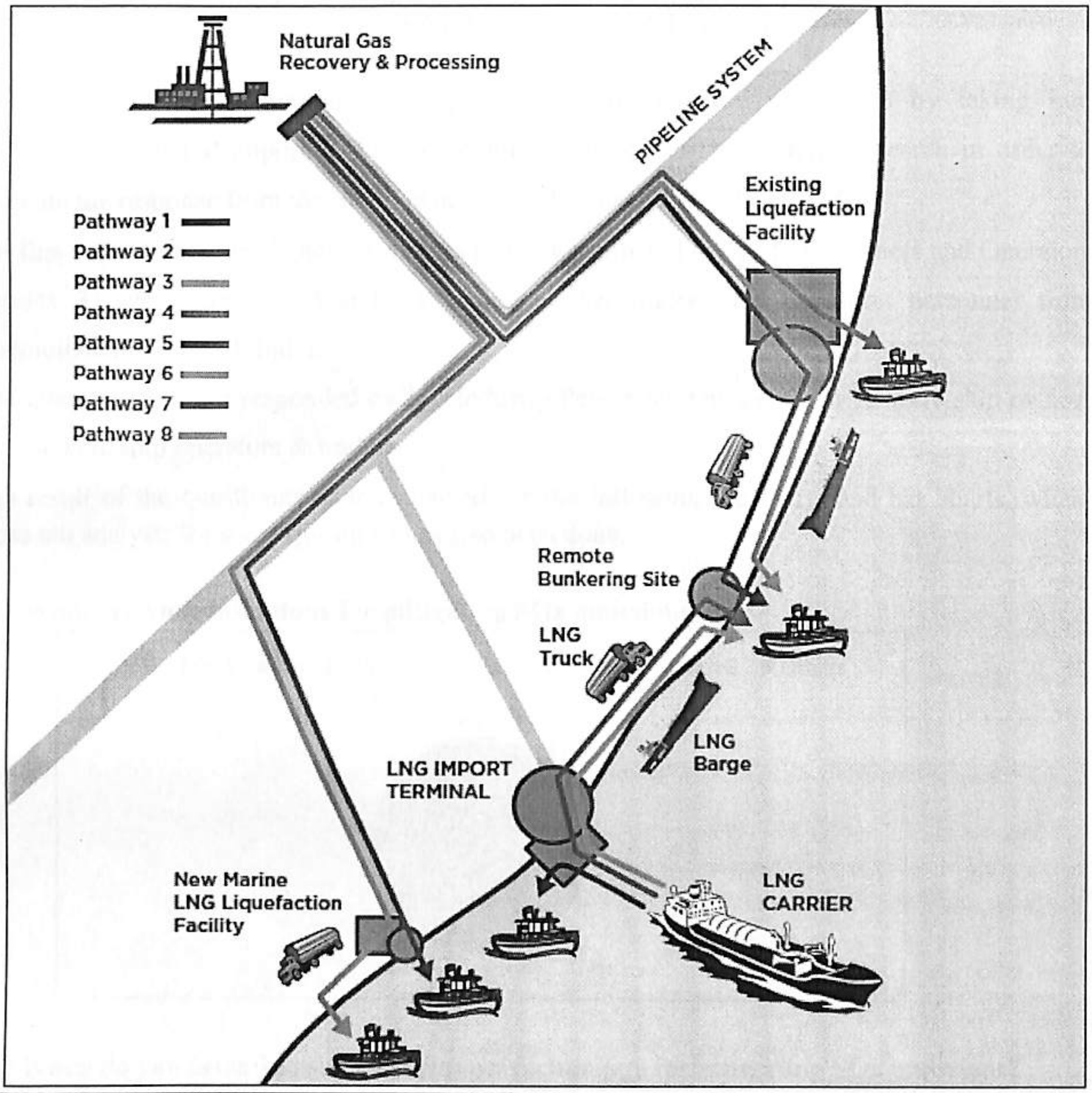


FIGURE 27. LNG BUNKERING LOCATIONS

6. ANALYSIS OF RESEARCH

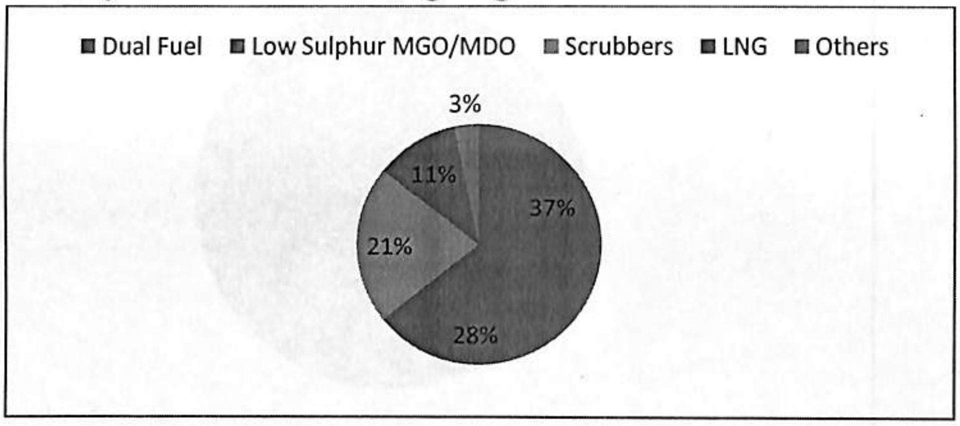
For the purpose of satisfying the objectives, a questionnaire was made by taking into consideration all the important facts determined out of the Descriptive Research in order to evaluate the response from the Ship Owners and Operators across the world.

For this a questionnaire (Annex 2) was made and was floated to 267 Ship Owners and Operators (Annex 3) across the world and also some bunker traders and operation personnel from ChemoilAdani Pvt. Ltd. India.

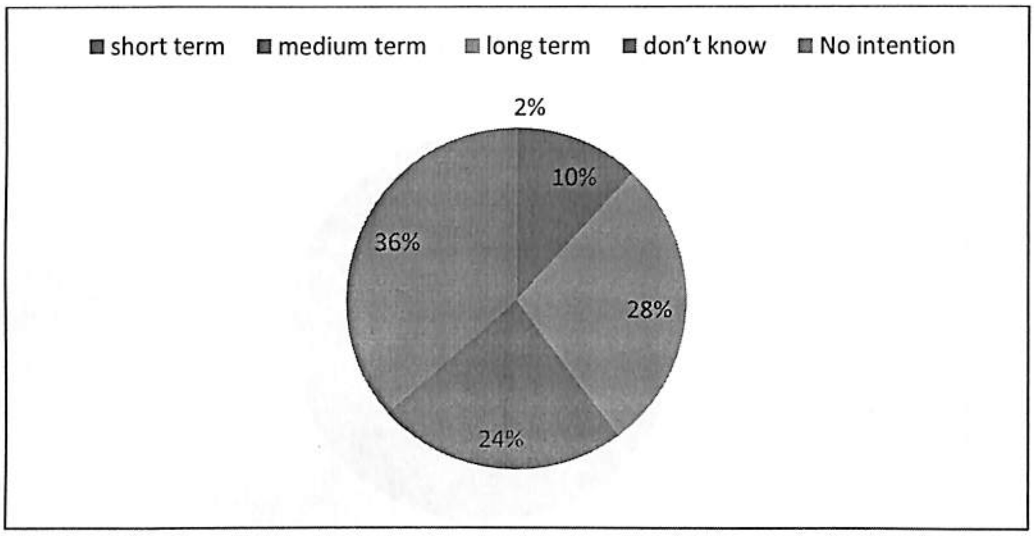
The questionnaire was responded by 126 Industry Personnel. Out of which 72 were ship owners and 54 were ship operators & traders.

The result of the questionnaire is explained via the following pie charts and bar charts, where cross tab analysis for some questions has also been done.

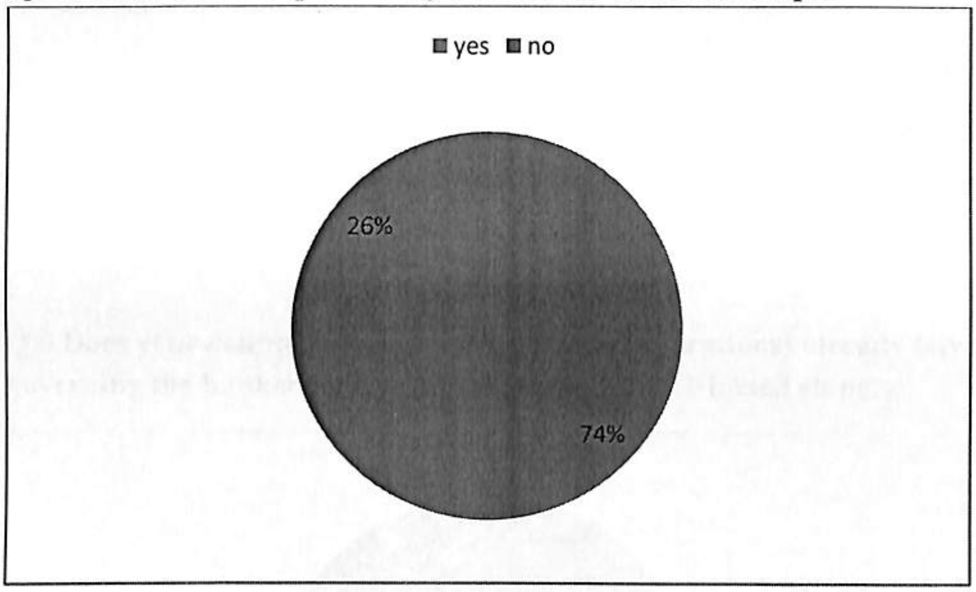
Q.1 What are your intentions for mitigating SOx emissions?



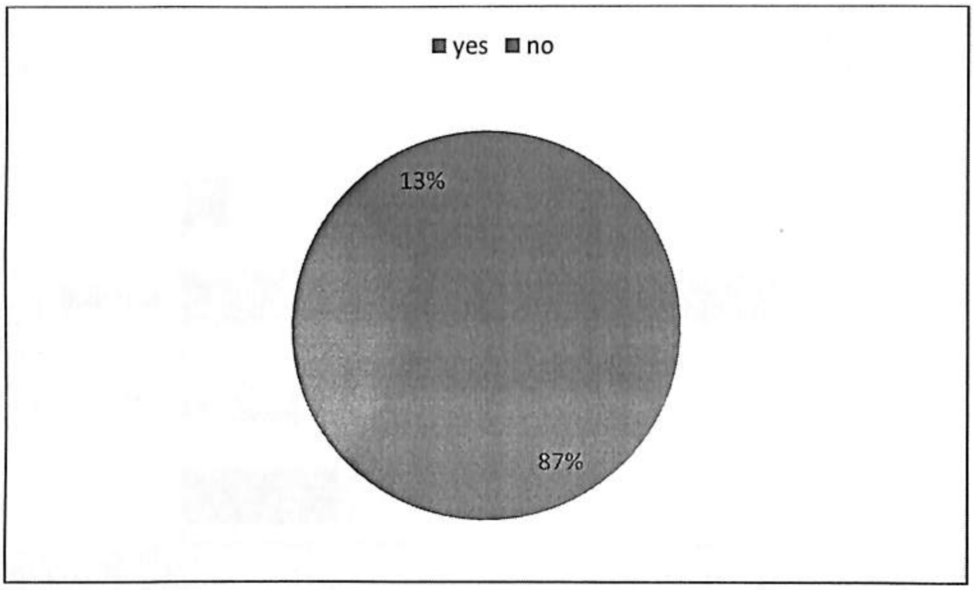
Q.2 When do you intend to switch fuel type/ technology for mitigating SOx emissions?



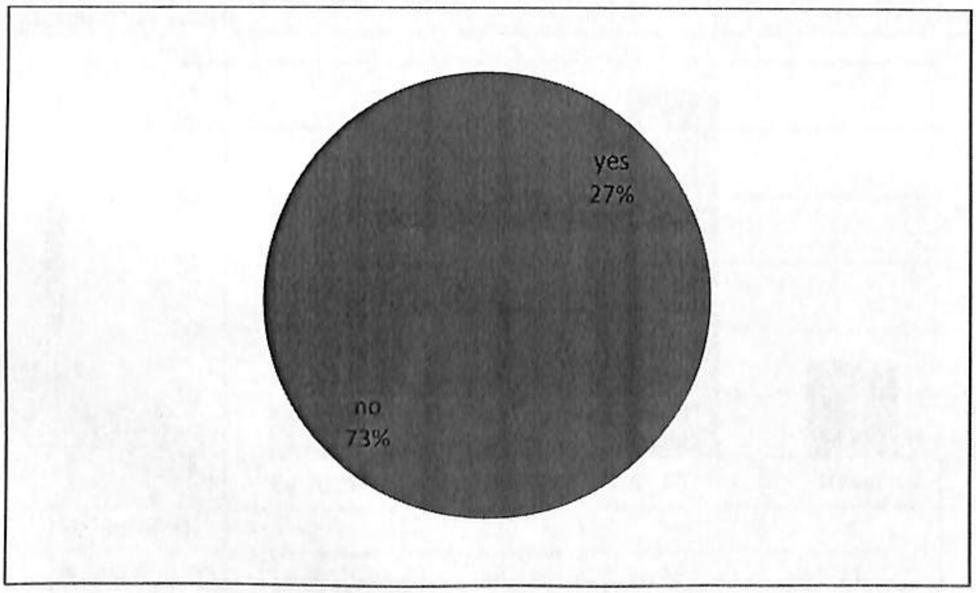
Q.3 Is LNG as a fuel potentially suitable for merchant ships?



Q.4 Do you see (the port authority/ government) as a driver of change regarding the use of LNG as a fuel?

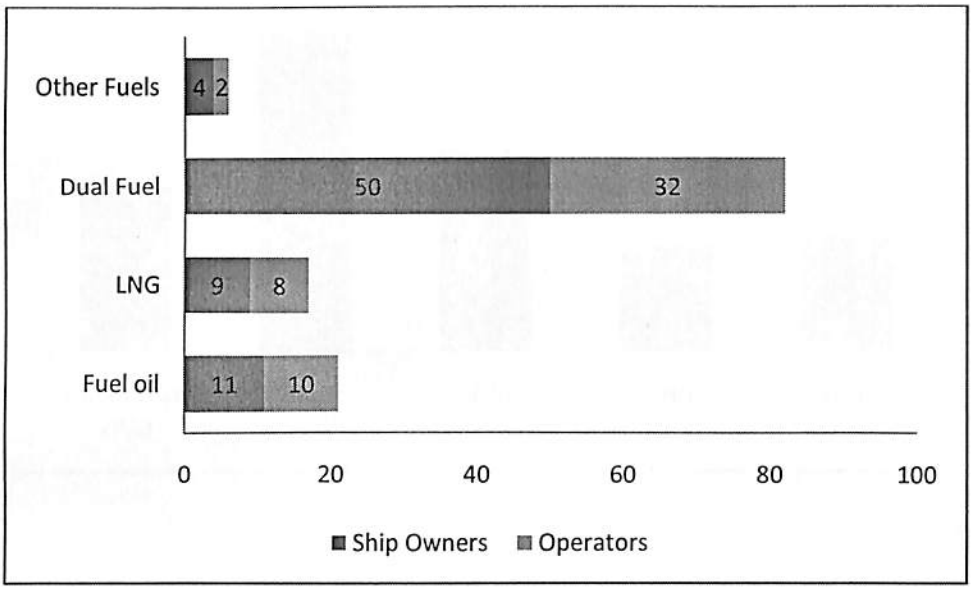


Q.5 Does your country (business area/ area of operations) already have local regulations governing the bunkering and/or operation of LNG-fueled ships?

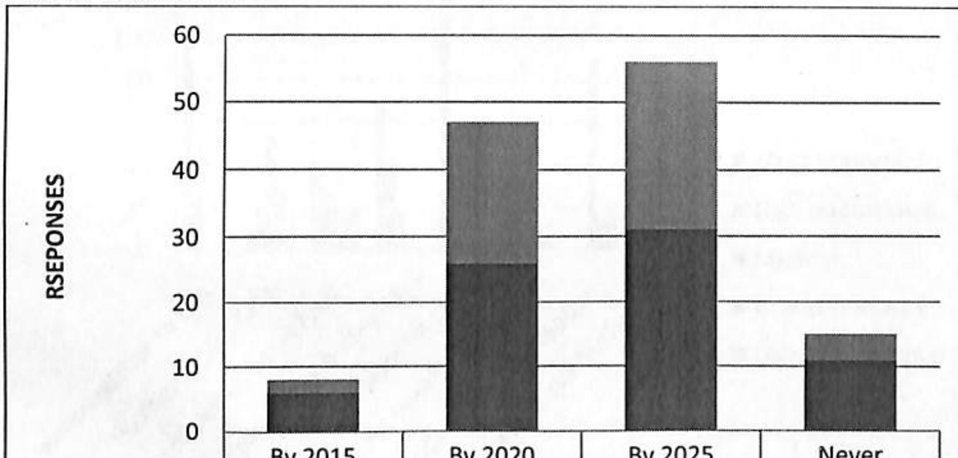


Q.6 According to you which type of fuel will most merchant ships designed/ built in 2020 be using?*Required (As the IHS Fairplay Research Report 2013 says about the order booked for

LNG carriers, that the 108 vessels under construction will be delivered by 2020, and owing to the mitigation of SOx emission limits by 2020,What technology according to you will be used?)

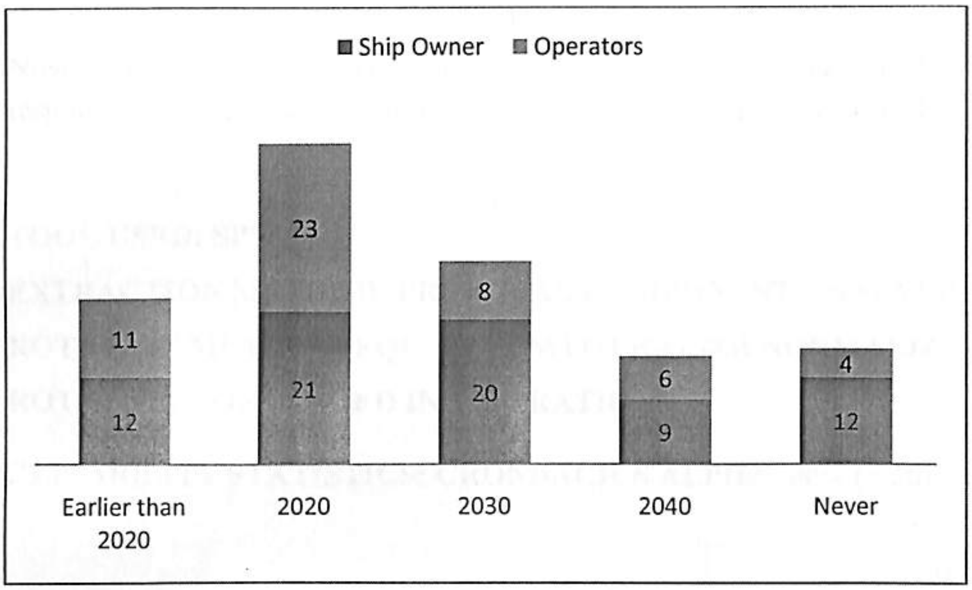


Q.7 When would world-wide LNG bunkering be available?*Required
The three options below are marked by three different time frames of the amendments in the Global SOx limits.

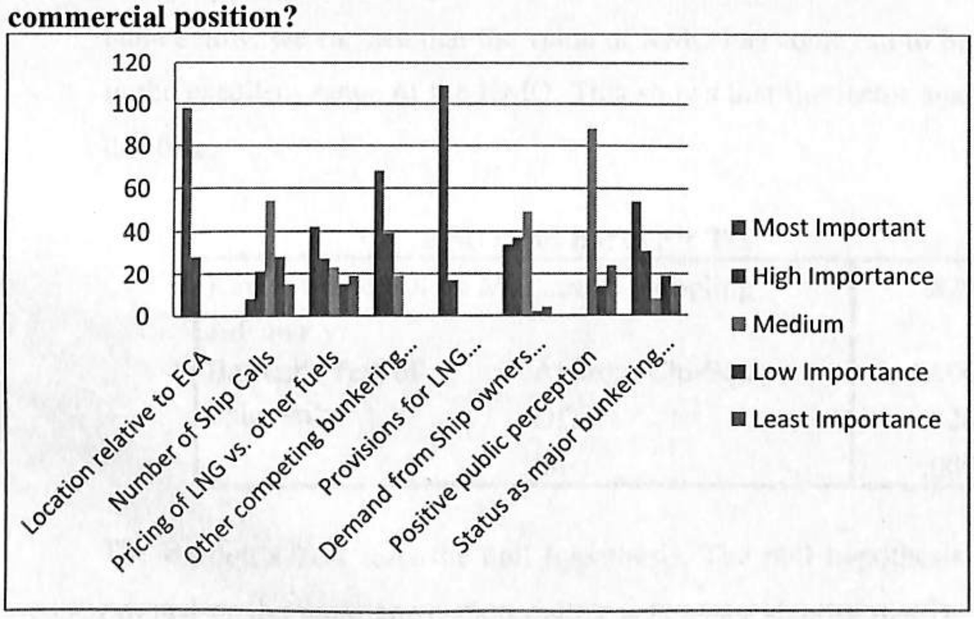


	By 2015	By 2020	By 2025	Never
Operators	2	21	25	4
Ship Owners	6	26	31	11

Q.8 When do you think bio fuels (liquid or gas) for ships could be viable?*Required



Q.9 What are the most important drivers for LNG bunkers in terms of the port's commercial position?



Q.10 Rate the factors that could prevent the use of LNG as a marine fuel? (1 being least important and 5 being most important)*

Now, In order to reduce the variables that could prevent the use of LNG as a marine fuels, the responses collected for the following factors have been put under FACTOR ANALYSIS.

TOOL USED: SPSS

EXTRACTION METHOD: PRINCIPAL COMPONENT ANALYSIS.

ROTATION METHOD: EQUAMAX WITH KAISER NORMALIZATION.

ROTATION CONVERGED IN 5 ITERATIONS.

RELIABILITY STATISTICS: CRONBACH'S ALPHA- .894 (>.50)

6.1. FACTOR ANALYSIS

6.1.1. KAISER-MEYER-OLKIN (KMO) AND BARTLETT'S TEST

The KMO test is used to measure the sampling adequacy of the data. The Bartlett;s Test is used to measure the sphericity. The KMO statistic values caries from 0 to 1. In the table below, we can see that the value of KMO has come out to be 0.820. This value lies in the excellent range of the KMO. This shows that the factor analysis is appropriate for this data.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.820
Bartlett's Test of Sphericity	Approx. Chi-Square	514.806
	Df	28
	Sig.	.000

The Bartlett's Test tests the null hypothesis. The null hypothesis is whether or not the original or the main correlation matrix acts as an identity matrix. For factor analysis to produce accepted results, some relationships between the variables are needed .The project's data, the Bartlett's Test is highly significant where ($p<0.001$), and thus, the factor analysis is absolutely appropriate.

6.1.2. CORRELATION MATRIX

The correlation matrix shows the effect, which the other variables have on each of the individual variables. The upper half of the table displays the Pearson Correlation coefficient between all the pairs of questions. The lower half displays the one-tailed significance of the coefficients. The determinant of the correlation matrix has to be checked. It is to be greater than 0.00001. Our value that has been calculated is 0.02. Thus, the multi-collinearity is not a problem for the data taken. All the questions correlate fairly well.

[redacted]

Correlation Matrix[a]

		lack_of policy	Unavailability_NG	Investment_Liquefaction_regasification	Cost_Modification	No_restriction_nonECA	Few_existing_LNGfleet	Lack_technology	Confusion_tchnology
Correlation	lack_of_policy	1.000	.293	-.199	-.021	.405	.531	.496	.551
	Unavailability_NG	.293	1.000	-.249	-.024	.317	.546	.528	.551
	Investment_Liquefaction_regasification	-.199	-.249	1.000	.707	-.074	-.143	-.275	-.141
	Cost_Modification	-.021	-.024	.707	1.000	.100	.138	-.024	.155
	No_restriction_nonECA	.405	.317	-.074	.100	1.000	.546	.467	.551
	Few_existing_LNGfleet	.531	.546	-.143	.138	.546	1.000	.729	.799
	Lack_technology	.496	.528	-.275	-.024	.467	.729	1.000	.762
	Confusion_tchnology	.551	.551	-.141	.155	.551	.799	.762	1.000
Sig. (1-tailed)	lack_of_policy		.000	.013	.407	.000	.000	.000	.000
	Unavailability_NG	.000		.002	.396	.000	.000	.000	.000
	Investment_Liquefaction_regasification	.013	.002		.000	.205	.055	.001	.058
	Cost_Modification	.407	.396	.000		.133	.062	.393	.041
	No_restriction_nonECA	.000	.000	.205	.133		.000	.000	.000
	Few_existing_LNGfleet	.000	.000	.055	.062	.000		.000	.000
	Lack_technology	.000	.000	.001	.393	.000	.000		.000
	Confusion_tchnology	.000	.000	.058	.041	.000	.000	.000	

a. Determinant = .014

From the SPSS output, following relationships can be concluded:

- ✓ The confusion pertaining to technology showed the highest correlation of .551 with the variable of lack of policy, followed by few existing LNG fleet and Lack of technology. Except Investment in Liquefaction and Regasification and Cost of modifications/ retrofits rest all variables have shown high correlation with lack of policy.
- ✓ The confusion pertaining to technology showed the highest correlation of .551 with the variable of unavailability of natural gas followed by few existing LNG fleet and Lack of technology. Except Investment in Liquefaction and Regasification and Cost of modifications/ retrofits rest all variables have shown high correlation with unavailability of natural gas.
- ✓ Only Cost of modifications/ retrofits has shown high correlation with Investment in Liquefaction and Regasification rest all variables have shown no correlation with Investment in Liquefaction and Regasification.
- ✓ The Investment in Liquefaction and Regasification showed the highest correlation of .707 with the variable of cost of modification. Except this, onlyConfusion pertaining to technology and few existing LNG fleet showed low correlation with cost of modification.
- ✓ The confusion pertaining to technology showed the highest correlation of .551 with the variable no restriction on non- ECA followed by few existing LNG fleet and Lack of Technology. Except Investment in Liquefaction and Regasification rest all variables have shown correlation with no restriction on non- ECA.
- ✓ The confusion pertaining to technology showed the highest correlation of .799 with the variable few existing fleet. Except Investment in Liquefaction and Regasification rest all variables have shown high correlation with few existing fleet.
- ✓ The confusion pertaining to technology showed the highest correlation of .762 with the variable of lack of technology followed by few existing LNG fleet. Except Investment in Liquefaction and Regasification and cost of modification/ retrofits rest all variables have shown high correlation with lack of technology.
- ✓ The few existing LNG fleet showed the highest correlation of .799 with the variable of confusion pertaining to technology. Except Investment in Liquefaction and

Regasification rest all variables have shown high correlation with confusion pertaining to technology, However Cost of Modification showed low correlation.

6.2.2 TOTAL VARIANCE EXPLAINED

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.082	63.529	63.529	5.082	63.529	63.529	4.902	61.272	61.272
2	1.053	13.168	76.697	1.053	13.168	76.697	1.234	15.425	76.697
3	.629	7.869	84.566						
4	.401	5.018	89.584						
5	.314	3.923	93.507						
6	.209	2.610	96.117						
7	.192	2.397	98.514						
8	.119	1.486	100.000						

Extraction Method: Principal Component Analysis.

This table lists the eigenvalues which are associated with each factor before extraction, after extraction and after rotation. SPSS helps displaying eigenvalues in the terms of the percentage of variance explained.

Here the 1st 2 factors are explaining large amounts of variance and the subsequent factors explain vary small variance.

The section labelled as Percentage of Variance column explains the total variability that can be accounted for each of the factors. Like for eg, The factor number 1 accounts for 61.272% of total variability. The section which is labelled as Rotational Sum of Squared Loadings displays the factors which meet our cut-off criterion.

The total variability explained by all the factors is 76.692% which is required to be above 65% according to set standards.

6.1.3. COMMUNALITIES

The table of communalities shows the reasons behind the lack of implementation of LNG as a marine fuel which most of the respondents have in common. The interpretation is:

- ✓ The most common reason that has been found out is that most of the respondents believe that the Cost of Modification/ retrofits is a matter of utmost importance and also gives rise to chicken-egg dilemma.
- ✓ The next common reason that has been found out is that most of the respondents believe that the Investment in Liquefacttion and regasification is a matter of decision by different governments and their respective port authorities.
- ✓ The next common reason identified was that they are sceptical about is the confusion pertaining to technology of overhaul/ retrofits.

Communalities

	Initial	Extraction
lack_of_policy	1.000	.469
Unavailability_NG	1.000	.474
Investment_Liquefatction_regasification	1.000	.869
Cost_Modification	1.000	.874
No_restriction_nonECA	1.000	.482
Few_existing_LNGfleet	1.000	.806
Lack_technology	1.000	.746
Confusion_tchnology	1.000	.833

Extraction Method: Principal Component Analysis.

6.1.4. ROTATED COMPONENT MATRIX

The rotation method helps in bringing the factors that are as different from each other as possible. It gives the factor loadings for each variable which are used to interpret meanings of different factors. In this case, The Principal Component Analysis Method is used for extraction and Varimax is the rotation method.

Rotated Component Matrix[a]

	Component	
	1	2
Confusion_tchnology	*.911*	.059
Few_existing_LNGfleet	*.896*	.050
Lack_technology	*.852*	-.140
No_restriction_nonECA	*.688*	.093
lack_of_policy	*.677*	-.104
Unavailability_NG	*.669*	-.162
Cost_Modification	.119	*.927*
Investment_Liquefatction_regasification	-.203	*.910*

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

1. From the table it can be clearly interpreted that the 1st factor is marked by highest loadings on the following variables:

- ✓ Investment for Liquefaction and Regasification at ports.
- ✓ Cost of Modification/ Retrofits of vessel.

The commonality which is found in the above 2 grouped variables is that both are economic factors. They are the external variables. So we can together name them as **Prime Variables.**

2. The 2nd factor is marked by higher loadings on the following variables:

Confusion pertaining to technology (SPB/Moss/Membrane Tanks & ME-GI/ Electric DF Engines)	
Lack of technology for Retrofits/ modification.	
Few existing fleet with LNG propulsion technology.	Technology Related Variables
Lack of Policy for LNG as a marine fuel for vessels	
No present restrictions on vessels in Non ECA's	
Unavailability of Natural Gas.	Port Related Variables

The above six variables are Operating factor. So these can be together termed as **Operating Variable.**

7. CONCLUSION

LNG as a marine fuel is found to be potentially suitable for merchant ships. However, In long run, in order to mitigate the Sox Emissions, the most preferable option is found to be as Dual Fuel Technology (ME-GI/ Electric DF Engines) to be retrofitted or newly build.

In shorter run, however, the ship owners and operators hold no intention to switch the fuel type as such owing to the variable "No restrictions on Non-ECA's" being the most important reason for the shift. As the majority of respondents firmly believe that the "Port/ Government" as an important driver for change off fuel type to LNG, which as of now is not widely present in majority of ports across the world.

The analysis shows that the respondents have firm belief in the implementation of Dual Fuel Technology in the merchant ships to be built in 2020. However, LNG as a sole fuel, used to propel the vessels is believed to come in the global picture not before 2025.

The important drivers for LNG bunker, in terms of the Port's Commercial Positioning is found to be:

- Provision of LNG Bunker on Ports
- Location relative to ECA's
- Other Competing Bunker (LNG) ports on the traversal routes.

However, there are lot of variables that prevent the implementation of LNG as a marine fuel, after factor analysis, they can be broadly classified as:

- Port Related Variables
- Vessel Related Variables
- Technology Related Variable.

8. REFERENCES

WEB REFERENCES

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- Bunkers and Bunkering, March 2011, - Gard
- BIMCO and IBIA - Bunkering Guide

BUNKER INSIGHTS

SR NO.	NAME	DESIGNATION	COMPANY	EXPERTISE
1	Mr. Anil Keswani	GM- Marketing	CAPL	Indian Oil and Bunker Market
2	Mr. Deepak Dharwal	Marine Fuel Trader	CAPL	Bunker Trader
3	Mr. Ravi Prakash	Marine Fuel Trader	CAPL	Bunker Trader
4	Mr. Kaman Singh	Marine Fuel Trader	CAPL	Bunker Trader
5	Mr. Rishi Srivastava	Marine Fuel Trader	CAPL	Bunker Trader
6	Mr. Rupesh Mishra	Marine Fuel Trader	CAPL	Risk Manager
7	Mr. Praveen Jaiswal	GM - Operations	CAPL	Bunker Operations
8	Mr. Rajesh Tarachandani	Head – Mundra Office	CAPL	Bunker Operations
9	Mr. AmitDingwani	Barge Manager	CAPL	Barge Management
10	Mr. K.V Rao,	Operations - Mundra	CAPL	Bunker Operations
11	Mr. DhavalBharakhada	Operations - Mundra	CAPL	Bunker Operations
12	Mr. BhargavaRajora&	Operations - Kandla	CAPL	Bunker Operations
13	Mr. ShankerRao	Operations - Kandla	CAPL	Bunker Operations
14	Mr. NareshPoddar	GM - Finance	CAPL	Bunker Finance
15	Mr. KetulModi	Finance	CAPL	Bunker Finance
16	Mr. J.P Shahi	Marine Fuel Services	WFS	Bunker Trader
17	Mr. SumitKDhawan	Marine Fuel Services	O.W. Bunker	Bunker Trader
18	Mr. PiyushRaghuvanshi	Bunker Trader and Operations	BGH	Bunker Trader and Operations

ANNEXURE 1
QUESTIONAIRRE

"Potential and Feasibility of LNG as a marine fuel"

I, Kashish Khanna am a student of MBA(Energy Trading) from University of Petroleum and Energy Studies, Dehadun (India). This questionnaire is intended for research purpose for determining the "Potential and Feasibility of LNG as a marine fuel", and the response will be considered purely for analysis purpose. The public disclosure of any content pertaining to response will be restricted. (Responses)

Name*Required

Name of Organization

Email id

What are your intentions for mitigating SOx emissions?*Required

- Dual Fuel
- Low Sulphur MGO/MDO
- Scrubbers
- LNG
- Other:

When do you intend to switch fuel type/ technology for mitigating SOx emissions?*Required

- Short Term
- Medium Term
- Long Term
- No intentions
- Don't know

Is LNG as a fuel potentially suitable for merchant ships?*Required

- Yes
- No

Do you see (the port authority/ government) as a driver of change regarding the use of LNG as a fuel?*Required

- Yes
- No

Does your country (business area/ area of operations) already have local regulations governing the bunkering and/or operation of LNG-fueled ships?*Required

- Yes
- No

According to you which type of fuel will most merchant ships designed/ built in 2020 be using?*Require((((As the IHS Fairplay Research Report 2013 says about the order booked for LNG carriers, that the 108 vessels under construction will be delivered by 2020, and owing to the mitigation of SOx emission limits by 2020,What technology according to you will be used?)

- Fuel Oil
- Dual Fuel (IFO and LNG)
- LNG
- Other:

When would world-wide LNG bunkering be available?*RequireD
The three options below are marked by three different time frames of the amendments in the Global SOx limits.

- By 2015
- By 2020
- By 2025
- Never

When do you think bio fuels (liquid or gas) for ships could be viable?*Required

- Before 2020
- 2020
- 2030
- 2040
- Never

What are the most important drivers for LNG bunkers in terms of the port's commercial position?

	Most Important	High Importance	Medium	Low Importance	Least Importance
Location relative to ECA	○	○	○	○	○
Number of Ship Calls	○	○	○	○	○
Pricing of LNG vs. other fuels	○	○	○	○	○
Other competing bunkering ports	○	○	○	○	○
Provisions for LNG bunkering facilities	○	○	○	○	○
Demand from Ship owners and suppliers	○	○	○	○	○
Positive public perception	○	○	○	○	○
Status as major bunkering port	○	○	○	○	○

What proportion of the total bunkering volume at your port do you expect to be in LNG within the following periods?*Required

	5 years	10 years	20 years	30 years
0%	○	○	○	○
5%-10%	○	○	○	○
10%-20%	○	○	○	○
More than 20%	○	○	○	○

Rate the factors that could prevent the use of LNG as a marine fuel? (1 being least important and 5 being most important)*Required

	1	2	3	4	5
Lack of Policies/ Regulations	○	○	○	○	○
Unavailability of Natural Gas	○	○	○	○	○
Huge Investments required for Liquefaction and regasification of natural gas	○	○	○	○	○
Cost of Engine overhaul/ retrofits/ new builds	○	○	○	○	○
No present restrictions on Non ECA's	○	○	○	○	○
Fewer existing LNG fleet	○	○	○	○	○

	1	2	3	4	5
Lack of technology for existing engines ovehauls and retrofits	○	○	○	○	○
Confusion pertaining to the technology of LNG tanks for new build (SPB/ Moss/ Membrane)	○	○	○	○	○

ANNEXTURE-3

SHIP OWNERS AND OPERATORS APPROACHED

Owner Name	Email	Operator name	Email
A&L CF March 5 Ltd	marsms@evergreen-marine.co.uk	ABC Maritime AG	sp@abcmaritime.ch
Ada S H+H Schepers	mail@hschepers.de	APL Ltd	erep_americas@apl.com
Adrien Shipping Pte Ltd	operations@klaveness.com	Aurum Ship Management FZE	ops@aurumship.com
Afrika	management@doehle.de	Bosowa Lloyd PT	info@bosowa.co.id
Alexandra Stefan Patjens	info@reederei-patjens.de	Ceylon Shipping Corp Ltd	cscl@cscl.lk
Alice Rickmers Schiffs	info@rickmers.com	Ceyship Management Ltd	corporate@ceyline-group.lk
Angeles	charterops@nsc-shipping.com	China Shipping Intl Shipmgmt	lys@csiscgz.com
Aquitania GmbH & Co	info@ahrenkiel.net	Claus-Peter Offen Reederei	bewerbung@offenship.de
Asian Wind Shipping Ltd	technical@ashipsmanagement.com	CMA CGM SA The French Line	webmaster@cma-cgm.com
Auguste Schifffahrts	de-sdc-man@bs-shipmanagement.com	COSCO BULK	xiangshch@cosbulk.com
Balearic Sea Shipping Corp	webmaster@cma-cgm.com	COSCON	ebsupp@coscon.com
Beaufort Sea Shipping Corp	ism@cma-cgm.com	Cosmo Sealand Co Ltd	lgbmo@mail.co.jp
Bering Sea Shipping Corp	ism@cma-cgm.com	CSC Oil Transportation S Pte	ncotcs@singnet.com.sg
Bernhard S	info@reederei-schepers.de	Danaos Shipping Co Ltd	danship@danaos.gr
Blue by Seven Shipping Co Inc	info@ftnshipping.com	Delmas	accueil@delmas.net
Blue	info@remimaritime.com	Delphis NV	info@delphis.be

Harbour Maritime SA			
Borkum GmbH & Co KG	info@sunship.de	Delta International Shipping	info@dis-libya.com
Bourbon Offshore Labuan Ltd	dist_bomi_qhse@bourbon-online.com	Denak Depoculuk	denak@denak.com.tr
Bourbon PS SASU	bourbon@bourbon-online.com	Densa Denizcilik Sanayi	operation@densashipping.com
Boxcarrier No 1 Corp	danship@danaos.gr	DOF Management AS	management@dof.no
Bruno Schulte Shipping GmbH	shipmanagement@schulteship.de	Dongwon Industries Co Ltd	www.dwml.co.kr
Caiano Ship AS	post@caiano.no	DST Shipping Inc	dstship@otenet.gr
Cape Flores Shipping Co Ltd	marketing@csmcy.com	Eastern Car Liner Ltd ECL	pcc-ame@ship.ecl.co.jp
Cape Magnus Navigation Co Ltd	whlship_mar@wanhai.com	El Reedy Shipping Agency	chartering@elreedyagency.com
Cape Mondego mbH & Co KG	martime@martime.de	Elisabeth Ltd	elisabeth@onvol.net
Cape Moss Shipping Co Ltd	marketing@csmcy.com	Elmira Shipping & Trading SA	general@elmira.gr
Carna Shipping Pte Ltd	nyksm@nyksm.com.sg	Emirates Shipping Lines FZE	info@emiratesline.com
Castle Dignity LLC	general@seacastleships.com	Emstrans Schpvaart Management	operations@grona-shipping.com
Castle Direction LLC	cn-sdc-man@bs-shipmanagement.com	Evergreen Marine Corp	master.eversummit@evergreen.amosconnect.com
Chahat Shipping Lines Inc	admin@primetankers.ae	Executive Offshore Pte Ltd	offshore@executiveoffshore.com
Chicago Schiffahrtsg	fleetmanagement@nsc-ship.com	Far Shipping Lines Pte Ltd	admin@farshipping.com

es			
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Christos Maritime	info@costamare.com	Franbo Sagacity SA	ism@franbo.com.tw
Clayton Shipping Inc	fastshippingagency@yahoo.com	Future Trend Nautical LLC	info@ftnshipping.com
Conti 33 Conti Baltimore	mail@hanjinsm.com	GAC Marine Services Pvt Ltd	hq@gac.com
Conti Hong Kong	info@reederei-nsb.com	GasChem Services GmbH & Co KG	gaschem@gaschem.de
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Cosco Istanbul Maritime Ltd	ebsupp@coscon.com	Gateway Shipping Pvt Ltd	shipping@gatewayshipping.org
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Costis Maritime	info@costamare.com	Golden Star Marine Pte Ltd	gdstar@singnet.com.sg
CSIC Pacific Pte Ltd	general@pstmanagement.com	Gram & Co AS	gramco@pdgram.com
Cypress Maritime Panama SA	pblmo@mail.mol.co.jp	Hachiuma Steamship Co Ltd	ship.bulk@hachiuma.co.jp
Cumeria Shipping Co Ltd	mail@intership-cyprus.com	Hafiz Darya Shipping Co	info@hdslines.com
Cypress Maritime/Koyo Shosen	www.shoei-kisen.com	Handytankers K/S	cph.ops@handytankers.com
Daphne	safety@doehle.de	Hanjin Shipping Co Ltd	samgim@hanjin.com
Darya Maan Shipping Ltd	aesmi.tech@angloeasterngroup.com	Hapag-Lloyd AG	chartering@hlag.com
Denak Depoculuk	denak@denak.com.tr	Hyundai Merchant Marine Co Ltd	gys@hmm21.com
Dino Shipping Co	info@costamare.com	Iino Kaiun Kaisha Ltd	imsstaff@ex.iino.co.jp

Dora SNC	matma1@evergreen-marine.com	International Shipping-INLACO	inlacosaigon@inlacosaigon.com
Dritte RHW Schiffahrts GmbH	info@reederei-wulff.de	Interocean Energy Pvt Ltd	bunkers@interocean.lk
Due Feng Shipping Co Ltd	ism@franbo.com.tw	Iran Shipping Lines	niknafs@irisl.net
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Eagle Shipping & Trading Ltd	operation@densashipping.com	JOSCO Yuansheng Shipping	josco_yuansheng@josco.com.cn
EM Astoria Shipping Ltd	eurobulk@euroltd.gr	Jubilee Sailing Trust Ltd	info@jst.org.uk
Erdinger Shipping Pte Ltd	lilent@dhiveinet.net.mv	Kalkavan Shipmanagement & Co	info@kalkavanshipmanagement.de
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European Carriers Inc	mail@ume.gr	KGJ Cement Singapore Pte Ltd	singapore@kgjcement.com
Evelyn Schulte Shipping GmbH	reederei@schulteship.de	Korea Shipmanagers Co Ltd	ksm@ksmgrs.com
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Express Offshore Transport Ltd	enquiries@miclynexpressoffshore.com	Larus SA	larus@larus.gr
Falcon Grace Pte	mail@synergymarine.sg	Lily Shipping & Trading Pvt	lilent@dhivehinet.net.mv

Ltd			
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Folegandros Maritime Co	cn-sdc-man@bs-shipmanagement.com	Maritime Enterprises Mgmt SA	info@marentp.gr
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FPG Shipholding Panama 4 SA	imsstaff@ex.iino.co.jp	MCP Mini Container Pool	info@mcp.com.cy
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Frisia Munster KG	info@hartmann-reederei.de	Mercator Ltd	mercator@mercator.in
Gaining Enterprise	matma1@evergreen-marine.com	Miclyn Express Offshore Pte	enquiries@miclynexpressoffshore.com
Genshipping Corp	plovba@s-plovba.si	Mitsui OSK Lines Ltd	pblmo@mail.mol.co.jp
Gentian Shipholding Inc	operations@roxanashipping.com	MPC Munchmeyer Steamship-GEU	info@mpc-steamship.com
GL Venture Shipping Inc	www.hms21.com	MSC Mediterranean Shipping Co	info@mscgva.ch
Golden Pacific Intl & Holdings	goldentankers@gmail.com	MTM Ship Management Pte Ltd	prashant.lokhande@mtmsm.com
Good Fortune Heavylift Shpg	joscocjb@josco.com.cn	Nanjing Tanker Corp	xujm@njtc.com.cn
Grace Ocean Pte Ltd	admin@graceoceanship.com	National Navigation Co	felmansy@nnc.egnet.net
Gram Car Carriers II Pte Ltd	osm.sin@osm.no	Navios Corp	www.navios.com

Great Lakes Navigation Pte Ltd	info@simatech.com	Nile Dutch Africa Line BV	info@niledutch.com
Great Song Shipping Ltd	operations@sinotranship.com	Nisshin Shipping Co Ltd	ship@bigthree.co.jp
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Kono Shipping Inc	temmkobe@temmkobe.co.jp	Sinoecl Auto Liners Ltd	seals@sinoecl.com.hk
KR Shipping Line Inc	chartering@elreedyagency.com	Sinotrans Ship Management Ltd	operations@sinotranship.com
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Letavia Schiffahrts GmbH	info@hammonia-reederei.de	Star Global Marine Pte Ltd	enquiry@starglobal.com.sg
Limar Liman	info@limar.com.tr	Stemat BV	info@stemat.com

Litohoro Shipping SA	dstship@otenet.gr	Sunship Schiffahrtskontor KG	info@sunship.de
Lockheart Shipping	mail@anangelmar.com	STX Pan Ocean Co Ltd	panocean@stxpanocean.com
Lomar Charters Ltd	info@lomarshipping.com	Synergy Marine Pte Ltd	mail@synergymarine.sg
Los Halillos Shipping Co SA	cn-sdc-man@bs-shipmanagement.com	Swissmarine Inc	ship@swissmarineinc.net
Macesal Shipping Inc-LIB	general@zodiac-maritime.com	Thomas Schulte Reederei GmbH	reederei@schulteship.de
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Manzanillo Shipping Ltd	ops@pacificcarriers.com.sg	Vietnam Sea Trans Chartering	operation@vitranschart.com.vn
Mare Siculum Schiffahrts	info@hansa-mare.de	Vinalines Shipping Co VLC	hanhnv@vinalines-shipping.com
MCC Leasing No 24 Ltd	marsms@evergreen-marine.co.uk	VISHIP JSC	info@viship.com.vn
Mercator Ltd	mercator@mercator.in	Wan Hai Lines Ltd	whlship_mar@wanhai.com
Mereda GmbH & Co KG	stw@navalis-ship.com	Wisdom Marine Lines SA	biz.op@wisdomlines.com.tw
Michael Maritime Co Inc	office@unimor.eu	Wulff H	info@reederei-wulff.de

WIZ GLS Co Ltd	sundo@sundoship.com
Yang Ming Marine Transport	kechu@yml.com.tw
Zodiac Maritime Agencies Ltd	general@zodiac-maritime.com

World's LNG Liquefaction Plants and Regasification Terminals

As of March 2014

World's LNG Liquefaction Plants:

Source: www.globallnginfo.com

On-Stream	Under Construction	Planned
Adgas LNG Plant (UAE)	Australia Pacific LNG Plant (Australia)	Abadi Floating LNG Plant (Indonesia)
Algeria LNG Plants (Algeria)	Colombia/Exmar LNG FLRSU (Colombia)	Arrow LNG Plant (Australia)
Angola LNG Plant (Angola)	Donggi-Senoro LNG Plant (Indonesia)	Baltic LNG Plant (Russia) Cancelled!
Arun LNG Plant (Indonesia)	Gladstone LNG Plant (Australia)	Bonaparte LNG Plant (Australia)
Atlantic LNG Plant (Trinidad & Tobago)	Gorgon LNG Plant (Australia)	Brass LNG Plant (Nigeria)
Bontang LNG Plants (Indonesia)	Ichthys LNG Plant (Australia)	Browse Floating LNG Plant (Australia)
Brunei LNG Plant (Brunei)	Iran (NIOC) LNG Plant (Iran) Suspended!	Cameron LNG Plant (USA)
Damietta LNG Plant (Egypt)	Petronas Floating LNG-1 Plant (Malaysia)	Cove Point LNG Plant (USA)
Darwin LNG Plant (Australia)	PNG LNG Plant (Papua New Guinea)	Delta Caribe LNG Plant (Venezuela) Suspended!
EG LNG Plant (Equatorial Guinea)	Prelude Floating LNG Plant (Australia)	Douglas Channel LNG Barge Plant (Canada)
Egyptian LNG Plant (Egypt)	Queensland Curtis LNG Plant (Australia)	Fisherman's Landing LNG Plant (Australia)
Kenai LNG Plant (Alaska, USA)	Sabine Pass LNG Plant (USA)	Freeport LNG Plant (USA)
Marsa El Brega LNG plant (Libya)	Wheatstone LNG Plant (Australia)	Gulf LNG Plant (Papua New Guinea) Cancelled!
MLNG Satu Plant (Malaysia)		Kitimat LNG Plant (Canada)
MLNG Dua Plant (Malaysia)		Lake Charles LNG Plant (USA)
MLNG Tiga Plant (Malaysia)		LNG Canada Plant (Canada)
Nigerian LNG Plant (Nigeria)		Olokola LNG Plant (Nigeria)
Nordic (Skangass) LNG Plant (Norway)		Pacific Northwest LNG Plant (Canada)
North West Shelf LNG Plant (Australia)		Pars LNG Plant (Iran) Suspended!
Oman & Qalhat LNG Plant (Oman)		Persian LNG Plant (Iran) Suspended!
Peru LNG Plant (Peru)		Petronas Floating LNG-2 Plant (Malaysia)
Pluto LNG Plant (Australia)		Scarborough (Pilbara) LNG Plant (Australia)
Qatargas I LNG Plant (Qatar)		Shtokman LNG Plant (Russia)
Qatargas II LNG Plant (Qatar)		Sunrise LNG Plant (Australia)
Qatargas III,IV LNG Plant (Qatar)		Vladivostok LNG Plant (Russia)
RasGas I LNG Plant (Qatar)		Yamal LNG Plant (Russia)
RasGas II LNG Plant (Qatar)		
Rasgas III LNG Plant (Qatar)		
Sakhalin LNG Plant (Russia)		
Snohvit LNG Plant (Norway)		
Tangguh LNG Plant (Indonesia)		
Yemen LNG Plant (Yemen)		

World's LNG Regasification Terminals:

Source: www.globallnginfo.com

On-Stream:	***Under Construction:***	***Planned:***
Adriatic (Rovigo) LNG Terminal (Italy)	Arun LNG Terminal (Indonesia)	Adria LNG Terminal (Croatia)
Altamira LNG Terminal (Mexico)	Bear Head LNG Terminal (Canada) Cancelled!	Bradwood Landing LNG Terminal (USA) Cancelled!
Andres LNG Terminal (Dominican Rep.)	Beihai (Guangxi) LNG Terminal (China)	Cacouna LNG Terminal (Canada) Suspended!
Bahia Blanca GasPort (Argentina)	Boryeong LNG Terminal (S. Korea)	Calhoun LNG Terminal (USA) Cancelled!
Bahia LNG FSRU (TRBA) (Brazil)	Brindisi LNG Terminal (Italy) Cancelled!	Canvey LNG Terminal (UK) Suspended!
Barcelona LNG Terminal (Spain)	Diefu (Shenzhen) LNG Terminal (China)	Casotte Landing LNG Terminal (USA) Cancelled!
Bilbao LNG Terminal (Spain)	Dunkirk LNG Terminal (France)	Cilacap LNG FSRU (Indonesia)
Brunnsviksholme LNG Terminal (Sweden)	El Musel LNG Terminal (Spain) Stalled!	Corpus Christi LNG Terminal (USA) Suspended!
Cameron LNG Terminal (USA)	Hachinohe LNG Terminal (Japan)	Creole Trail LNG Terminal (USA) Cancelled!
Canaport LNG Terminal (Canada)	Hainan LNG Terminal (China)	Crown Landing LNG Terminal (USA) Cancelled!
Cartagena LNG Terminal (Spain)	Hitachi LNG Terminal (Japan)	East-Central Java LNG FSRU (Indonesia)
Chita I,II,III LNG Terminals (Japan)	Jieyang (Yuedong) LNG Terminal (China)	Ennore LNG Terminal (India)
Cove Point LNG Terminal (USA)	Kita Kyushu LNG Terminal (Japan)	Fujairah (Emirates) LNG Terminal (UAE)
Dabhol LNG Terminal (India)	Klaipedos LNG FSRU (Lithuania)	Gioia Tauro (Medgas) LNG Terminal (Italy)
Dahej LNG Terminal (India)	Lampung LNG FSRU (Indonesia)	GNL del Plata LNG FSRU (Uruguay)
Dalian LNG Terminal (China)	Pagbilao (Quezon) LNG Terminal (Philippines)	Goldboro LNG Terminal (Canada) Cancelled!
Dragon LNG Terminal (UK)	Porto Empedocle LNG Terminal (Italy)	Ingleside Energy LNG Terminal (USA) Suspended!
Elba Island LNG Terminal (USA)	Samcheok LNG Terminal (S. Korea)	Jordan Cove LNG Terminal (USA)
Energia Costa Azul LNG Terminal (Mexico)	Shandong LNG Terminal (China)	Kitimat LNG Terminal (Canada) Cancelled!
Escobar GasPort (Argentina)	Shin-Sendai LNG Terminal (Japan)	Le Havre LNG Terminal (France) Suspended!
Everett LNG Terminal (USA)	Swinoujscie LNG Terminal (Poland)	Levan (Falcione) LNG Terminal (Albania)
Fos Cavaou LNG Terminal (France)		LionGas LNG Terminal (Netherlands) Cancelled!
Fos Tonkin (Fos-Sur-Mer) LNG Terminal (France)		Lumut (Lahad Datu) LNG FSU Terminal (Malaysia)
Freeport LNG Terminal (USA)		Mangalore LNG Terminal (India)
Fujian LNG Terminal (China)		Mashal LNG Terminal (Pakistan)
Fukuoka LNG Terminal (Japan)		Mundra LNG Terminal (India)
Futtsu LNG Terminal (Japan)		Oregon LNG Terminal (USA) Cancelled!
Gate LNG Terminal (Netherlands)		Pengerang LNG Terminal (Malaysia)
Golden Pass LNG Terminal (USA)		Port Arthur LNG Terminal (USA) Cancelled!
Guanabara LNG FSRU (Brazil)		Port Dolphin Deepwater LNG Port (USA)
Guangdong LNG Terminal (China)		Priolo (Augusta) LNG Terminal (Italy) Cancelled!
Gulf Gateway GasPort (USA) decommissioned!		Rabaska LNG Terminal (Canada)
Gulf LNG (Clean Energy) Terminal (USA)		Rosignano LNG Terminal (Italy)
Gwangyang LNG Terminal (S. Korea)		SemanGas (ASG) LNG Terminal (Albania)

Hatsukaichi LNG Terminal (Japan)
Hazira LNG Terminal (India)
Higashi-ohgishima LNG Terminal (Japan)
Himeji I LNG Terminal (Japan)
Himeji II LNG Terminal (Japan)
Huelva LNG Terminal (Spain)
Incheon LNG Terminal (S. Korea)
Ishikari LNG Terminal (Japan)
Isle of Grain LNG Terminal (UK)
Izmir (Aliaga) LNG Terminal (Turkey)
Jebel Ali (Dubai) LNG FSRU (UAE)
Jiangsu Rudong LNG Terminal (China)
Joetsu LNG Terminal (Japan)
Kagoshima LNG Terminal (Japan)
Kawago LNG Terminal (Japan)
Kochi LNG Terminal (India)
Lake Charles LNG Terminal (USA)
Livorno LNG FSRU (Italy)
Manzanillo LNG Terminal (Mexico)
Marmara LNG Terminal (Turkey)
Mejillones LNG Terminal (Chile)
Melaka LNG FSU Terminal (Malaysia)
Mina Al-Ahmadi GasPort (Kuwait)
Mizushima LNG Terminal (Japan)
Montoir-d-Bretagne LNG Terminal (France)
Nagasaki Work LNG Terminal (Japan)
Naoetsu LNG Terminal (Japan)
Negishi LNG Terminal (Japan)
Neptune Deepwater LNG Port (USA)
Niigata LNG Terminal (Japan)
Northeast Gateway GasPort (USA)
Nusantara LNG FSRU (Indonesia)
Ohgishima LNG Terminal (Japan)
Oita LNG Terminal (Japan)
Panigaglia LNG Terminal (Italy)
Pecem LNG FSRU (Brazil)

Shannon LNG Terminal (S. Ireland)
Soma LNG Terminal (Japan)
Sonora LNG Terminal (Mexico)
Sparrows Point LNG Terminal (USA)
Tenerife LNG Terminal (Canary Isl.- Spain)
Texada LNG Terminal (Canada) Suspended!
Trieste LNG Terminal (Italy)
Vasiliko LNG Terminal (Cyprus) Suspended!
Vista del Sol LNG Terminal (USA) Cancelled!
Weaver's Cove LNG Terminal (USA) Cancelled!
Wilhelmshaven LNG Terminal (Germany) Suspended!

Penuelas LNG Terminal (Puerto Rico)		
Pyeong Taek LNG Terminal (S. Korea)		
Quintero LNG Terminal (Chile)		
Rayong LNG Terminal (Thailand)		
Reganosa (EL Ferrol) LNG Terminal (Spain)		
Revithoussa LNG Terminal (Greece)		
Sabine Pass LNG Terminal (USA)		
Sagunto LNG Terminal (Spain)		
Sakai LNG Terminal (Japan)		
Sakaide LNG Terminal (Japan)		
Senbokui I,II LNG Terminal (Japan)		
Shanghai LNG Terminal (China)		
Shin Minato Works LNG Terminal (Japan)		
Sines LNG Terminal (Portugal)		
Singapore LNG Terminal (Singapore)		
Sodeshi LNG Terminal (Japan)		
South Hook LNG Terminal (UK)		
Sudegaura LNG Terminal (Japan)		
Taichung LNG Terminal (Taiwan)		
Teesside GasPort (England)		
Tianjin (Tangshan) LNG Terminal (China)		
Tianjin LNG FSRU (China)		
Tobata LNG Terminal (Japan)		
Tongyeong LNG Terminal (S. Korea)		
Yanai LNG Terminal (Japan)		
Yokkaichi LNG Terminal (Japan)		
Yokkaichi Works LNG Terminal (Japan)		
Yung An LNG Terminal (Taiwan)		
Zeebrugge LNG Terminal (Belgium)		
Zhejiang Ningbo LNG Terminal (China)		
Zhuhai LNG Terminal (China)		

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