FEASIBILITY OF LNG POWER GENERATION TO PAVE IN SELF-SUFFICIENCY OF ENERGY IN SRI LANKA

GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

INTAKE 37

FEASIBILITY OF LNG POWER GENERATION TO PAVE IN SELF-SUFFICIENCY OF ENERGY IN SRI LANKA

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AIM

Is to study about the feasibility of Liquified Natural Gas power generation to pave the path in achieving self-sufficiency of energy in Sri Lanka.

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LIST OF ABBREVIATIONS

Abbreviation	Word
ADB	Asian Development Bank
CALM	Catenary Anchor Leg Mooring
CEB	Ceylon Electricity Board
CH_4	Methane
COM	Cabinet Of Ministers
CO_2	Carbon Dioxide
FSRU	Floating Storage and Regasification Unit
HRSG	Heat Recovery Steam Generator
H_2S	Hydrogen Sulfide
InfraSAP	Infrastructure Sector Assessment Program
JICA	Japan International Cooperation Agency
kWh	Kilowatt Hours
LHF	Lanka Hydraulics Institute
LKR	Sri Lankan Rupee
LNG	Liquified Natural Gas
MMBtu	Million British Thermal Units
MPM	Multi Point Mooring
MW	Megawatt
NFE	New Fortress Energy
NG	Natural Gas
R-LNG	Re-gasified Liquified Natural Gas
ROE	Return Of Equity
SALM	Single Anchor Leg Mooring
SPM	Single Point Mooring
STS	Ship To Ship
TJV	Tripartite Joint Venture
USD	United States Dollar

CHAPTER 1

INTRODUCTION

1. Electricity systems around the world are changing at a rapid pace. With the increase of the world's population the living standards and the power consumption will increase. Therefore, according to the calculations and analyzations done by Ceylon Electricity Board, the global demand of energy will be expected get doubled in 2050 compared to 2000.

2. Sri Lanka consists of a wide range of renewable energy sources including biomass, hydropower, solar and wind power. But the electricity supply is interrupted time to time due to climatic conditions like droughts and also due to technical failures in power stations. Therefore, Sri Lanka requires an additional energy source that is more efficient and reliable.

3. Introducing LNG to Sri Lanka is a timely discussing point, where the Government intends use it for initial needs of the energy sector as Sri Lanka is aiming to be a zero-carbon country by 2050, developing cleaner energy sources.

4. In order to initialize the LNG project, the government has built an LNG energy generation plant called Yugadhanavi at Kerawalapitiya currently functioning using fossil fuel which can be further developed to function using LNG. In future, most of the fossil fuel power generation plants such as Kelanithissa will be working using LNG.

5. Simply, LNG is natural gas that is converted into a liquid form for the ease of storage and transportation. It represents approximately 1/600 of the volume of gaseous natural gas. It is odorless, colorless, toxic, and non-corrosive.

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OBJECTIVES

6. The objectives of this study are as follows:

   a. To extract the technology and engineering basics used in natural gas extraction, LNG conversion and transportation.

   b. To investigate about the Floating Storage & Regasification Unit and the on-shore LNG pipeline network.

   c. To explore the processes used inside the LNG power plant at Kerawalapitiya.

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CHAPTER 2

PROCESS OF IMPORTING LNG TO SRI LANKA

LAND - EXTRACTION OF NATURAL GASES

7. As shown in the figure 2.1, Natural gas deposits are traditionally accessed using a single vertical well by installing a steel casing and cement layer between hole and earth surface. This process is repeated until reach the layer above the natural gas deposit. Once certain amount of water has been removed from the coal seam to reduce pressure gas starts to flow from the seam. Various techniques have been developed to increase the amounts of gas that are at least from the coal. One option is an artificial fracture, and another option is multiple wells from the one pad.

8. To enhance the overall production area within the coal seams. Secure production can start as the water and gas reach the wellhead at the surface they are separated. In an underground network of pipes, the extracted water is treated to filter the salt content and alter the chemical balance so it can be reused in several beneficial ways. The gas is transported to dehydration and compression facilities to make it completely dry before it is sent up the main gas transmission pipeline to be further processed.

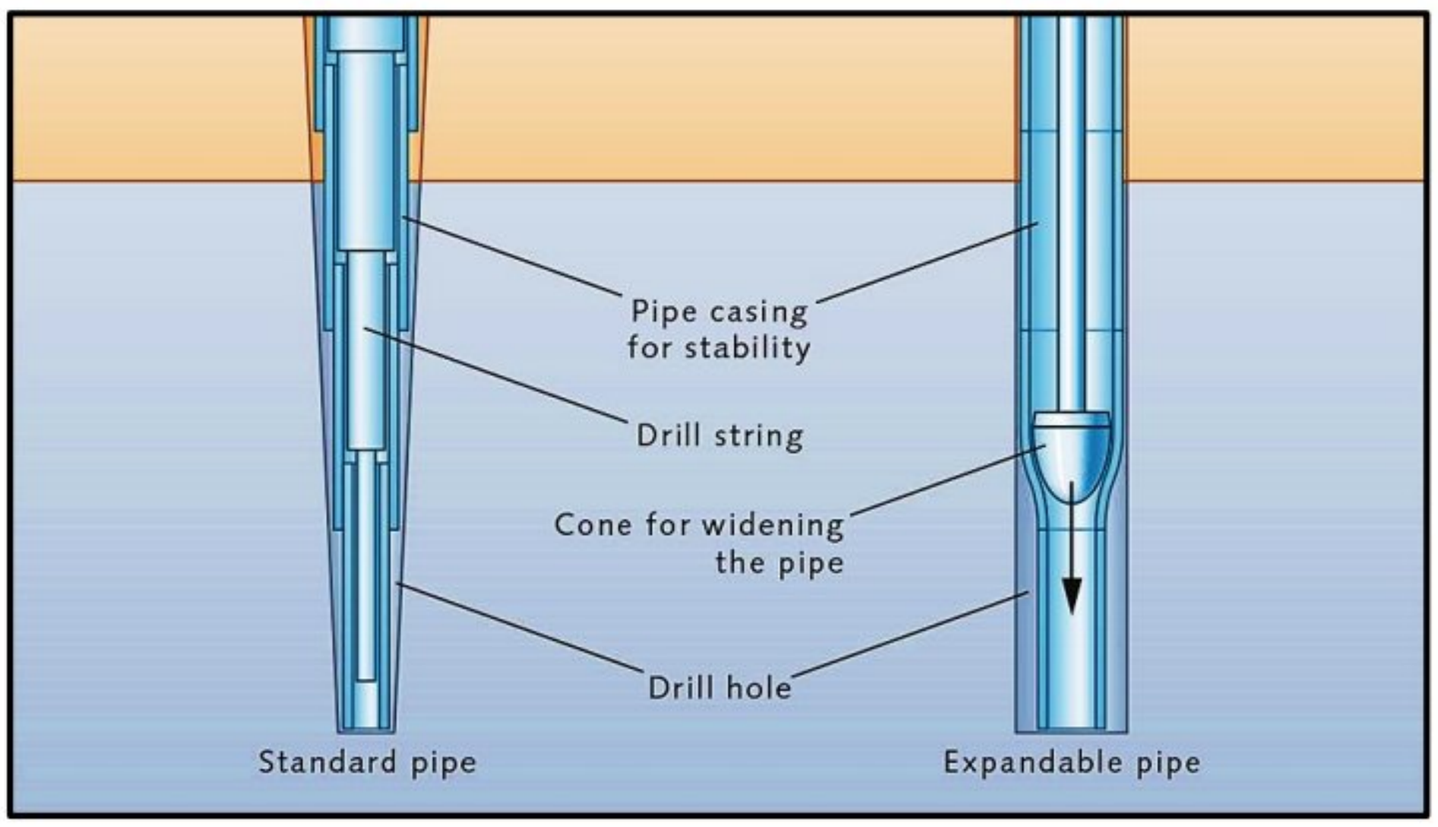

Figure 2.1 : Land Extraction

UNDER SEA - EXTRACTION OF NATURAL GASES

9. Wells are trained by two methods a drill ship, or an oil rig called mobile offshore drilling units. Each is adapted to a range of depth of water down to more than 2500 meters. The platform semi-submersible which floats and retains a stabilized position by means of anchors fixed on the seabed. A hole is drilled into the ocean floor using a large diameter drill bit and a steel pipe is installed. The smaller drill bit is then drilled through the conductor to drill. Once it reaches a predetermined depth more steel pipe casing is installed supporting the newly drilled hole. Cement is pumped through the casing moving between the casing and the hole surface. Securing it in the ground the cement is allowed to fix before drilling continues before drilling deeper. The equipment called blowout preventer or Bo P is installed on top of the well. Drilling fluid is continuously pumped into the hole while drilling this helps to keep the drill bit lubricated and cool to prevent overheating.

10. This production consists of the separation of oil and gas and water before the oil and gas is taken by pipeline towards a mainland terminal. Where it's impossible too expensive to link the field to the coast by a pipeline. As shown in figure 2.2, a ship is used as the floating production storage and offloading barge. On board the hydrocarbons and the water are separated the gas is stored.

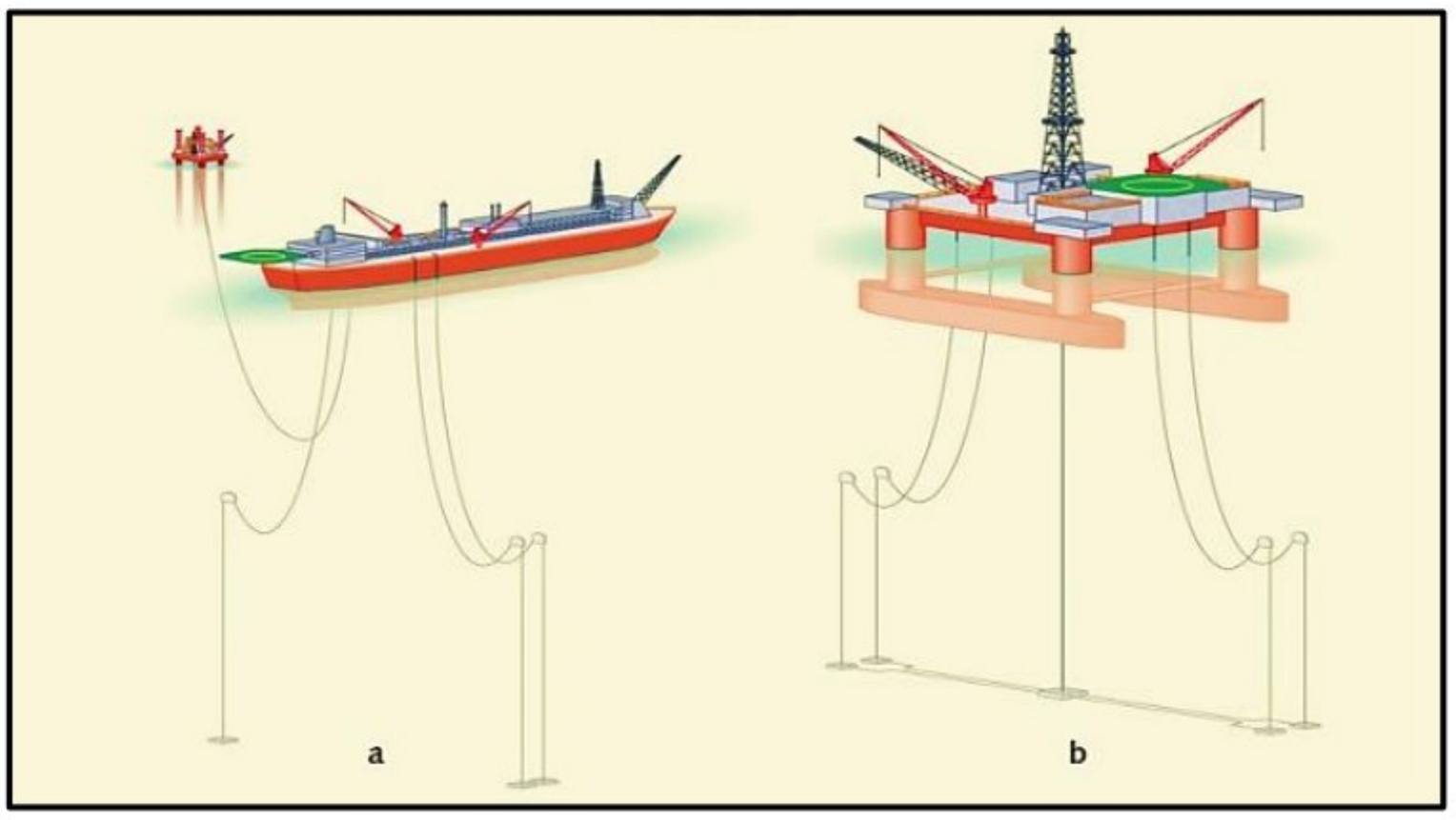

Figure 2.2 : Under Sea Extraction

CONVERSION OF NATURAL GAS IN TO LIQUIFIED NATURAL GAS

11. Natural gases extracted from the ground contains impurities like water and other liquids. First it is purified by using a series of pipes and vessels where impure liquids get separated due to effect of gravity. Then the gases like CO_2 and H_2S and the remaining water are removed to avoid them blocking the process by freezing during the cooling process.

12. Then the purified CH_4 is sent through giant heat exchangers where the gas is cooled up to -162 ^{o}C temperature where natural gas gets liquified. It shrinks its volume by six hundred times. Finally, this process creates a colorless, non-toxic liquid that is much easier to store and transport. The figure 2.3 shows the value chain of LNG production.

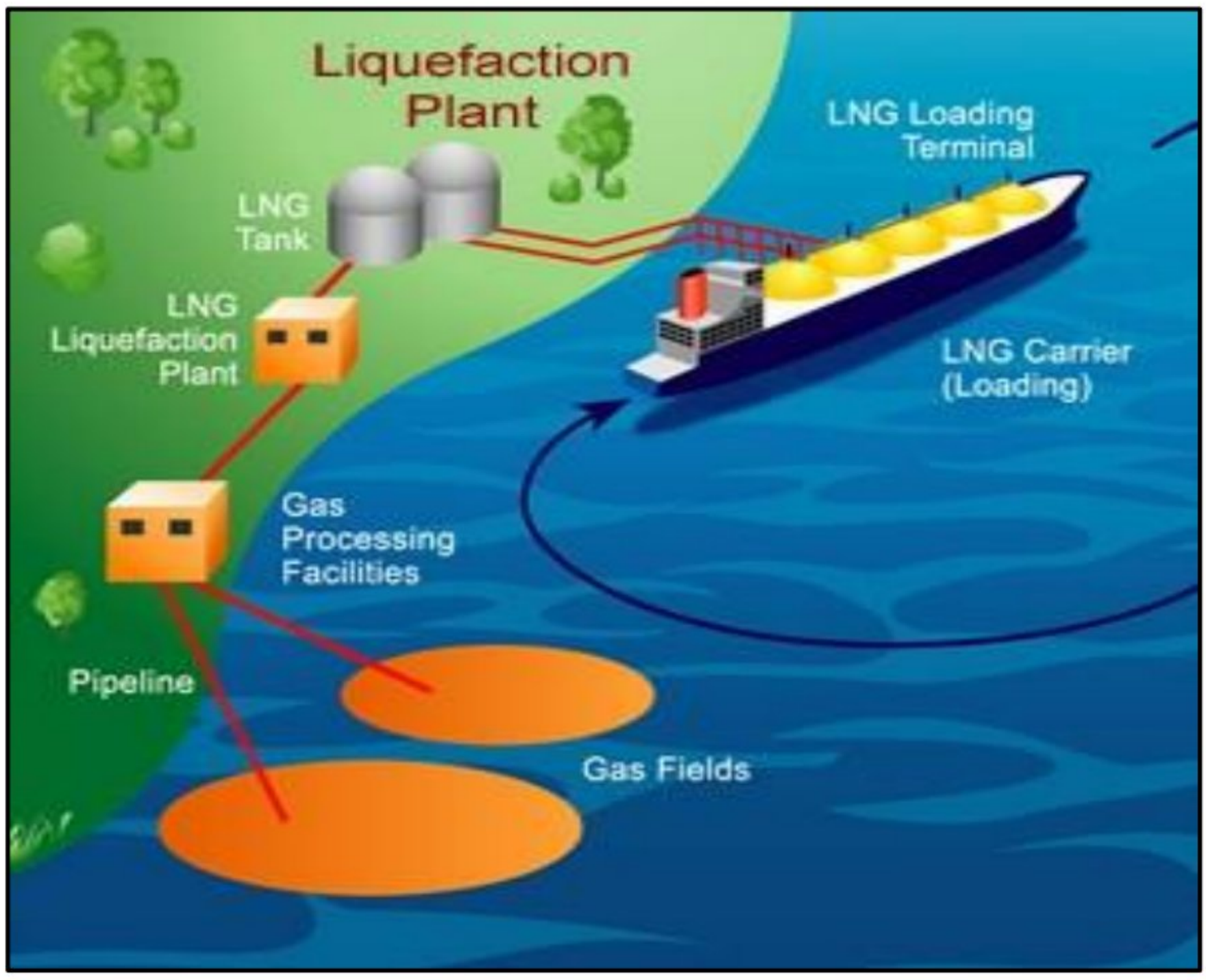

Figure 2.3 : LNG Conversion and Shipping

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SHIPPING

13. There are two prominent types of LNG Carrier vessels. Moss/Spherical type vessel and Membrane type vessel. The moss vessel consists of insulated single walled spherical tanks and membrane vessel is based on a very thin primary barrier supported through insulation. Moss type vessels are commonly used in the world because membrane type tanks are not self-supporting like the independent tanks in moss vessels.Figure 2.4 shows a Moss Type Tanker and figure 2.5 shows a Membrane Type Tanker.

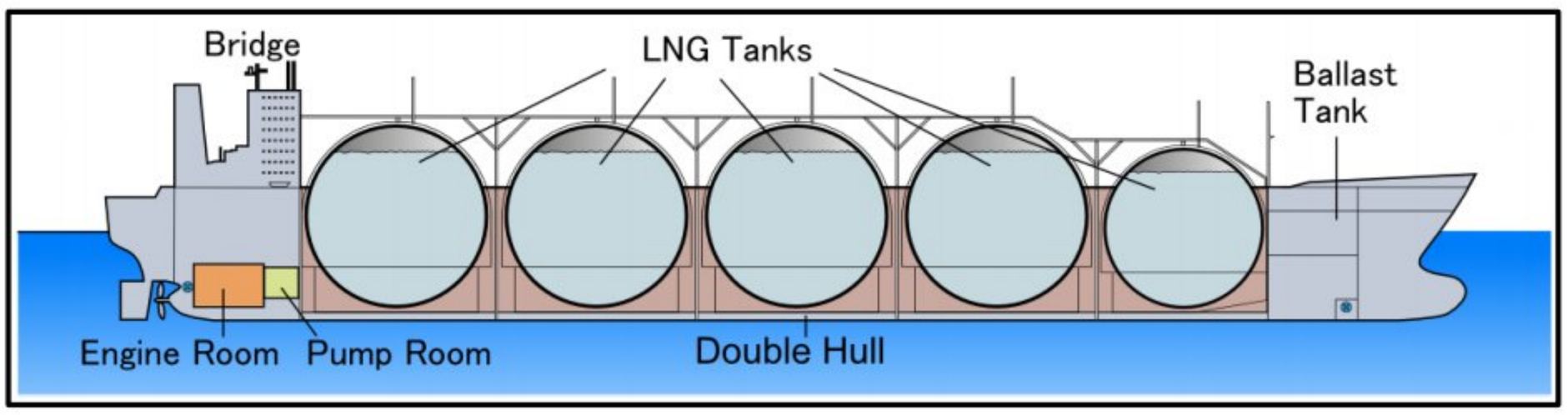

Figure 2.4 : Moss/Spherical Type Tankers

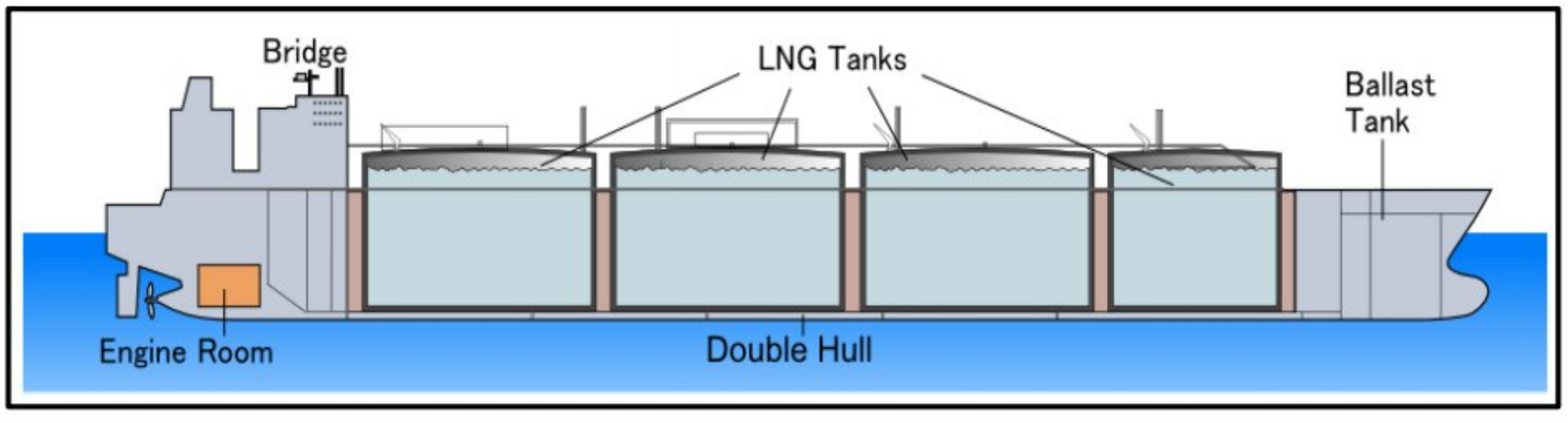

Figure 2.5 : Membrane Type Tankers

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CHAPTER 3

IMPLEMENTATION OF LNG TECHNOLOGY TO SRI LANKA

SHIP TO SHIP OPERATIONS

14. Ship to ship transfer refers to the transfer of ship's cargo, which can be oil or gas cargo, between two merchant tanker vessels positioned alongside each other. Either the ships can be stand still or the STS operation can also be performed while ships are underway. But it requires proper coordination, equipment, and approval to perform such operation. Both the masters of the ships are responsible for the entire STS operation. It is shown in the Figure 3.1.

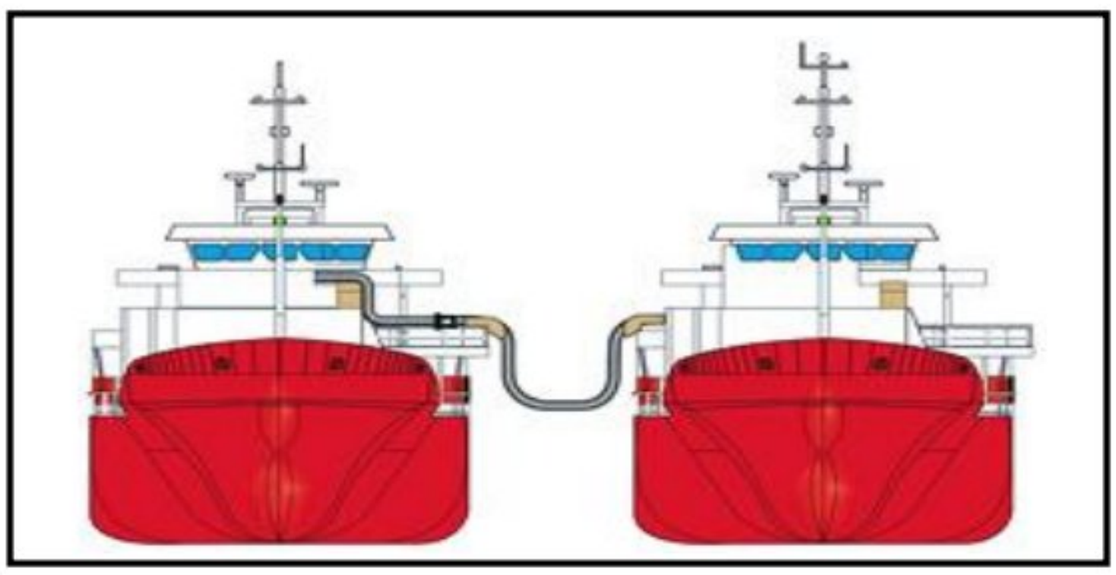

Figure 3.1 : Ship-To-Ship Transfer

15. During STS transfer pneumatic fenders shown in figure 3.2 are recommended to be used because the movable FSRU can absorb higher berthing energy.

Figure 3.2 : Pneumatic Fenders

FLOATING STORAGE & REGASIFICATION UNIT

16. Floating Storage and Regasification Unit is one of the main components that has to be introduced in order to initiate the development of LNG infrastructure in Sri Lanka. Since Sri Lanka does not have any platform terminals or land-based terminals in Sri Lanka it is suggested that investing on a FSRU is the most cost-effective option. A Membrane Type FSRU is shown in the figure 3.3.

17. FSRU is basically a ship which is having both storage and on-board regasification facilities. Here the stored LNG which is in the liquid phase is converted into gaseous phase using regasification process. It involves raising the temperature of LNG using sea water by passing through a heat exchanger to convert it into a gaseous state.

18. Then it is distributed to the required LNG plants along the pipe-line network. From the analysis done by ADB, The FSRU is expected to have a regasification capacity of 380 million cubic feet per day and 156,000 cubic meters storage capacity. It will be deployed at the Kerawalapitiya shore.

19. Considering the overview of LNG Carriers, the recommended FSRU size is 160,000 m^3-216,000 m^3 (Membrane type) with an internal pressure between 80 – 140 kPa and it will be stationed at 7°2'22.63"N, 79°49'29.15"E, roughly 4.97 kilometers off the beach on Kerawalapitiya's west coast. The site's water depth is approximately 15.4 meters. Within a 300-meter radius, the sensitivity of location may be changed. The FSRU is expected to enter operation in 2024 and supply volumes to CEB's power plants until 2033.

20. Boil-Off is a factor that has to be considered in storage and transfer of LNG. The LNG tank absorbs heat from the atmosphere and small portion of the LNG warms and turns to gaseous state. This gas is called "boil-off" and is removed from the tank, compressed, and piped back into the transmission pipeline. Boil-off is limited to a very small percentage of tank capacity by the large amount of insulation surrounding the tank.

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Figure 3.3 : Membrane Type FSRU

MOORING SYSTEM

21. Securing a ship or a vessel to the terminal or to a specific location is done through the mooring system. It is very important to consider about the mooring system to ensure the safety of the vessel and the neighboring infrastructure.

22. There are two types of Mooring systems. Single Point Mooring and Multi Point Mooring. Out of the two mooring systems, SPM (Consists of a large buoy anchored by catenary mooring lines) as shown in the figure 3.4 is recommended because it functions well in many oceanic conditions and provides easy access compared to MPM.

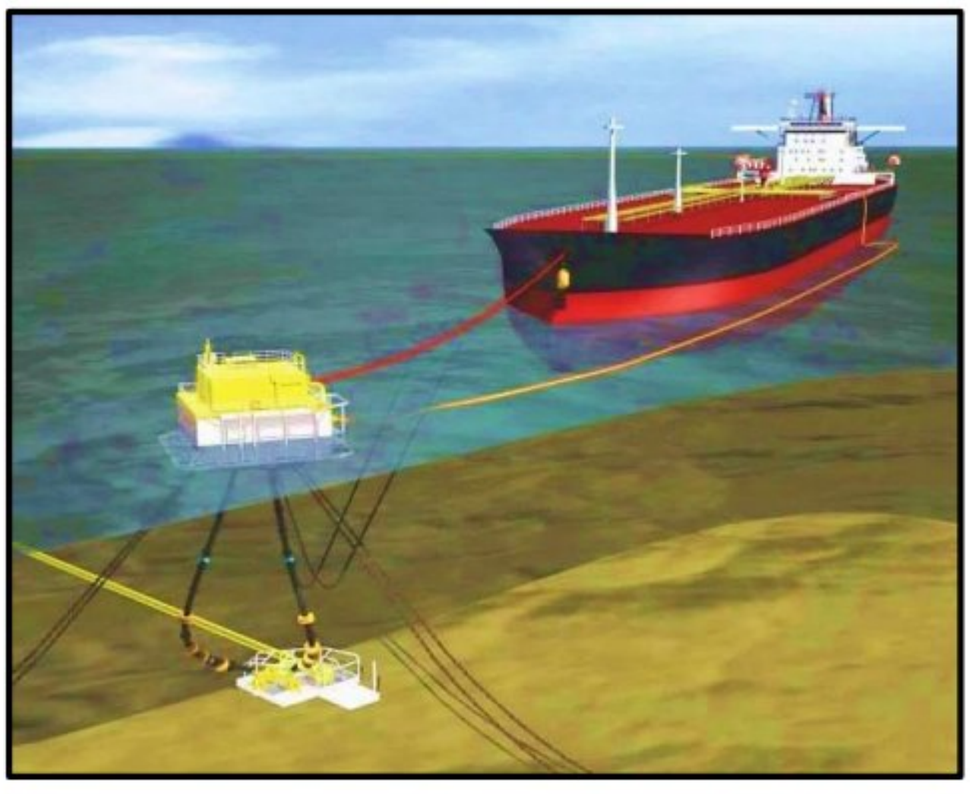

Figure 3.4 : Single Point Mooring System

REGASIFIED LNG DELIVERY NETWORK TO POWER STATIONS

23. High pressure gas line will be used to transfer the regasified LNG to the power plant which is approximately 5km straight path from the location of FSRU. According to the geographical study carried out by the Asian Development Bank, this requires a dredging and piercing of "Kalapu Gala" reef. But from a comparative assessment of several routes, it is recommended to lay a subsea pipeline of 20 inches diameter and total length approximately 5.66km bypassing the reef. This option avoids the risk of damage for fuel lines and avoids dredging.

24. The total length of onshore pipeline network to transport Regasified-LNG to identified power plants is approximately 15.21 km including pipeline in Kelanithissa power plant premises. The inside diameter of the pipeline is 11.7 inches. The inlet pressure at subsea pipeline is 42 bar while pressure required at power plants would be in the range 32 – 35 bar. The temperature of the gas inside will be at 30 ^{0}C The disadvantage is the requirement of longer lengths of pipelines.

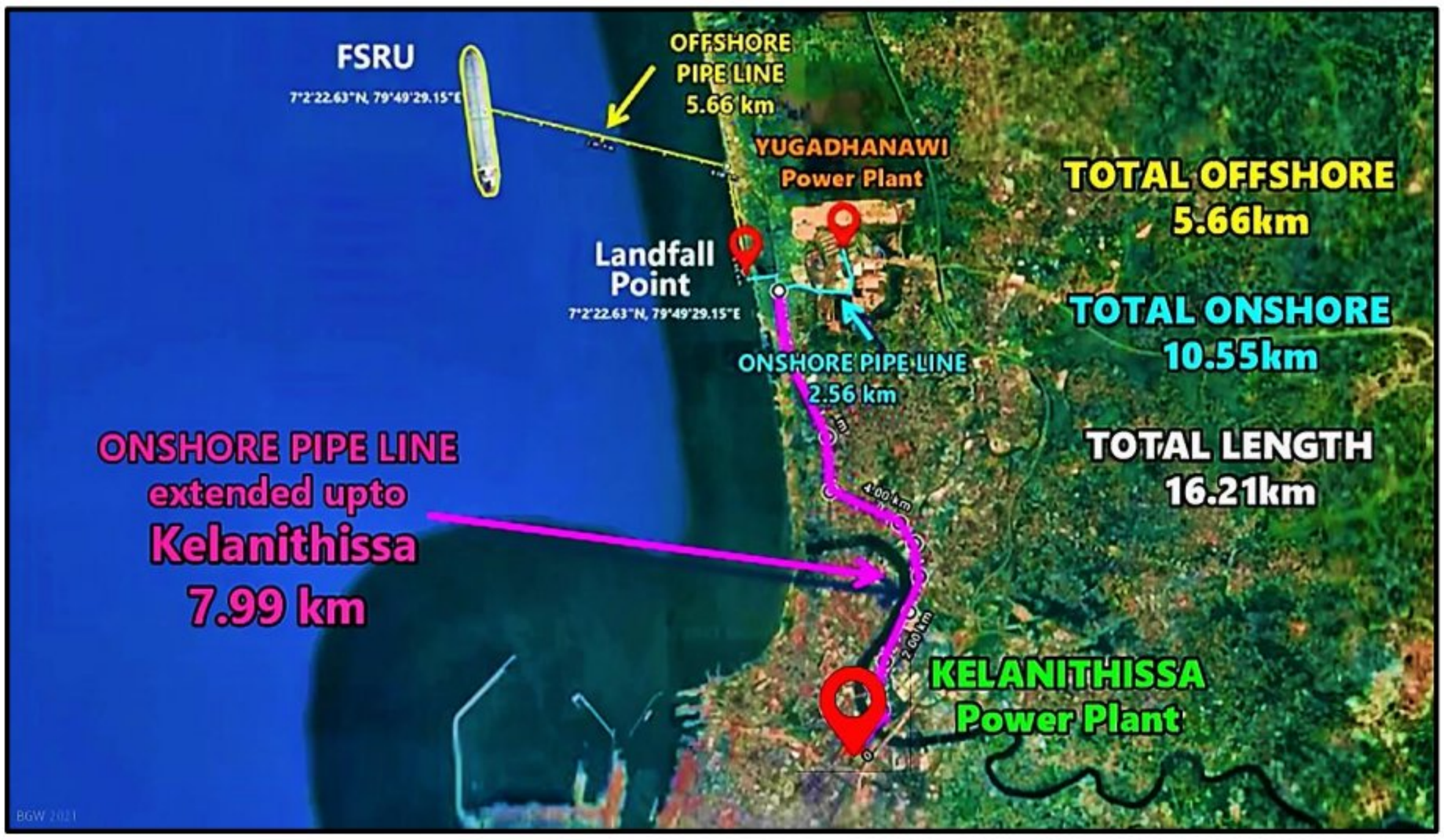

Figure 3.5 : Recommended Pipeline Route.

THERMODYNAMIC PROCESSES USED IN LNG POWER PLANT

25. Basically, Sri Lankan government commence to construct two combined power plants each one capable of 350 MW. There are two types of turbines are inside of a power plant that's why it's known as a combined power plant. Those two types are gas turbines and steam turbines.

26. Gas turbines can make 220 MW and steam turbines are capable of making 130 MW. That's how 350 MW were made. There are two Heat Recovery Steam Generators to generate required steam for the power plant.

27. According to the study carried out by CEB, this process has an average considerable efficiency because coal-fired power plants emitted 915 grams of CO_2 every kWh of energy generated. The average CO_2 emissions from combined cycle LNG plants were 436 grams per kilowatt hour. So, The LNG fired power plants emit around 40% less CO_2 than coal-fired power plants; It is most suitable for 350 MW size of power plants because those power plants are comparatively small scale capacitive than other units. So, this is the core process inside the Sri Lankan LNG power plants.

28. From thermodynamic point of view this is a combined gas cycle. In first step the pressurized LNG is mixed with atmospheric air and burned inside the combustion turbine. Electricity is produced by the gas turbine working due to that air flow.

29. The heat energy produced by the first turbine is used to produce steam by heating the water, supplied from the sea. This process happens inside the HRSG, which works as boiler. Then the Steam turbines working from the steam flow will again generate electricity. The process is shown in figure 3.9.

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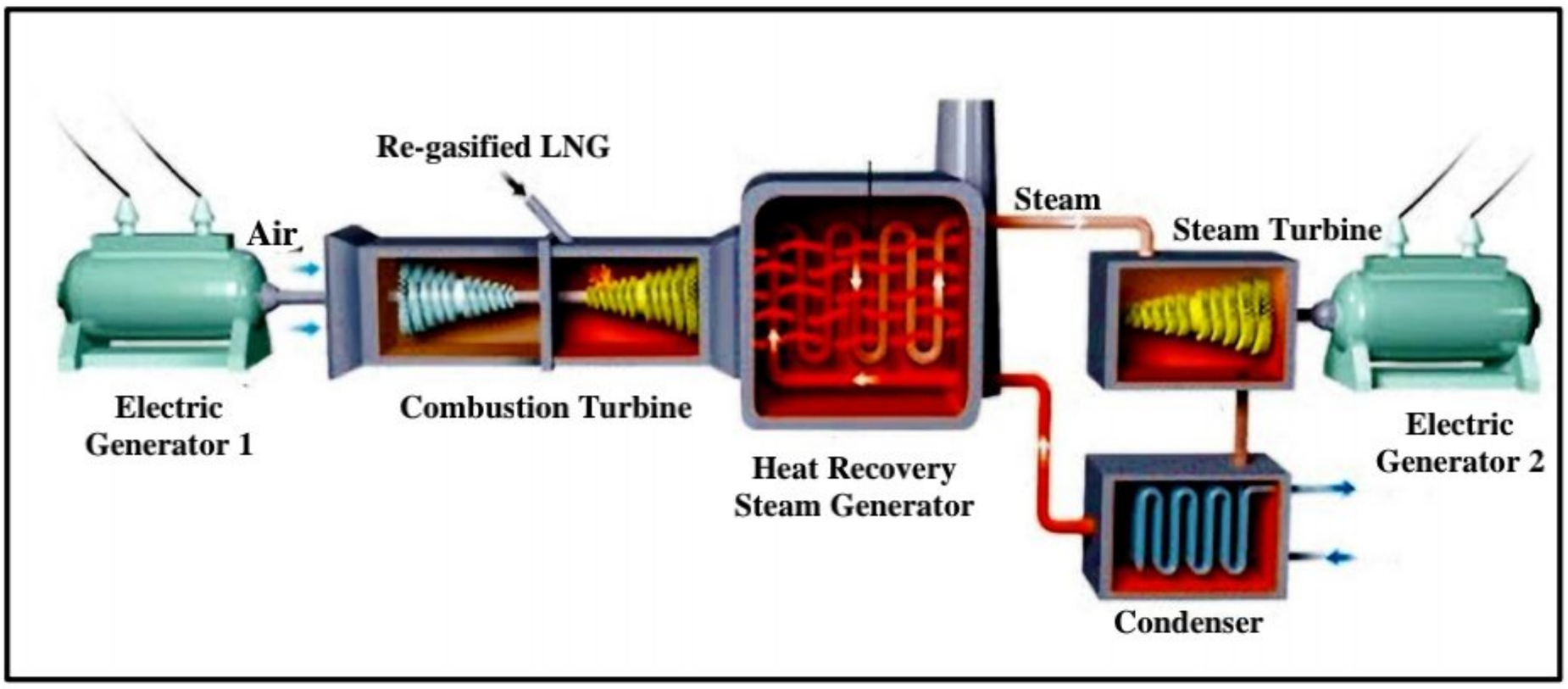

Figure 3.6 : The Combine Cycle Power Plant Schematic Diagram

30. According to the ADB analysis report, water is required to be supplied throughout this process for cooling and steam generation. Therefore, the constructions are done near the seacoast as a solution. On-site, a seawater cooling tower has been constructed. This is the first time in the country that such technology has been used. Our cooling water consumption is 25,000 cubic meters per hour.

31. The water required for the plant's continuous operation and for household usage inside the complex is taken from the sea. In this regard, a seawater intake system with two duty pumps and a pipeline buried at a depth of nearly 2 m under the seabed need to be constructed. The pipeline is 400 meters off coast and 1,000 meters on land. The saltwater will be filtered and demineralized as required to meet the plant's requirements.

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CHAPTER 4

ECONOMIC FEASIBILTY OF LNG POWER GENERATION WITH NEW FORTRESS ENERGY

32. The framework agreement allows the company New Fortress to supply liquefied natural gas to the west coast private company for a period of five years. Accordingly, it would be advantageous to allow New Fortress to come to the Sobhadanavi plant.

33. The Government of Sri Lanka, through the Secretary to the Treasury, has the option to include in the Gas Supply Conditions as part of the agreement on sale and purchase of shares or as an independent document. New Fortress & Company if the LNG power plant is installed at the Kerawalapitiya premises within a period of five years subject to age. Priority rights of Gas supply to any other potential power plant in Kerawalapitiya Will be delivered to the Company New Fortress.

34. At the same time the supply agreement is in accordance with the acting agreement and lasts for five years. The Government of Sri Lanka has the option of extending the LNG supply Agreement for a further period, subject to notice before the end of the fourth year.

35. To set the price for LNG supplied by New Fortress energy company, The Government of Sri Lanka will be given the option to select one of the following formulas.

a. Henry Hub *115%+5.05/MMBtu
b. JKM +USD 1.15/MMBtu

36. Another suitable formula, such as Brent-based formulas, for a more favorable price. With conversion back into gas by the Government of Sri Lanka That LNG is available up to the floating storage unit There is no need to pay any other charges including transport charges outside the above formulas for certification.

37. As stated in the Framework Agreement The entire cost of developing the terminal project will be borne by New Fortress energy company It includes a floating storage unit to convert it back to gas Shipyard system, Supply pipelines routes and associated facilities and infrastructure.

38. If the construction cost of the terminal exceeds its expected level Those cost are borne by New Fortress energy company It therefore has no effect on the proposed price. New Fortress has also agreed to pay full damages if the terminal project is more than 12 months old, as agreed in the framework agreement.

39. The company must obtain the necessary approval and approval from the Government of Sri Lanka to New Fortress & Co. to facilitate the proposal, including its revision, including the terminal project.

40. As terminal fixed fee the company New Fortress energy offering around US $ 1.5, and It has been agreed to provide 175 MMBtu gas capacities for a period of five years. This will cost the Ceylon Electricity Board an average annual cost of US $ 50.75 million.

41. However, the current fixed fee for the tender currently in progress for a floating storage unit and pipelines for conversion back into gas is US $ 3.11 MMBtu, as a result, the Ceylon Electricity Board will incur an annual cost of US $ 125.7 million in the first five years alone. Accordingly, compared to the above proposal, the company's proposal of New Fortress will result in an average savings of US $ 75 million per annual and an average savings of US $ 375 million within 5 years of the contract limit. Ceylon Electricity Board floating warehouse agreement and ongoing tenders for pipelines hence minimum guaranteed purchases for five years is US $ 202.

42. Although the pipeline terminal project is not currently expected to be connected to the Kelanitissa power plant If the Government of Sri Lanka requests New Fortress to do so New Fortress, has agreed to extend the pipeline at no additional cost .Therefore there will be no increase in the US $ 1.45 list fixed Cost on the extension of the pipeline to the Kelanitissa power plant.

43. Considering the deviations that have occurred due to the deviation of their hypothesis regarding Heat charges and the activation of this plant by 12 years of burning oil. New Fortress has warned that it may be difficult to comply with clause 3.1 (b) of the Framed agreement, which will lead to a deviation of US $ cent 9.9 / - from West Coast private LTD.

44. However, the average generation cost of West Coast Private LTD was US 4 cent 12.32KWh cents USD due to the weed supply and terminal tariff terms included in the New Fortress one proposal and the energy cost is about US $ 8 KWh .The average five-year generation cost, based on current crude oil prices(Rs.70per liter), is $ 13.79 cents. Accordingly, this is 11% cheaper than the cost of generation from fuel.

45. West cost private Ltd. will be provided with a fixed fee of US $ 3.11 West Coast Private LTD. has no savings and will only have the advantage of being a liquefied natural gas cleaner energy than fuel oil. Then it will be more advantageous to carry out operations using fuel oil. Then it will be more advantageous to carry out operations using fuel oil.

46. Also New Fortress This proposal will provide a Sobhadanavi power plant at a cost of US $ 5.57 million with an average cost of 5 years and it will be able to operate at a total cost of around US $ 7.18. Energy costs of US $ 5.83 million should compared to coal-based energy costs.

47. Considering the average cost of generating a unit of electricity, Inability to generate coal power, carrying out aggressive dredging to expand renewable energy capacity and Realistic inclusion of such electricity capacity in the national grid by 2023 to 2028 etc. West Coast Private (Pvt) Ltd with a total capacity of 650 MW subject to the policy framework and the average upgrade cost of the Sobhadanavi power plant will be around US $ 9.75 under New Fortress terms.

48. The sale of 40% share of the Kerawalapitiya power plant to American New Fortress Energy company for $ 350 million is only for the shares of a company, would allow a Company Director but no impact on power plant or the power generation. The only advantage is NFE will get their share of massive profits made by selling oil-based electricity at Rs. 28 instead of LNG-based electricity for Rs. 18, a Rs. 10 additional profits for every unit of electricity sold to CEB.

49. Considering the above-mentioned points, LNG is considerably more straightforward and cost-effective to manufacture than any other fossil fuel. Its price is more constant than other fuels, allowing companies to estimate energy expenditures more properly.

CHAPTER 5

ANALYSIS

50. Using natural gas, a fuel is one option that can achieve the energy sector targets that are arising with the increase of population and development of the country. since LNG is a cleaner gas out of other fossil fuel, it emits less CO_2 compared to coal and diesel respectively. Natural gas fired combined cycle power plants have more efficiency and require less maintenance and operating costs as compared to coal or diesel fired power plants.

51. Considering the initial requirement of finding a LNG source, there are two methods. Import LNG from another country or develop the infrastructure to extract or own Natural gases from the ground like the Mannar Basin. To identify the exact location of natural gas reserves, new scanning technologies are required. Since such technology is not available, If the reserves are located at the depth of seabed, it is required to build a suitable type of drilling and extracting platform as this is under sea extraction. Sri Lanka is lacking behind in such a technology and experience, so again have to purchase such services from another nation. Currently, Sri Lankas economy is having a lot of limitations. To overcome those limitation, requires investors to invest on our projects. According to the analysis, Sri Lanka is not having that much of capital investment at this moment and therefore the most suitable method is importing LNG at a minimum rate from a supplier in the LNG market.

52. Sri Lanka currently don't have tax provisions for natural gases. Therefore, for comparative analysis, diesel fuel cost has also been considered exclusive of all applicable taxes. The analysis report of ADB has analyzed the savings in fuel costs from switching the fuel from Diesel to natural gas for the identified power plants (for the LNG requirement estimated by Generation Planning Branch of CEB). Net savings in the fuel costs for the average condition remain positive until the LNG cost of USD 14.03 MMBtu. It is highlighted here that efficiency factors used for the estimation have been considered based on long term Generation Expansion Plan 2020-2039. Based on financial returns and computation of estimated savings, it can be concluded that in the present scenario, gas is one of the most suitable alternatives to other fossil fuels for generation of electricity. Table 5.1 exhibits the annual savings which can be obtain by switching to LNG.

Table 5.1 : Annual Savings from 2024 – 2032.

Year ending March 31	Annual Savings(USD million)
2024	241.93
2025	232.83
2026	243.72
2027	276.66
2028	306.74
2029	279.16
2030	310.95
2031	349.30
2032	388.97

53. After importing the fuel, have to analyze the type of terminal or method of storing of those importing fuel that needs to generate power by the plant. There are two types of terminals that suitable for Sri Lanka. They are land terminal and FSRU. In here, analyzing the Construction cost for LNG Terminal, Operation and Maintenance Cost for terminal (A typical rental fee for FSRU), Economic life of LNG Terminal is required. By analyzing the cost for each factor separately, the most suitable terminal type and find the total fuel supply cost as for some assumptions can be identified.

54. The following table shows a comparison of fuel supply cost for two types of terminals to power plant of 1200MW according to the JICA Survey Team to the LNG prize of 13.69 USD/MMBTU.

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LNG terminal type		Land	FSRU
Construction cost for LNG Terminal	MSUD	488	170
Operation and Maintenance Cost for terminal (A typical rental fee for FSRU)	MSUD /Year	3.9	50
LNG Price	USD /MMBTU	13.69	13.69
Economic life of LNG Terminal	years	30	30
Total supply amount of heat (Per working years)	MMBTU	1.08×10^9	1.08×10^9
Fuel (natural gas) supply cost	USD/MMBTU	14.25	15.24

Table 5.2 : Fuel Supply Cost with compared to land terminal and FSRU.

55. From this result, it is considered that the land type is more advantageous than the FSRU type in terms of fuel cost. In addition, the land type has better capacity expandability and more stable operation compared to the FSRU type. In consideration of possibility for national gas field development, it is anticipated that usage period of LNG will be shorter than 30 years. The FSRU type is advantageous when usage period of LNG is within 7 years.

56. Although when considering the storage feasibility, Kerawalapitiya is near to Colombo high population area where it is hard to find a suitable land area to establish a land terminal. Since Sri Lanka is a small island, it is secured from hazards like explosions if the regasification terminal is located away from the plant.

57. However, the Sri Lankan government is hoping to realize the operation of gas-fired power plants as early as possible to mitigate the tight power supply and demand, and the FSRU type is considered to be advantageous in terms of the short construction time. In addition, the FSRU type has lower capital investment than the land type, and the usage period of LNG is unclear at the present time. Therefore, the FSRU type has the advantage that the investment risk is low for the Sri Lankan Government.

58. The R-LNG would be transported from FSRU moored in open sea at Kerawalapitiya through a subsea manifold and subsea pipelines to reach onshore tie-in point. Lanka Hydraulics Institute has analyzed multiple route options for laying and building the subsea pipeline to transport R-LNG from FSRU to landfall point. The landfall point is taken at Dikkowita coast near seawater intake plant of West Coast Power plant. From the geographical analysis done by ADB, the 'kalapugala' reef is approximately 700 m – 800 m from the beach where it starts from Kelani estuary and ends at 1.2 km north of Kerawalapitiya. The LHI has analyzed the following options for route to landfall point in Kerawalapitiya.

(a) **Option 1.** Drilling across Reef-The shortest pipeline length of 4.9km will be from the straight path from FSRU to Kerawalapitiya. This requires a dredging and piercing of "Kalapu Gala" reef.

(b) **Option 2.** Bypass Reef-Based on analysis of different subsea route options and considering the location of the FSRU terminal, "Kalapu Gala" reef and landfall point, it has been recommended that subsea pipelines shall bypass the reef section and run parallel to the shoreline.

59. Based on comparative assessment of those routes, bypassing the reef and lay the subsea pipelines as per the Option 2 is recommend, because no dredging is involved, and it is cost effective even longer pipeline lengths are required.

60. After considering all facts on this project, an analysis was done by the ADB to estimate the annual savings.

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Particulars	Details
Cost of LNG	USD 7.0 per MMBtu
Pipeline Taxes	USD 0.20 per MMBtu
Regasification Tax	USD 1.85 per MMBtu
Total LNG price at plant gate	USD 9.05 per MMBtu
Price of diesel	USD 15.08 per MMBtu
Gross Calorific Value of natural gas	10,000 kcal per SCM

Table 5.3 : Annual Savings Estimation Based on Assumptions.

61. The savings would become zero at plant gate price of USD 16.09 per MMBtu for whole cost of LNG Regasification tax and pipeline tax. This implies that the project would be feasible for CEB until the sum of quotes received from bidders against three Request for Proposals (LNG sourcing, FSRU and Mooring and Pipelines) is below USD 16.09 per MMBtu. Considering LNG cost at USD 7.0 per MMBtu, the ceiling of regasification and pipeline tariff combined is estimated at USD 9.09 per MMBtu.

62. Based on assumed LNG cost of USD 7.0 per MMBtu which is realistic as per the future trends in LNG industry and the estimated regasification and pipeline tariff of USD 1.85 and USD 0.20 per MMBtu respectively, the plant gate price of natural gas is estimated at USD 9.05 per MMBtu. The annual savings earned from switching the fuel from diesel to natural gas is estimated at 43.8 billion LKR in 1st year of operations at average rainfall conditions.

CHALLENGES AND LIMITATIONS

63. During the process of implementing LNG power plants, as a country then are some limitations and challenges should overcome. As a third world country Sri Lanka is not in a easy position to proceed with any project.

64. The first and foremast challenge is security. As proceeding with such massive project natural disasters like tsunami and earthquake can affects the LNG power plant and FSRU units. So as solutions can artificially make wave breaks and as for the date Kerawalpitiya power station is the safest place. Not only that in order to prevent attack to this FSRU system, RADAR and SONAR system is recommended to install utmost units.

Not only that to maintain operation safety at the power plant due gas leakage and fires installing sensors and fire detectors at the power plant and FSRU unit highly recommended.

65. As a point choosing more efficient and profitable method for the construction of the terminals, pipelines and the power plant should be considered. In order to overcome such situation , as in future expect to extract natural gas and petroleum from mannar basin constructing terminal and power plant closer to proximity can be pumped out as more securely.Building 350 MW power plant or kerawalapitiya to meet up present needs it won't be sufficient to fulfil future energy demand. So, to overcome this limitation exploding the power plant up to at least 1200 MW and upgrade the power plants with high capacity turbines is the most reliable solution.

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CHAPTER 6

RECOMMENDATION AND CONCLUTIONS

66. Sri Lanka is trying to become a 24/7 uninterrupted power supplying country. For that With the uprising power crisis, CEB has recommended the most convenient and the profitable energy substitution is the LNG energy source.

67. Therefore, CEB recognized necessity of natural gas as a fuel for power plants. Even though in present there is no natural gas production in Sri Lanka, as a preliminary step CEB has looked at the possibilities of LNG power plant to meet the electricity demand of Colombo. Considering LNG over other sources of power there are some convenient positive feedbacks such as natural gas is more eco-friendly, profitable compared to problems cause due to other sources such as petroleum and coal power plants. This can be a good solution for problematic situations faced with thermal and coal power plant.

68. If it is possible to extract our own NG source from the Mannar basins, it will more profitable than importing. For extraction of NG, requires new technology and machinery from the experts in the world. From these kinds of projects, knowledge and technology could be gained from other nations and include them in future development projects.

69. The option of adopting a FSRU as an immediate requirement while the possibility of a land-based LNG terminal as a long-term solution is considered. However, LNG infrastructure must be established at least by 2021 in order to gain the maximum benefit of avoiding high-cost fuel oil. The combined cycle plants which are operating using oil in western region can be converted to Natural Gas immediately when the facility is made available.

70. As the ships are already being manufactured in Sri Lanka, it is possible to develop the technology to make those FSRUs instead of hiring from another country as this is a long-term project. If it is succeeded, extraction of NG can be done from the saved money and store in FSRUs and finally sell the excess in the Global LNG Market. Such improvements will lead Sri Lanka to become a developed and economically stabilized country in the future through smart patriotism. If the project of mining own NG becomes

successful, LNG can be used in domestic usage instead of other fuel, which is more efficient and eco-friendlier.

71. As the Energy is a very powerful weapon that enemy can cause a huge destruction for a country by interrupting at once. In fact, the security has to be ensured for this whole project as this is a most important project in the country. Securing the FSRU located at Kerawalapitiya is the initial step in this process. As it is a ship, securing by establishing a RADAR system and a set of guns on the ship is highly recommended.

ADVANTAGES AND DISADVANTAGES OF LNG POWER GENERATION

72. The main advantage is NG is less expensive than other fossil fuels and more efficient. In LNG power plants NG is used as the fuel. It is environmentally friendly because it burns cleaner than other fossil fuels. It's safer to store when compared to other fossil fuels because it stores at very low temperatures.

73. LNG requires special materials for storage as most materials become brittle and lose strength due to low temperature. As LNG is colourless and odourless gas if there is any leakage it makes detection virtuality impossible.

74. Though there are some negative thoughts holding back LNG power plants when comparing data with other power plants, LNG power supply can be the most convenient and promising solution for the energy crisis in countries like Sri Lanka. So as for this prevailing situation the best and the most convenient option for energy necessity is, moving to a LNG power plant.

75. 2x350MW Dual Fuel Combined Cycle Power Plants wiil be commissioned in western region by 2022. The associated LNG importing infrastructure to be developed on a fast-track process with sufficient capacity to serve for both the new power plants and the conversion of other oil-fired combined cycle power plants in the western region. Furthermore, an additional 3x350MW Natural Gas Combined Cycle Power Plants are expected to be commissioned by 2026 in either Kerawalapitiya or Hambantota. Associated transmission facilities also to be expedited in parallel to the power plant implementation schedule.

76. Introducing the project proposals of implementing new power plants to supply electricity directly to New Port City, Katunayake Free Trade Zone or Hambantota New

Industrial zone will ensure that the power could be used without any interruption due to high demands.

77. Even though there are some ups and downs in the proposal of LNG power plant, the Sri Lankan government had taken a positive step where they made an agreement with the US based energy firm "New Fortress Energy" to implement LNG power plant of 350MW at Kerawalapitiya which can cover up high percentage of the energy necessity. In near future Sri Lanaka can get the harvest of the LNG power generation to pave in self sufficiency of energy.

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