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# Vessel replacement plans considering emission control regulations

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# Vessel Replacement Plans Considering Emission Control Regulations

BY

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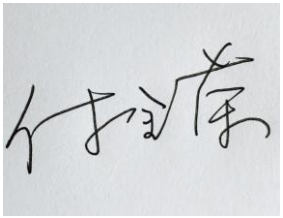
# DECLARATION

I certify that this master thesis presented here is the result of my independent research under the guidance of my supervisor. In addition to the part that has been annotated, this thesis does not contain other research results that have been published or written by others. Individuals and groups who have made important contributions to the research work in this paper have been annotated. The legal results of this statement will be fully borne by me.



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Review of the unforgettable study period, all sorts of feeling well up in my mind, and also I gain a lot. At this moment, I want to express my deepest appreciation to my teachers, friends and family for your consistent support and help to me.

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# ABSTRACT

In order to consolidate international status and enhance international competitiveness, countries around the world are improving their economies positively. Meanwhile, it is accompanied by a sharp consumption of fossil fuels such as oil and coal. The emissions of $CO_2$ and NOx lead to sea level rising and environmental pollution that is increasingly serious. Therefore, taking energy-saving emission actively gradually becomes an international consensus. However, Marine transportation, which was regarded as not very harmful to the environment, has become one of the focuses of international attention. There is some data that shows that the world's shipping industry consumes 2 billion barrels of fuel a year, which is more than 1 billion 200 million of the total emissions of $CO_2$, accounting for about 6% of the total amounts of global emissions. As we know that 30% of the world's annual emissions of NOx comes from ships at sea. As a result, governments and environmental organizations keep on improving environmental regulations in order to reduce the emission standards. In this context, shipping companies have to find new alternative solutions to deal with the increasingly stringent international conventions and rising fuel costs.

For the new ship replacement scheme, this paper mainly studies from four aspects, which including the government, market, port and shipping enterprises. The key point of this paper is to find how to take measures to save energy and reduce emissions of shipping enterprises. From the perspective of new energy instead of traditional energy, I will analysis the applications of wind energy, solar energy, nuclear energy and LNG and other new energy in shipping. Consequently, I found that LNG as a new kind of marine energy, did the best in the field of environmental and technical feasibility and also economic feasibility.

In this paper, I discussed the issue through the comparative method, case analysis, model analysis of specific application of LNG in the shipping, and I found that LNG

technology seems to give us a hope because it is not only clean, but also rich in reserves, even more than the oil reserves. If people use LNG as a ship power, we can easily alleviate the above two problems. Through this way, we can both reduce the consumption of fossil fuels in the shipping industry; as well effectively reduce the air pollution. Besides, low LNG can also lessen the operating costs of shipping companies. However, for the existing technology and policy, we still have a long way to go to achieve all the ships using LNG as fuels.

**KEYWORDS**: shipping industry, energy conservation, emissions reduction control, new energy, LNG

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# CHAPTER 1 INTRODUCTION

## *1.1.Background*

Shipping as the oldest mode of transportation, with its advantages such as low cost, large capacity and long distance, dominates in various modes of transportation. Along with the development of global integration and international economy, shipping industry has been developing rapidly, and made great contributions to the world economic trade. However, the problem of energy consumption and environmental pollution has become more and more severe, which has aroused wide attention from all over the world. Currently, many countries and regions have made very strict laws and regulations to restrict the fuel consumption and greenhouse gas emissions of shipping enterprises. Under this background, developing green shipping as well as paying attention to energy conservation and emissions reduction is the trends of the times.

In March 2008, the United Nations Climate Change Conference finally decided that shipping, air transportation and road transportation will be included into greenhouse gas emission reduction targets. This indicates that under the unified deployment of the United Nations, new standards and legislative restrictions about the ships' $CO_2$ emissions will be proposed inevitably.

At present, the global petrochemical energy is gradually reduced, thus the fuel costs account a majority part of the total cost of shipping transportation. Therefore, how to further improve the ship's energy saving work, and thus effectively reduce the cost of transportation is imminent. At the same time, how to combust efficiently and reduce the discharge of pollutants have also attracted the attention of the International Maritime Organization (IMO). That is to say, faced with tremendous pressure, the world shipping industry is increasingly influenced by high oil prices and the

challenge of environmental policies. As a result, in order to meet the need of this new form, the applications of new energy, and new technology is an important solution, as well as the future developing direction of shipping.

### *1.1.1. The present status of the shipping industry emissions*

Shipping is an important part of the world's transport industry, and nearly 80% of the foreign trade depends on shipping. Especially in the large and bulky goods transportation, its position is difficult to be taken place by other means of transportation. There are three main transportation systems (road transportation system, water transportation system and air transportation system), among which, water transportation is considered as the cleanest mode of transportation. Therefore, it is also known as "green transportation", however, it is still a threat to environment. There are also reports show that 30% of the world's annual emissions of NOx gas comes from the ships at sea. At present, the discharge of pollutants from ships at sea just like the automobile exhaust can seriously pollute the air, thus affect the health of the residents in the surrounding areas.

CO2 is considered to be blamed for climate change because of its accounts the majority part of greenhouse gases emitted by international ocean shipping. Although the emissions of CO2 from international shipping only account for 1.8% ~ 3.5% of the total global emissions, which is equivalent to the total CO2 emissions of Germany.(Zhang Shuang, Li Zhen, 2011) International Maritime Organization expert group’s research reports show that in 2007, the shipping industry discharged 1.2 billion tons of carbon dioxide. By 2020, it will reach 1.4 billion tons. Other research reports illustrate that the shipping industry currently consumes about 2 billion barrels of fuel every year, and the emissions of carbon dioxide are more than 1.2 billion tons, accounting for about 6% of global emissions. Some people forecast that by 2020, the global shipping industry will consume 500 million tons of fuel, and the emissions of greenhouse gases will rise by 75%. (Qi Kuanyuan, 2010)

Consequently, how to reduce the greenhouse gas emissions of the vessel and gas pollution as well as improve the competitiveness of shipping transportation are urgent for us.

### *1.1.2. Increasingly strictly anti-pollution conventions and laws*

With the control of sulfur content in the fuel of ships, MARPOL Annex VI and the regulating of ECA, which are in order to gas emissions are the most closely watched international rules and regional regulations of domestic and foreign shipping industry. The ECA includes the Baltic Sea area, the water area from North Sea to the English Channel southern continuous, and parts of North America will also be included in the future. As for the latest rules of MARPOL Annex VI and ECA requiring the use of low sulfur fuel oil, shipping industry is faced with a quite urgent schedule after ships entering the ECA:

①Since July 1, 2010, fuel sulfur content limit of ships that entering ECA down to 1%;

②Since January 1, 2012, the upper limit of the fuel sulfur content of the global sailing ships down to 3.5%;

③Since January 1, 2015, fuel sulfur content limit of ships that entering ECA down to 0.1%;

④Since January 1, 2020, the upper limit of the fuel sulfur content of the global sailing ships down to 0.5%; (Huang Zheting, 2010)

However, the actual implementation date depends on the assessment before 2018. If

the result of the assessment is not ideal, the actual implementation date will be postponed to January 1, 2025. Another test of the sulfur content of the fuel formulates a set of precision testing procedures that control the sulfur content value to 0.01%. At the same time, the European Commission stipulates that from January 1, 2010, the fuel sulfur content of all ships that park in the EU port must not be higher than the upper limit of 0.1%. (Chen Wei, 2013)

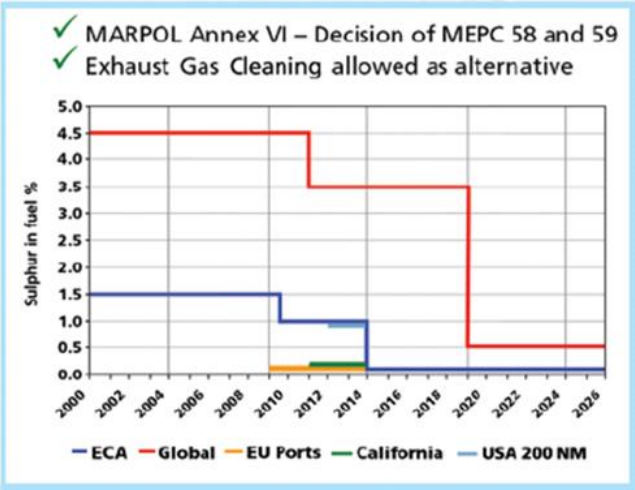


Figure 1 The term of national emission limits

Source：From Internet

China, as a member of the IMO, once accepted the requirements of the convention, thus we must conscientiously fulfill our obligations. It means that all ships flying the flag in the convention of ECA will reach the specified discharge standards; otherwise they are not allowed to enter. All of this put forward higher requirements for our country's shipbuilding industry and the shipping industry.

About the control of NOx emissions, according to the ship's construction year, the 2008 amendment has established three layer control standards in order to ensure that the gradual pattern can reduce the NOx emissions of ships. Compared with the NOx emissions limit value of Tier I, NOx emissions limit value of Tier II which was implemented on January 1, 2011 had decreased by 20%. Meanwhile, compared with the NOx emission limit value of Tier I, NOx emissions limits of Tier III which will

be implemented on January 1, 2016 had reduced by 80%. (Hou Zhongsen, 2013)

Although the shipping industry is relatively clean, the energy conservation and emissions reduction are still an irreversible trend all over the world. Shipping industry must make its contributions to the global environmental protection. In the face of serious environmental situation and regulatory policies, owners must be fully prepared both in software and hardware in order to make sure that the operation of the ships will meet the relevant regulatory requirements.

## *1.2. Purpose of the dissertation*

Due to the increasingly serious pollution of the shipping industry do to the ocean and air, the development of green shipping is the destined trend. Under the condition of the constant strict requirements of the ship emissions, the ships that compliance with environmental standards is not allowed to sail at sea. Therefore, the development of green shipping is the certain requirement to fulfill the international convention, and also the unavoidable choice for the shipping industry to improve the competitiveness among enterprises.

In this paper, through the study of alternative solutions to the ship, I found that these solutions can help the government and the market, mainly shipping companies, find a way to achieve energy conservation and emission reduction, pay attention to the combination of economic efficiency and environmental protection, and strive to achieve the green, recycling, low carbon and sustainable shipping industry, thus realize the shipping economic benefits, social benefits and ecological environment mutual promotion and common progress.

## *1.3. The research literature review*

### *1.3.1. Literature on emission control*

The related literature can be categorized into two main streams: literature on emission control and literature on vessel replacement.

There is a significant amount of literature on emission control. Many survey papers （Huang Zheting.2010; Hou Zhongsen, 2013; Li Zhenghong.2002) provide comprehensive reviews on this issue, and they all mentioned the increasingly stringent environmental regulations and regulations on ships' emission control. From "the Kyoto protocol" to "the United Nations framework convention on climate change" then to the "Copenhagen protocol", continuously control greenhouse gas emissions all over the world in order to make sure the concentration of greenhouse gases at a stable level. And in the discharge of pollutants, the most important thing is the establishment of new Annex VI of MARPOL and Emission Control Area (ECA). Both of them control the fuel sulfur content of the ships which enter the emission control area, and further promote the use of low sulfur oil in shipping industry.

### *1.3.2. Literature on vessel replacement*

The second stream of relevant literature is on vessel replacement. Qi Kunyuan (2010), Li Zhenghong (2002), Xu Wei(2015), and Zhang Shuang (2011), they all put forward that the government, the market, the port and shipping companies should work together to meet the current needs of the current policy for energy conservation and emissions reduction. In the terms of technology, the method includes ship's adjustment, the ship power alternatives, the use of low sulfur fuel, and also using exhaust gas scrubber and catalytic reduction method in order to carry out technological transformation on the ship. In Ship operations, we can achieve emission reduction targets by reducing the speed, strengthening the scientific

management of ships as well as the control of gas leakage and other methods.

Also some paper analysis the relative new energy, Zhang Fuxing. (2012), Yan Xinping. (2010), Wu Ming. (2013), Chen Wei. (2013), the development and application of some new energy sources. The main new energy sources are wind energy, solar energy, biomass energy, nuclear energy, ocean energy and LNG, etc. Through the analysis of the development status, the feasibility and characteristics of all kinds of new energy, we can ease the global energy crisis and reduce emissions of pollutants from ships; therefore, we can realize green shipping in the future.

### *1.3.3 Existing problems and improvement*

Although the literature I collected includes detailed analysis of the current development of emission control regulations, the necessity and measures of energy saving as well as emission reduction, and also the development and application of some new energy, there remains some problems.

First, the perspective that these papers are discussed is one-sided, not from the point of view of a systematic and complete way of thinking. My dissertation is combined with the background of the emission control and present condition of the emissions from shipping industry, including the related theory, measures and also the use of new energy sources. From multiple perspectives of analysis, the problem of the research seems to be more systematic and feasibility.

Second, these articles are lack of comparative analysis of Chinese and foreign countries. They did not highlight the gap of energy-saving emission reduction between China and other foreign countries. While my dissertation will pay attention to the improvement of this problem, enrich the research content and make the research more convincing and meaningful.

Third, these articles are lack of case analysis. They did not combine with the actual situation to analyze the replacement of new energy. Nowadays, LNG is the most realistic new energy, and the new energy ship mainly uses LNG as the fuel. My paper will focus on the application of LNG in the development of the ship, the technology applicability of LNG and economic feasibility in order to demonstrate the feasibility of alternative.

## *1.4 Main content*

This dissertation is divided into 6 chapters. Firstly, I analyze the current situation of shipping industry under pollutant emissions. Then based on the theory of scarce resources and sustainable development, I analyze the relationship between the shipping industry development and ecological system, thus through comparing the development of shipping industry of domestic and external, I find the main factors of restricting the low carbon development of our country's shipping industry. From the perspective of the government, the shipping enterprises and ports find out corresponding solutions in order to reduce energy consumption and pollutant emissions. Next, I illustrate some new energy sources that are to find out the alternative energy for the ship industry, and achieve the sustainable development of shipping industry in the future, especially LNG. Then I focused on the analysis of the characteristics, merits and drawbacks and application of the LNG ship, thus propose its technical and economic feasibility through using case study.

Finally I come to the conclusion that, in the context of energy-saving emission reduction, LNG is the cleanest, most economical and feasible new energy for shipping companies, and it also brings us a hope to cope with the increasingly stringent international convention.

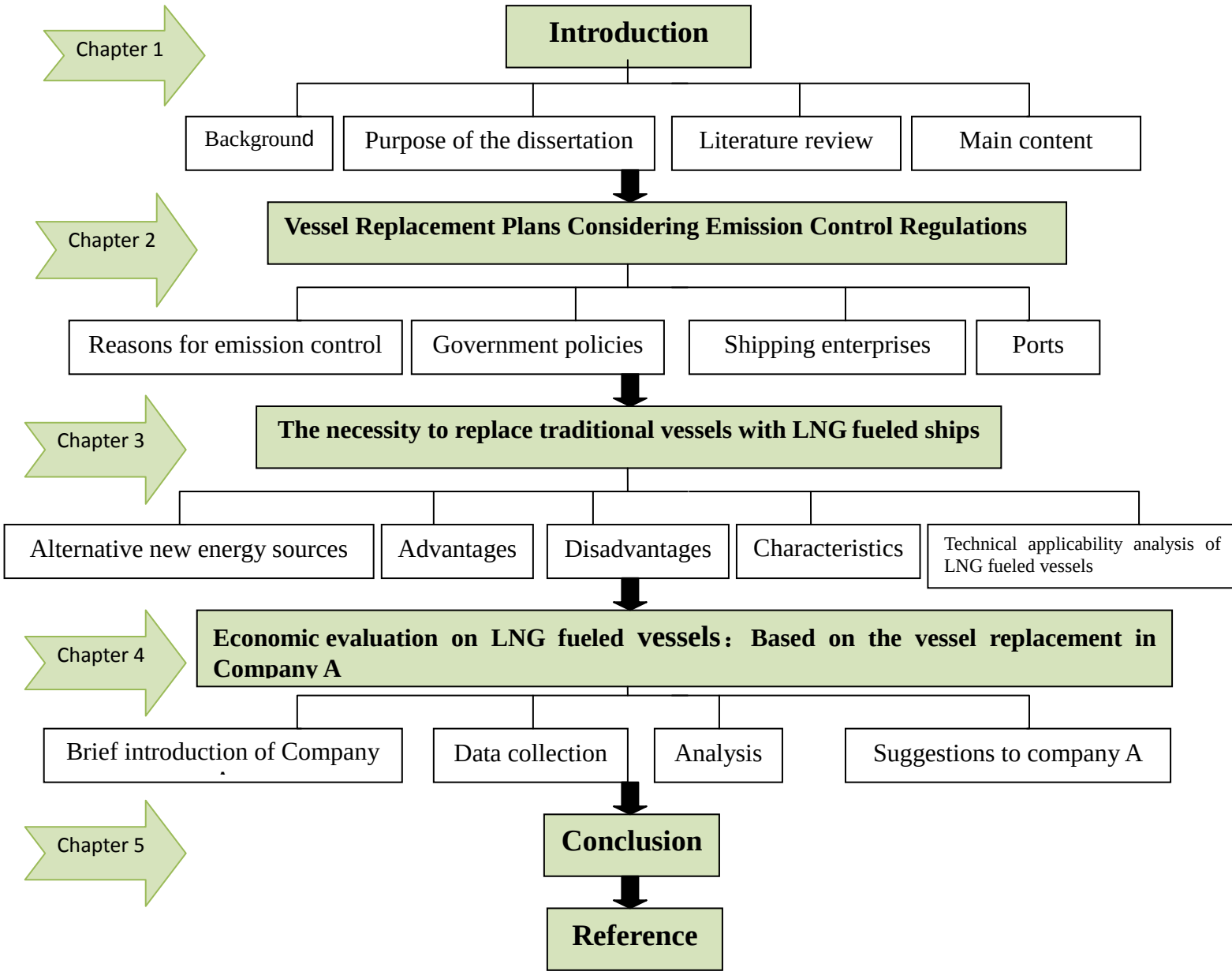


Figure 2 Structure of dissertation

Source: Own presentation

# CHAPTER 2 VESSEL REPLACEMENT PLANS CONSIDERING EMISSION CONTROL REGULATIONS

## *2.1. Reasons for emission control*

In the course of the operation of ships, it is inevitable that some pollutants will be produced. These pollutants include: waste gas, greenhouse gas, sewage, ballast water pollution, solid waste and so on, which can cause different degrees of damage to the atmospheric and oceanic environment. The main pollution mainly has two aspects:

### *2.1.1. Exhaust gas pollution*

In the operations of ships, it will emit large amounts of greenhouse gases. The pollution of atmospheric marine environment caused by the harmful gases mainly includes: $CO_2$, $SO_2$, NOx and PM, etc. Meanwhile, shipbuilding technology has been improved in recent years, thus the application of low quality fuel oil in large ship is no longer a problem, therefore, the ship companies use low quality fuel and oil in order to reduce operational costs and pursuit economic efficiency. However, the fuel sulfur content is still high, and the combustion is not sufficient, which will emit large amounts of sulfur dioxide, nitrogen oxide and harmful smoke and dust, leading to Marine environment acidification. The atmosphere also suffered the pollution.

### *2.1.2. The influence of ecological environment on shipping industry*

The prosperity of global economy and trade promotes the development of the shipping industry, but it also brings irreparable damage to the ecological

environment, and it seriously affected the production and life of mankind. Meanwhile, disorders of the ecosystem also affect the shipping industry.

Nowadays, the greenhouse effect caused by the current shipping industry emissions of greenhouse gases has become the most important factor affecting human's shipping activities. Besides, global warming will lead to sea level rise, even weather disasters, ocean acidification and so on, which will seriously affect the safety of navigation of the shipping.

## *2.2. Government policies*

Under the national regulation, the green shipping enterprise should be unified. The relevant administrative departments of the government shall supervise the shipping management departments, and on the basis of ensuring the coordination of the normal regulations, pollution charge system, licensing system, environmental protection and low carbon green shipping development, establishing standards to carry on the management and constraints is necessary.

**1) Establish and improve laws and regulations**

China should perfect the relevant laws to prevent the emission of greenhouse gases. This will not only promote China's effective implementation of the Convention, but also has important significance on reducing emissions work of China's shipping industry. For example: according to the requirements of Annex IV, fuel suppliers and fuel quality inspection agencies need recognition of the maritime authority, but the maritime sector does not have the related rights. (Xu Wei, 2015)

**2) Formulate relevant guidelines**

Maritime departments and organizations should actively help shipping companies understand and familiar with international laws and regulations on the ship emissions

control in order to effectively reduce the emissions of greenhouse gases and oil pollution emissions.

**3) From the angle of the ship inspection control**

Before putting into operation, each ship needs to be specified by the test. From the ship construction to operation, through a variety of test such as classification inspection, annual inspection, temporary inspection, and etc., maritime sector should co-operate with ship inspection department to examine the emissions standards in order to check whether the ship meets emission reduction assessment, and also eliminate those who failed to meet the requirements in the emission standard.

**4) Set up ECA (Emissions Control Area)**

Maritime authorities should set up the emissions control area to control the emissions of greenhouse gases and pollutants. For example, in port, terminal or channel install monitoring equipment, monitoring the wasting gas emissions during the process of ships entering and leaving the port. Then the relative maritime sector will receive the data through some network platforms.

## *2.3. Shipping industry*

### *2.3.1. Current situation of foreign shipping industry under the background of emission control*

Due to the Green Industrial Revolution caused by the current global climate change spread all over the world, the international community gradually realize that the relationship between the development of shipping industry and global ecological environment protection. Government agencies in some developed countries formulated strict regulations and laws, constrained the shipping Marine energy

consumption, and reduced greenhouse gas emissions, but at the same time, this also led to the shipping company's operating costs increased in the short term.

**1) America**

The port of long beach in California formulates the law of environmental protection stipulate that any ships enter or exit the port of long beach, and all kinds of cargo ships including container liner, dry bulk cargo, liquid bulk cargo ship and ship in port must comply with the following environmental regulations: in the distance of 40 nautical miles from the long beach port range must use clean fuel, though this clean fuel oil is very expensive; And they require that the speed of ships must be no more than 12 knots, and ship docked at the port must switch to shore power and stop using internal engine power. (Hou Zhongsen, 2013)

**2) Europe**

Some European Union governments and relevant environmental groups have formulated laws and regulations to reduce $CO_2$ emissions, and required that the EU countries' transportation fleet reducing the total emissions of greenhouse gases such as $CO_2$ and nitrogen oxides, and until 2020, reduced by 20% - 40% based on the data of 2015. By 2050, the data will be reduced by 50 %.( Huang Zheting, 2010)

In the case of the slow recovery of the global shipping industry, the EU developed such stringent environmental regulations, which was no doubt bringing tremendous pressure to the development of shipping industry. Meanwhile, some big shipping companies said that due to the current ship building and power system design technology, the targets for carbon emissions reduction will be achieved, but the shipping industry will be faced with tremendous cost pressures of vessels' rising operating costs.

At present, the primary mission of shipping enterprises should be maintaining the operating costs, while thrives to reduce greenhouse gas emissions to a minimum, in

line with the provisions of the international convention, thus achieve the transformation of green shipping as soon as possible.

### *2.3.2. Current situation of domestic shipping industry under the background of emission control*

In 2009, China ocean development report from China's Marine development strategy research administration institute shows that part of the Bay and shipping area of our country is faced with more serious pollution at present, the ranges of polluted offshore waters expanded about doubled in the past 10 years, which were more than 15 million sqkm. (Liu Xiancheng, 2012) Meanwhile, as a result of crude oil transportation and offshore oil exploration and other activities caused by the maritime oil spill accidents, leading to a considerable degree of damage to the ecological system, which is difficult to recover within 10 years.

Of course, the current situation of the protection of the marine environment is very severe, and all levels of government in our country set up environmental protection laws and regulations of the shipping industry. Shipping company, COSCO Group said that it will actively observe and implement national advocacy for green industrial revolution in response to global climate change which will induce a series of basic principles and measures in order to reduce the carbon emissions in the shipping process, and commit to become a "green services provider". (Liu Xiancheng, 2012)

### *2.3.3. Order environmental friendly ship*

In view of the increasingly strict marine environmental regulations and the increased prices of ship fuel, to control the operating costs, strengthen competitiveness, and build new type of energy conservation and environmental protection ship is the trend

of the times. MARPOL Annex VI made mandatory regulations for the new ship EEDI (Energy Efficiency Design Index), and introduction of energy efficiency management plans for all ships. According to a report, in the future for a long period of time, due to the overcapacity, market freight rate is likely to remain a weak volatile, thus under such background, more energy-efficient green ship operators will win the important competitive advantage in the market. In Europe, some green alliance of shipping companies has emerged, which has been received a lot of environmental awareness of the owners and the public.

### *2.3.4. Using low sulfur oil*

In view of the current international shipping industry hasn't found efficient energy which can completely replace the high sulfur fuel, shipping industry must comply with various international regional environmental regulations , therefore, the emission of marine fuels should be highlighted in the energy-saving and emission-reduction. The shipping industry must effectively control and manage the quality of the ship fuel.

### *2.3.5. Technical renovation*

**1）Optimization on ship design**

The improvement and innovation of ship design include the optimization of hull, the choice of the propeller and the improvement of the engine efficiency, etc.

In order to increase the efficiency of propeller propulsion and reduce the resistance of the ship to the friction of the water, the propeller shroud or cutting edge of ship propeller should be installed. As for the technological innovation on the engine, we need to eliminate that traditional ship type of low efficiency engine and use the most advanced RT-FLEX host.

When choosing a new type of ship, we should take full account of the ships linear and draft, thus using new type of silicone material will make the surface of ship coating become smooth and reduce the surface energy consumption. Therefore, the marine life is difficult to attach, so as to minimize the resistance of the ship sailing, and improve the effective power of the engine, then achieve the purpose of reducing energy consumption and exhaust emissions.

After selecting the reasonable operating speed which is suitable for the specific ship type, we should choose the host with low power as far as possible, and also select waste gas boiler with proper structure to make full use of the waste gas heat energy. However for some existed ships, technical measures like the hull optimization techniques may not be economically feasible, so it is unlikely to be achieved, at least the new ship is more difficult to achieve.

**2）Improvement of ship dynamic performance**

We should vigorously develop the new host, improve the structure and performance of the host as well as reduce fuel consumption. For example, like cars, considered as the implementation of the hybrid or pure electric ship, adding electric motor and battery on the host, and through dock charging, the electrical energy and fuel can work together in the ship, thereby reducing fuel consumption. At the same time, fuel-LNG dual fuel engine, pure LNG engine and the engine products which can convert from heavy oil into low sulfur oil are relatively mature.

Diesel fuel spray nozzle is an energy saving technology which has been put on the market. The main function of the fuel nozzle is to increase the injection pressure and control the injection timing and injection rate. This has a very good effect on the optimization of engine fuel emissions.

**3）Exhaust gas reprocessing**

The owner can think about the use of physical or chemical methods to discharge the waste gas in respond to meet local environmental friendly requirements. SOx and other emissions cleaner as well as NOx selective catalytic reduction are two ways to reduce NOx and SOx.

Europe and the United States and other countries or regions in selective catalytic reduction system are in a leading position of exhausting gas recirculation and gas scrubber development. SCR is a post-processing technique that can effectively reduce the emission of nitrogen oxides from moving sources. In a more ideal operating environment, the closed-loop SCR system can realize NOx emissions by more than 90 %.( Xu Wei, 2015)

However, installing these systems on board not only take up a certain space, but also the initial installation and operation costs are very high, furthermore, it cannot completely meet the requirements for the ship owners with less investment high return.

**4) Use of alternative fuels**

At present, the development of new clean energy which is suitable for marine use has become the focus of energy conservation and emission reduction. Some experimental projects such as LNG, wind energy and solar energy, etc. that started from the government or enterprises with regard to the recycling of renewable resources are expected to further accelerate the process of green shipping. LNG is a very good choice for the internal combustion engine, for the Marine machine technology is more mature, we should focus the technological transformation of natural gas system and fuel supply system; wind energy transforming natural monsoon into wind resources, thus we can equip sail system on board, sailed by the wind; as for solar energy, we can equip solar energy conversion device on the ship, converting solar energy into electrical energy and then reduce fuel consumption.

In addition to wind power and solar energy, nuclear energy and fuel cell has gradually entered the vision of shipping industry to develop new energy. Nuclear-powered vessels can use small PWR reactor, and other types of commercial reactors in the near future will become a reality. (Zhang Fuxing, 2012) Fuel cell is the technology that directly transforms the fuel energy into electric energy, which is beneficial to reduce the emission and improve the energy efficiency.

### *2.3.6. Scientific operation management*

**1) Reduce the ship's speed**

In general, if the speed is reduced by 5%, the greenhouse gas emissions can be reduced by 14%. (Zhang Shuang, Li Zhen, 2011) Through reasonable speed control, we can improve the efficiency of maritime logistics, and then improve the energy efficiency as reduce the greenhouse gas emissions. It is possible to realize the reduction of international shipping industry's greenhouse gas emission within a specific region or in a global scale as soon as possible. At the same time, it is also helpful to improve the status of port logistics.

However, the reduction of speed may also bring problems to the ship operation. Speed is a sensitive problem between the carrier and the shipper, therefore, in order to win the transportation share, the ship must choose a competitive transport speed. In some cases, after a cost benefit comparison, the shipper may choose other means of transportation to replace shipping on the sea. On the other hand, the reduction of speed will lead to the increase in transit time, thus cause more emissions. In addition, the low speed ship may cause damage to the logistics. For example, once the port emerge cargo congestion phenomenon, it will become a logistics bottleneck.

**2) Strengthen management and improve the efficiency of loading and unloading operation**

The improvement of the efficiency of ships in the port can significantly reduce the

emission of greenhouse gases. People optimize the loading and unloading operation, scattering ports peak to reduce land transport, ease the port congestion, and shorten the time of the ship in port in order to reduce greenhouse gas emissions.

### *2.3.7. Analysis of alternative new energy sources on ships*

At present, the global oil and gas energy gradually decreases, while shipping fuel costs are getting bigger, therefore, it is imminent to further improve the ship's energy-saving work so as to effectively reduce the transportation cost. At the same time, how to efficiently burn and reduce pollution emissions has drawn more attention from the IMO (International Maritime Organization). Nowadays, the world shipping industry is challenged by high oil prices and environmental protection regulations, facing the huge pressure of energy conservation and emissions reduction. In order to meet the requirements of the new situation, the green ship became the most important channels and the future development direction of ships, including the application of new energy on the ship, which is the most innovative and representative technology.

## *2.4. Ports*

When the port choosing investor or operator, it is necessary to add more favorable terms of the control of carbon dioxide emissions in the contract in order to control the amount of carbon dioxide emissions from trucks and terminal machinery. When the ship is at anchor, we should advocate the use of shore-based power so as to reduce emissions of carbon dioxide during ships in port. But the premise condition is that shore-based power must come from clean energy sources such as wind power, nuclear power, and hydropower, thermal power instead of coal or oil. In addition, with the increasing number of ships, the size of ships and loading of dangerous goods ships constantly test the ecological environment of the waters near the port,

therefore, port should continue to strengthen management in the process of production and operation, pay attention to protect the port waters environment, and strengthen emergency drills.

## *2.5.Summary*

Although shipping enterprises can through the co-operation with government and port to achieve green shipping. But we can find that the unified management and control of the government and port infrastructure have a certain degree of difficulty. The increase in port charges is only play a driving role. From the initiative, the shipping companies should consider themselves to find solutions. However, the investment of environmental protection ship and the technical transformation of the ship have the disadvantages of high investment cost and high technical difficulty. The use of low sulfur oil will encounter power shortage, the problem of insufficient combustion. Moreover, reducing the speed will also lead to the logistics bottleneck, so it is concluded that only the use of new energy sources can be worth our reference and research.

# CHAPTER 3 THE NECESSITY TO REPLACE TRADITIONAL VESSELS WITH LNG FUELED SHIPS

## *3.1. Alternative new energy sources on ships*

New energy is non-conventional energy sources; it is a variety of forms of energy besides the traditional energy sources which refers to the energy at beginning of the development such as wind energy, solar energy, ocean energy, biomass energy and nuclear energy. New energies have the characteristics of large reserves and less pollution, which are of great significance to solve the serious environmental pollution problem and resource depletion today.

### *3.1.1. The wind energy*

Wind energy which is generated by a large amount of air flow on the earth's surface is a kind of non-pollution and unlimited renewable resource. The use of wind energy in human history can be traced back to BC. With the continuous progress of science and technology, industrial society has rich experience in the use of wind energy, and infrastructure is relatively mature. However, wind energy utilization has the shortcomings of being intermittent, high noise, and difficult to eliminate the influence of terrain, the interference of radar signal and so on.

Wind energy is widely distributed all over the world, and it has the characteristics of renewable and inexhaustible, thus it is a typical clean energy with no pollution, however, its stability is poor and the investment cost is high.

### *3.1.2. The solar energy*

The utilization of solar energy mainly has two aspects of technology, that is, solar-heating technology and photovoltaic technology. The solar-heating technology use solar radiation and the most successful application of the field is solar water heater. Further extension of this technology is solar thermal power generation, and it used solar radiation to heat the hot water so as to produce steam, and then through the turbine and generator to generate electricity. (Yan Xinping, 2010) In view of the ship operation of the hot water demand is not high, and the thermoelectric conversion is difficult to implement in the limited space of the ship, therefore, the feasibility of solar-heating is not very high. Photovoltaic technology is the solar light in the short wave radiation which can be irradiated on the silicon semiconductor power generated by the modulation, and it is also known as photovoltaic effect. (Zhang Fuxing, 2012)

The existing solar energy ships use the sun light as auxiliary power, and the power source mainly depends on the fuel oil. Especially for large ships, the solar power supply occupies only 8% of the total power consumption of the ships. Ships that are powered by solar energy are always small boats, and its speed is low, therefore, the technology of solar power ship still needs to be improved. In addition, the investment cost is big, and the economic benefit is not high, therefore we can say the solar energy ship is still in the experimental stage.

### *3.1.3. Nuclear energy*

Nuclear energy is a kind of power energy. Nuclear power reactors can be used to generate electricity, heat and push the ship. As the power source of the ship, nuclear power plant was first used in submarine, aircraft carrier and other military vessels. Later, some countries have built nuclear-powered warships, thus nuclear power reactor is also used to push civilian ships, such as nuclear powered ships, bulk carriers and icebreakers and others. (Yan Xinping, 2010) Nuclear energy has the

advantages of small size, powerful, convenient transportation and storage, high security as well as low pollution, but it also has a strong radioactive and destruction, high requirements of technical and management.

### *3.1.4. Biomass energy*

The utilization of biomass energy mainly has 3 kinds of ways, such as direct combustion, thermos chemical conversion and biochemical conversion. Biochemical conversion is divided into bio fuels, bio diesel and biomass. The ship has a relatively independent structure and relatively limited space area. It is highly integrated with the electrical, gas, heat equipment and system in the engine room. (Zhang Fuxing, 2012) Considering the inevitable limitation of the additional installation of the biomass energy conversion device in the ship, the feasibility is not high. In terms of the existing equipment conditions, the direct or indirect use of alternative fuels (such as bio diesel, etc.), which is converted from biomass energy, is the main application mode. Biomass energy can be recycled and widely distributed with low pollution and low nitrogen.

### *3.1.5. LNG*

LNG is the abbreviation of liquefied natural gas. First, the natural gas produced from gas field should be purified, then through ultra-low temperature (-162 C) pressurized liquefied form LNG. (Wu Ming, 2013) The main component of it is methane.

LNG is colorless, tasteless, non-toxic and non-corrosive, and its volume is about 1 / 600th of the amounts of gaseous natural gas volume, besides the weight of the LNG is only about 45% of the water and the calorific value is 52MMBtu/t (1MMBtu=2.52 * 10^8cal). (Wu Ming, 2013).

### *3.1.5.1. Current situation of LNG in global market*

Although the world economy is still in rapid development, mankind is faced with increasingly serious problem, that is, the continuous deterioration of the global climate and the depletion of fossil fuels. Under the two major problems, people have to find effective, environmentally friendly method to solve the current problem gradually, and for the world's shipbuilding industry is even more so. With the increasing price of refined oil, the International Convention on pollution has become more and more strict, which makes the whole ship industry try to seek a new way to solve it. LNG technology seems to bring us a hope, for it is not only clean, but also abundant reserves. If we use LNG as ship power, it seems to ease the two problems above. However, for the existing technology and policy, to realize full application of the LNG is still a long way to go.

According to statistics, the world shipping industry consumes 2 billion barrels of oil per year and discharge more than 13 tons of $CO_2$, accounting for about 7% of the total global emissions. (Huang Zheting, 2010) Laws and regulations which are to deal with the world climate change stipulate the standards and time limit for the prevention and control of the pollution of ships and emissions reduction. Then, we should look for a new path of energy conservation and emission reduction. LNG, which is much cheaper than oil and abundant, with its significant environmental benefits, has become the first choice for the future marine fuels.

Over the years, scientific research including DNV and other professional units efforts to promote the “oil to gas” study. At present, the use of LNG fuel ship under construction has no difficulty in technology, but the path of "oil to gas" is not flat, because of the high cost of the construction and equipment of cylinder type LNG storage tank, which will reduce the cargo space and other ancillary supplies, is not mature.

In terms of global Marine development status of LNG, nowadays, the LNG, as a fuel in the worldwide popularity is low, and only sporadic several countries, they use LNG as fuel for ships for fixed-point transportation. Most of the world's ship LNG application is in Norway. LNG fueled ship is a double power system with diesel and BOG, and its propulsion system without exception is steam turbine power plant. At present, there are more than 300 LNG Cs in the world and BOG is used as fuel for steam turbine unit.

At the same time, the international ship emission standards will promote the rapid development of marine LNG. In recent years, the International Maritime Organization (IMO) strengthened the mandatory provisions of ship emissions. If all countries implement the mandatory provisions of the IMO, and after 5-10 years, most offshore trade ships will use LNG as fuel. (Chen Wei, 2013) The key areas for the development of the international market for LNG are the Baltic Sea area, the North Sea and the Mediterranean region.

At present, the LNG fueled ships' power system is mainly supplied by four companies, that is, Rolls Royce, MAN, Wartsila and Mitsubishi Heavy Industries. Wartsila and MAN are dominated by dual fuel engine, while Rolls Royce and Mitsubishi Heavy Industries are dominated by gas engine. (Chen Wei, 2013)

In LNG hull manufacturing, Japan and South Korea are the main origin. Mitsubishi Heavy Industries is main engine supplier of LNG fueled ship. In 2009, Japan's Mitsui OSK lines announced the design of environmental ferry "ISHIN-II". Daewoo shipbuilding and marine company is currently developing the LNG fuel of large container ship. MAN and its' companies are developing the application of ME-GI engine and DSME for 14000TEU container ship. (Chen Wei, 2013)

### *3.1.5.2. The development of LNG fueled ships in China*

At present, the use of liquefied natural gas in China is basically in the blank area. The fuel of inland water shipping is dominated by diesel fuel in our country, not using the LNG in shipping yet. But in nearly two years, the LNG industry has tried to treat the LNG as an important direction of the future development of the LNG industry. There are many types of ship mainstream diesel engine has been tested, and passed the national organization of relevant departments of the inspection and acceptance, thus proved the feasibility of technology and economy.

From the trend of the development, on one hand, the number of LNG fueled ship will grow rapidly in the future. China's inland navigation resources are rich, there is more than 5800 large and small natural river, and the total length is 430000 kilometers. (Liu Xiancheng, 2012) With the background of energy conservation and emission reduction, on the basis of the increasing of LNG receiving station, it is very important to develop inland waterway LNG fueled ships to prevent and control the pollution of ships. It is expected that there are more than 50 thousand ships to be modified and direct drive energy equipment market incremental value will reach as high as 26 billion RMB in next 3 years. (Wu Ming, 2013)

On the other hand, government increased capital investment to promote the development of inland navigation, which forms a strong support for the development of the LNG fueled vessels. Xu Zuyuan, a deputy minister of transportation ,he said that, "During ‘Twelfth Five Year Plan’ period, government will arrange 450 million yuan of financial funds to support the instruction of ports and channels, and arrange 50 million Yuan as guide funds to promote inland ships standardization and transport structure adjustment. (Li Li, 2010)

## *3.2. The advantages of LNG fueled ships*

Compared to other alternative energy sources, the LNG has the following advantages:

**1) Reserves of natural gas**

At present, the world's proven natural gas reserves are abundant. The non-conventional energy sources, such as shale gas, according to the current usage are to calculate the gas available for human use 250 years. The spot price of LNG is equivalent to 1/4 of diesel oil. Up to now, China has become the world's major LNG importing countries, and to 2015, the annual supply of 2800-3350 will reach LNG billion cubic meters. (Pan Ruiyu, 2010)

**2) Cost advantage.**

In accordance with the current level of oil prices and LNG prices, the use of LNG clean energy compared with the use of diesel fuel saving 60% - 40% of the cost of fuel. Calorific value calculation, LNG price of only about 60% of diesel, and because of the natural gas burning completely, it is not easy to accumulate carbon to reduce costs more than 50%. (Ch.N. Stefanakos, 2012). Large LNG fueled ship is more economically.

**3) Environment friendly**

Using natural gas as a fuel, compared with the heavy oil, make nitrogen dioxide emissions reduced by 80%, and carbon dioxide emissions reduced by 25%, sulfur dioxide and particulate matter emissions reduced by 100%. (Li Li, 2010) China and the development of LNG marine fuel in northern Europe will be largely determined by the increasingly stringent government regulations on carbon emissions. Especially if the higher the cost of carbon dioxide emissions, the more it can promote the development of LNG marine fuel.

Comparison between LNG, gasoline and diesel oil:

① There is almost no sulfur, dust and other harmful substances in the natural gas, which produced less carbon dioxide produced than fossil fuels during the process of combustion;

② According to data, the use of natural gas, as a marine fuel compared to diesel fuel, carbon monoxide can reduce emissions by 90%, with no carbon dioxide emissions

③ Before liquefaction, natural gas must pass strict pre-purification, and the impurities in the LNG are much lower than LPG, CNG. If the ship uses it as fuel, the exhaust emissions can be basically zero emission

In view of the price of fuel oil is likely to rise gradually, and international regulations on marine environmental protection requirements become more stringent, LNG as a marine fuel, its advantages becomes more and more obvious. Compared with the marine diesel oil and heavy oil, its price is relatively low; and it can make the emissions of carbon dioxide and other emissions and particulate matter decreased significantly. Therefore, within the next 5 to 10 years, the number of ships using LNG as a fuel will continue to increase, which is expected to 10 years later, will occupy 10% ~ 15% in the market. (Li Zhenghong, 2002)

## *3.3. Disadvantage of LNG fueled ships*

At the same time, the use of LNG as a ship fuel also has some disadvantages:

**1) The large volume of LNG fueled system.**

The fuel system of LNG storage tank is large in space and heavy in weight, which will affect the cargo capacity, thus it occupied storage space about 4 times larger than the traditional diesel fuel, while the weight is 1.5 times of the latter.

**2) Higher initial cost.**

According to the survey, the costs of a LNG storage tank were supposed to be

several million dollars, and if the owners only focus on the cost of this account, they will often be in the state of disappointment. However, in terms of the ship emissions requirements are increasingly stringent; Denmark, Norway and the Nordic countries now have to start using LNG as fuel for ferry, ro-ro, LNG carrier and platform supply vessel. This shows that with the increasing demand for gas emissions worldwide as well as less oil resources, the barriers of ship-owners and ports are gradually removed.

**3) LNG fueled ships lack of technical safety general rules.**

At present, only Norway Classification Society (DNV) made the relevant classification standard on natural gas fueled vessels，while most of the country has not introduced the relevant government regulations on technical standards of LNG yet.

**4) Weak endurance.**

At present, the maximum time range of LNG for the fuel of the ship is only 22 days, which cannot meet the ocean transportation demand. (Wu Ming, 2013) Although the ship fuel oil tank volume is big, it can place on the boat randomly. But LNG storage tank volume is small, and its structure and system is complex. This phenomenon will bring huge difficulty to design this ship.

**5) LNG supply facilities are not complete in port**

Lacking of LNG filling infrastructure is considered to be the bottleneck of the development of LNG fueled ships. Because of the shortage of the current automobile filling stations has restricted the popularization of the fuel gas vessels. And the popularity of the future gas ships will depend on the construction of the supporting equipment of the port.

## *3.4. Characteristics of LNG fueled ship*

LNG, regarded as safe and clean, is an upgraded version of compressed natural gas, which has disposable filling volume and low voltage operation system. Compared with the use of diesel fuel alone, the use of LNG-diesel hybrid ship can save fuel costs by about 25%, and carbon emissions index is lower. (Zhang Fuxing, 2012)

### *3.4.1. Power system*

#### *3.4.1.1. LNG hybrid power system*

Existing ships are mainly diesel powered, and have the characteristics of high fuel consumption, large amount of waste water and emissions. Not only do they increase transport costs, but also pollute the environment.

Marine diesel-LNG hybrid power is able to convert the existing diesel power into diesel and natural gas hybrid, and the efficiency of natural gas can be as high as 50%-80% instead of diesel. The work of mixing the burning diesel natural gas can completely satisfy the needs of ship power, carbon, sulfur, dust and waste water emissions can being greatly reduced. Meanwhile, fuel consumption costs can be declined by more than 25%, and significant economic and good environmental performance can be greatly improved.

The test proves that the marine double fuel hybrid power technology be advanced, economical, reliable, energy saving and environmental protected, and the market potential be huge, and have the broad value in terms of development.

#### *3.4.1.2. Characteristics of LNG hybrid power system*

While diesel plays the role of the fuel of the ship, the oil pollution of the engine room

is heavy and noise is also loud. After the conversion of dual fuel power, oil pollution, smoke and noise are significantly reduced, the crew's work and living environment has been greatly improved. At the same time, once there is a combustible gas leak, automatically alarm will cut the gas pipeline automatically, start the explosion-proof fan, which is separated from the storage tank, the cabin and engine room to ensure safety of ship operation and crew because of the equipment of intelligent security monitoring and disposal system. In addition, even if the ship meet sank accident, it will not produce water pollution in a large area.

### *3.4.1.3. Generalization of LNG fueled ships*

A large number of experiments and studies have indicated that the diesel-LNG power technology have already had the condition of popularization and application. In order to quickly transform the scientific research into practical productive forces, it is necessary to greatly accomplish the following aspects:

**1) Study and establish relevant technical standards.**

Due to the LNG power and diesel engine having great difference, the leakage of LNG will cause the cold brittle damage to the hull, deck and other steel structures, which can also cause frostbite to personnel on the ship. At the same time, it could also be full of explosion risk. Therefore we need to carry out special research on LNG fueled ships filling, storage, transportation, supply, basic research of risk assessment, and economic benefit evaluation so as to improve technical research and advisory services and to lay the foundation for the promotion along with application of LNG fueled ships.

**2) Research on relevant policies.**

At present, the promotion of LNG fueled ships still has some problems, which includes the slow construction of filling point, inadequate storage and transportation facilities, the difficulty of raying funds, etc. It is necessary to improve LNG fueled

ships in the following five aspects:

①Increase infrastructure investment, improve layout LNG filling stations, develop the LNG filling station development plan so as to solve the bottleneck problem of LNG fueled ships promotion.

②Stimulate local enthusiasm, increase policy subsidies and funds. The owner will greatly enhance the willingness to renew ship.

③Set up a financing bridge, multi-channel to raise funds. Banking sector should also carry out credit business in appropriate time so as to help shipping enterprise transformation and upgrading.

④Provide convenient services to support the operation of LNG fueled ships. For example: LNG fueled ships can enjoy priority through treatment, which can greatly save the operating turnaround time. Besides, there are also implement personnel services, tax relief and other measures.

⑤ Strengthen industry cooperation, optimize the industrial chain structure. With the rapid development of the LNG fueled ships technology and equipment, mainly research projects have also been carried out among the owner, classification society, equipment manufacturers, design companies and the shipyard. Therefore, production enterprises, shipping enterprises, scientific research institutions, government agencies and others should strengthen cooperation and increase investment of LNG fueled ships power application in the long term to achieve the good function of the industrial chain of LNG energy applications.

**3) Pay attention to the operator's qualification and training**

Due to the particularity of LNG, the necessary things must include LNG filling, LNG safety operation, accident emergency treatment, safe berthing and so on. Operators

should have a certain quality so as to reduce the loss and avoid security risks. It is essential to carry out the training for relevant personnel as soon as possible in order to make up for their lack of qualifications.

### *3.4.2. Safety*

LNG is a cryogenic liquid. Even when a leak occurs, it will soon be spontaneous. The density is lighter than air leakage. It will be automatically open to overflow instead of producing the water pollution. After adding a special snuff element, gas leakage can be found in a timely fashion. The point of gas ignition is higher than gasoline and diesel. Meanwhile, instantaneous ignition is slower than the oil, and it is not easy to reach the explosion limit.  In terms of the use of security, the natural gas is much better than fuel.

①The ignition point for LNG is 650, which is much higher than gasoline (260) and diesel (427);

②The density of LNG is about 0.47 but the density after gasification is only about half of the air, and a slight leak will cause volatile diffusion;

③LNG explosion limit is 4.7 ~ 15%, gasoline is 1 ~ 5%, and diesel is 0.5 ~ 4.1. The contrast caused that LNG is much harder to achieve explosion conditions than gasoline and diesel. Thus, LNG is much safer than gasoline and diesel. (Zhang Fuxing, 2012)

#### *3.4.2.1.The safety problems of LNG in the process of production*

LNG production process is a purely physical changed process, and the process period is very short. The main technology is the cryogenic technology, and natural gas is cooled to- 162 ℃, (Yu Xiaoli, 2012) which becomes liquid under atmospheric

pressure. And other heavy elements have become solid floaters which are removed; some gases such as N2 still remain in the gaseous state and are discharged. In this way, most of the liquid fuels are pure alkenes, mainly methane and ethane. A liquid LNG is pumped into an insulated storage tank and stored in it.

From the point of the whole production process, low temperature operation is the main process. Therefore, to prevent liquid splash, damaged pipeline, valve leakage, interfaces, and leakage, etc. is the main aspect of safety. Because the whole production process system and piping is operated within the enclosed space, cryogenic liquid splash hurt only exists in the condition of the container, pipeline, and valve damage. And both at home and abroad, vessel and pipeline are made by the low-temperature adiabatic container manufacturing process; welding material has good compatibility, inner and outer adiabatic insulation filler by the United States imported materials layered around to fill and reflect insulation diaphragm insulation. Between two layers using vacuum processing, making the vessel and the pipeline safety is a good trend. Cryogenic valves adopted by Japanese famous enterprise products with high reliability. Cylinders, tanks, and unloading valve mouth are sealed transmission, which will not produce cryogenic liquid splash hurt accidents generally under normal operating conditions.

Secondly, once a cryogenic liquid drops, it will quickly raise gasification. The latent heat of LNG is sufficient to causing the temperature of the gasification gas in surrounding environment to drop a lot. At the same time, because the gas density is smaller than one of air, it should be quickly dissipated in the air in impossible conditions for the formation of combustion and explosion. Of course, all those can just occur in the open space. Therefore, all of the LNG may occur at liquid leakage part with the low temperature, and they should not be installed and operated in a confined space. This is also one of the safety precautions to improve in the production and storage of LNG.

### *3.4.2.2. The safety problem of LNG in the process of storage*

LNG storage in the storage tanks occurs to a problem about natural endothermic gasification boost. Because of a good insulation without any possibilities of completely isolated heat transfer. The new development of modern science and technology provides a guarantee to solve this part of the security issues. Whether it is a large storage tank or car transport tanks, they are required to maintain a certain pressure in order to facilitate the flow of the liquid. But this pressure can only be kept at a low level, just to meet the liquid flow. If the pressure continues to rise, it will need to be relieved. Nowadays, the automatic regenerative liquid technology low temperature can fill the gap. Over pressure limiting saturated vapor is introduced into the spray pipe through the unloading valve, and is re-injected into the LNG. The saturated steam is re-liquefied by the environment of 162 degrees Celsius in the tank. This process is also a buck one. After the liquefaction of gas, its volume contraction becomes 625 times, however the steam pressure naturally reduced. (Jin ling, 2011)

Like this constant cycle, as long as there is a certain amount of LNG (low liquid level line), this cycle can be carried out. This is the reason why LNG can be long-term storage tank LNG. In order to ensure that the circulating pipeline is always smooth, the gas can keep a certain pressure in the circulating pipe, and the liquid flow cannot be caused by the spraying pipe below the liquid level. This can be achieved by adjusting the position of the spray pipe and the gas transmission pipe. Then the insulation condition of the pipeline can be changed.

As mentioned above, due to the pressure balance automatic regulation system, LNG liquid storage conditions are compared to gasoline and diesel storage those and show much more secure and more economical. Of course, in the tank are equipped with pressure limiting emptying tube in case of emergency. This LNG storage technology contributes to the development of the LNG industry to create the conditions in China in the future.

In terms of safety, the stability of the storage tank and the thermal insulation conditions take the leading roles, and then the reliability of the pressure exhaust pipe is limited. The storage tank's own condition request in the construction process has the good foundation to resist the earthquake, in order to resist the gas from the earth's deep, some even carrying the liquid to gush out together. Local ambient temperature for liquid endothermic gasification and poly suddenly reduces, whose result is not conducive to the combustion taking place, and LNG lighted up to 650 DEG C, than gasoline burning 427 C higher than nearly 230 degrees. There is no such a high temperature ignition source. Furthermore, the explosion limit of LNG is 5% ~ 15%, 3 ~ 4.7 times higher than gasoline, LNG leakage, return air, quickly gasification. (Yang Jianghui, 2014) While the LNG is much smaller than the density of air, it will soon evaporate without explosion condition. Even inside and outside the tank are two layers seriously damaged, and the result is similar with the above. Even if the gas has been burned in the case of flame combustion, the flame center will move up instead of spreading along the ground. Due to low absorption of moisture in the air, the temperature of the liquid leakage and landing will form the ice layer, which covers the damage around. This is one of the factors that hinder the occurrence and spread of combustion. If the vehicle in distress is to encounter severe impact, the accident seriously damaged the two layers of the tank, the consequences and the tank valve damage will be basically the same. The friction heat generated in violent collisions, which was not enough to ignite the liquid 160C.Moreover, there is a good protective effect in the insulation layer between the two layers of tanks. Foreign collision experiments show that as soft armor, there exists a large number of collision energy absorption on the adiabatic layer so as to prevent the destruction of the inside and outside the tank.

In summary, the safety of LNG transportation is higher than gasoline and diesel fuel. Just in the moment of overturning and collision should prevent the liquid flying out .The burn of the cryogenic liquid is very dangerous. Therefore, LNG fueled ships with excellent operation and protection performance can be against general

emergency disaster. At the same time, LNG transportation drivers passed professional training, and ensured the safety of LNG transport. But LNG is not CNG without quite high pressure, and it will not collapse. However, the low temperature is also easy to hurt. When a failure occurs, the professional personnel should be asked to handle.

Through the analysis of the above aspects, the comprehensive safety of the new fuel LNG is higher than that of any kind of fuel (according to foreign data, its security is higher than in methanol, ethanol, ether, and hydrogen, etc.). In spite of this, China's LNG industry has just started, but there are many aspects of the lack of experience. And those cannot be ignored in order to prevent accidents. To make full use of the security of LNG, it is essential to have the bold development and utilization with paying attention to safety at the same time.

### *3.4.3. Green performance*

The main difference between the LNG fueled ships and the ship is their power plants, and this study of LNG fueled ships is green, which is mainly focused on its power plant. According to energy saving and emission reduction, the green evaluation index of marine power plant can include two aspects: energy and environment.

#### *3.4.3.1. Energy attribute*

The relevant indicators about ship power plant and energy attributes have the following several aspects: energy type, energy consumption, energy efficiency, energy recovery, etc. Energy consumption and the utilization are generally for non-renewable energy in the process of evaluation of single ship power plant, energy consumption and energy utilization rate for the overall performance of the fuel consumption rate; in the process of use of the power plant is not considered energy recovery, so here only discuss energy type and fuel consumption rate.

The main energy source of the LNG fueled ships is LNG. Natural gas is the combustible gas which is naturally produced in the gas field, and the main composition is composed of methane. LNG is cooled by natural gas at atmospheric pressure to -162 degrees Celsius, so that it can be condensed into the liquid. The storage space, the cost of storage and transportation can be greatly saved after the liquefaction of natural gas, and it has the characteristics of high calorific value and high performance. Relative to the current ship mainly adopts energy - diesel, LNG is a kind of clean energy. And using the LNG as fuel can reduce CO2 emissions by 10% ~ 20%, NOX emissions by 90%, 100% of the sulfur and particulate emissions. Moreover, the LNG fueled engine does not need to install the lubricating oil cleaning equipment. So the internal environment is good. (Chen Wei, 2013)

### *3.4.3.2. Environmental attribute*

General product environmental indicators include the water environment indicators, atmospheric environmental indicators, solid waste emissions indicators, and noise and vibration indicators in the product life cycle. For marine power plant, in the different stages of its life cycle, the main environmental indicators are also different, the focus is also different. For the LNG fueled ships, there is no use of a small amount of diesel oil. So its oily sewage discharge is very small with the mainly consideration of its impact on emissions and noise.

### *3.4.3.3. Exhaust gas emission*

In the exhaust emissions, LNG propulsion plant exhaust emissions do not contain lead and benzene, and sulfur content is very low. Relative to diesel engine and gasoline engine, CO2, NOx and other harmful emissions also have varying degrees of reduction. Application device of LNG power plant and power generators in the boat can greatly reduce the environmental pollution caused by the exhaust gas.

### *3.4.3.4. The noise*

Crew members working and living in the ship for a long time, the strong noise leads to crew mental fatigue, lower productivity, and serious impact on physical and mental health, and the safety of navigation. In 1980s, due to the vigorous development of the shipping industry, the international community generally concerned about the noise of the ship cabin in the relevant research is more, which is also prompted the introduction of a series of norms of our country. (Li Zhenghong, 2002)

After a period of time, with the mature of shipbuilding technology, the cabin noise has gained control, the attention has been gradually reduced, and the domestic related research has been also reduced. However, the current ship power plant widely accepted diesel engine of high noise and as people's requirements of work and living environment is increasing day by day, noise problem as a main factor affecting the quality of work and life of its crew cannot be allowed to be ignored.

The gas turbine used in the LNG fueled ships is mainly with three forms: intake and exhaust noise, radiation noise and structure noise. In general, its body radiation and structural noise are smaller than the diesel engine. Because it needs a large amount of air, its intake is much bigger than the diesel engine altogether with the louder noise.

## *3.5. Technical applicability analysis of LNG*

### *3.5.1 Existing ship modification technology is feasible*

If existing ships want to use LNG or LNG/ diesel as fuel, it must be fitted with LNG storage tanks and other equipment. Under the general conditions, the main

equipment is the LNG storage tank and gas processing system in the process of ship modification.

The most easily converted ship types include LPG fueled ship, offshore oil/chemical tanker, difficult to be modified are passenger ship, ferry, container ship, and the large container ships, bulk carriers and large oil tanker (VLCC) oceangoing ships are much more difficult. At present, in the process of ship "oil to gas" project, the biggest challenges are two aspects: one is how to arrange storage tanks and other subsystems of gas fuel system; the other is how to meet ship two-stroke and four stroke host work requirements.

### *3.5.2. The new ship actively use LNG as fuel*

DNV is a "pioneer" of LNG application. In 2001, it took the leader in developing the LNG fuel related to the ship's specifications firstly. (Wu Ming, 2013) At the summit, DNV was introduced during the "ECO - Ship 2020" project which developed with the Japanese Oshima shipbuilding co., LTD. The first phase of this project has ended, and completed the open hatch bulk carrier conceptual design. The ship integrated with a number of innovative solutions, and one of the most striking is the ship filled with use of LNG without any other fuel or electric propulsion system. The ship is equipped with 4 C type high pressure storage warehouse, and it can store 3000 cubic meters LNG. Rawls, Royce Company provides the ship with 2 sets of four stroke medium gas engines whose stand-alone power is up to 4000 KW. (Yan Xinping, 2010) Combined with the application of waste heat recovery, air lubrication, and other energy-saving technologies, the ship can meet IMO Tier III emissions standards. While the sulfur emissions to zero and the nitrogen oxide emissions can be decreased by 90%, carbon dioxide emissions can be decreased by more than 50%. (Hou Zhongsen, 2013)

In addition, at the conference DNV showed another future ship type: operating in

Australia to China route of environmental protection concept ore carrier (The eco - friendly ore carrier) "Ecore". The ship uses a flexible fuel scheme and two strokes ME - GI gas engines to make sure the using two kinds of fuels. Noteworthy is that the ship using the optimized design scheme with only one cabin. The “C” type LNG storage tank is located in the aft of the cockpit, and this program is helpful to make full use of ship space so as to ensure that the LNG storage tank will not occupy cargo space or reduce the amount of freight.

In addition to the above ship type, DNV is still in research and has gained some development of environmentally friendly VLCC recently. It is said that the ship will be equipped with dual fuel engine in order to match the use of LNG fuel, which will also install two “C” type storage tanks. And each tank volume will reach 13500 cubic meters.GL recently released "Fulla tanker optimal add" design concept also reserved space for the installation of gas storage tank with the natural gas use . In addition, the Rolls Royce Company introduced environmentally friendly ship design concept (Enviroship Concept), and treat LNG as fuel of container ships and so on.

### *3.5.3. Gas engine technology is relatively mature*

In the field of Marine power system, the international major engine manufacturers, through technical research and development, its products have been able to meet the needs of the application of LNG.

Wartsila Company introduced DF type machines including 20 DF, 34 DF and 50 DF, and has been successfully applied in many ships. Compared with the model of fuel, DF gas model can make 75% reduction in carbon monoxide emissions of engine, reduce CO2 emissions by 20%, nitrogen oxide emissions by 80% and realize the zero discharge of sulfur, and meet the international maritime organization (IMO) Tier III standard. At present, the DF dual fuel engine has been successfully applied in the LNG fueled ships, offshore supply ship, FPSO, chemical ship and other ship types,

and the cumulative commercial application of the time has exceeded 150 hours. Since 2005, DF dual fuel engine orders have accounted for 45% in the Wartsila because of Marine engine order. (Chen Wei, 2013)

### *3.5.4. Using small LNG ship for refueling*

How to carry on the LNG fuel supply is a very concerned problem in shipping industry. At present, the lack of the marine gas supply device is a major bottleneck restricting the promotion and use of the LNG. With the success of some ship modification project and some of the concept of LNG for the ship's design plan, under the conditions of lack of marine gas supply device, gas supply is a more feasible solution of the ship.

According to the Norwegian some successful cases, the LNG fueled ships berthing in port can be replenished of fuel by the shore of the pipeline; and when operating on the sea, the ship can be accomplished by small LNG ship fuel supply. Not only that, some of the new concept ships also takes a similar gas supply program. DNV described in the concept of environmental protection ore carrier "Encore" is used in the similar solution, where a fuel supply ship provides liquefied natural gas and fuel supply for the ship. "Ecore" of the LNG reserves is up to 4000 cubic meters; the fuel supply ship goes through 6 to 8 inches in diameter hose, and whose the supply time is about from 9 to 15 hours.

Not only can taking LNG as fuel make the ship meet the emission standards of Tier III IMO, but also it is an effective way to help the ship to meet the EEDI. And the existing technology of the shipping industry has been able to meet the requirements of ships using LNG. Therefore, some people predict that by 2015, the number of LNG fueled ships is expected to increase to 800 ~ 1000. (Pan Ruiyu, 2010) At present, some international organizations have been prepared to draft LNG fuel supply ship related interfaces, operational regulations and standards. And according

to the prediction of DNV and other agencies, the future of offshore LNG supply device is expected to increase to some degree. It can be expected that the future of LNG fueled ships in the shipping industry will continue to expand the application scope because of these favorable factors.

### *3.5.5. The successful application of LNG power system at present*

LNG began to be used as fuel in 1964, which was applied on the LNG carrier. But it has not been applied to other types of ships until 2000. According to statistics, from 2000 to 2010, the total number of LNG fueled ships was 22 (not including the LNG transport ship).

Compared with other marine fuel, LNG is the main advantage of the small environmental impact, minimal emissions. But the host LNG is wanted to be changed as bunker fuel, where fuel tank design layout and the space for cylindrical pressure tank is approximately 3-4 times of space of diesel. Special gas-holder and compartment structure can increase the weight of the LNG, which is about 1.6 times of the marine diesel, the construction cost increasing by 8% ~ 20%. At the same time, it will also increase maintenance costs. (Yu Xiaoli, 2012)

At present, the main constructed LNG fueled ships type is the ferry, including car/passenger ferry, Ro-Ro, and roll-on ship, etc. Because these ships belong to short coastal navigation, requirements for the size of the LNG storage tanks are low. Here are several LNG fueled ships power systems.

#### *3.5.5.1. The world's first LNG fueled ferry*

Norway as a major LNG production country is devoted to improving the Norwegian gas fuel technology and obtained good environment effect. In 1996 the Norway Council decided to build two types of vehicles using CNG and LNG as the fuel of

the car or passenger ferry. In 2000, the world's first LNG fueled ferry "M/F Glutra" was completed by Aker shipyards. Through the use of LNG, the ship can reduce 80% of NOx emissions, total cost as high as 30% than the diesel fuel ferry, but shipyard and operators think that because of the first application of new technologies, the cost is within an acceptable range. (Wang Feng, Lin Pu, 2011)

Figure 3 LNG fueled ferry-"M/F Glutra"

Source: from Internet

It is known that, through the operation of LNG fueled ferry during many years, this ship has good environmental protection performance, and can reduce 19% of CO2, 91% of NOX, 100% of SO2, and low noise pollution. While construction costs may increase by 15% ~ 20%, the maintenance cost is higher than the diesel engine. (Yu Xiaoli, 2012)

### *3.5.5.2. Wartsila 65000 - ton LNG fuel cruise ships*

In 2011, Wartsila announced the design of 65000- ton LNG fueled luxury cruise ship. The vessel is 260 meters in length, 34 meters in width, and its maximum width is 43.2 meters, 650 crews, 780 cabins and capacity for 1900 passengers and its speed is 19 knots. (Wang Feng, Lin Pu, 2011)

Figure 4 “Wartsila” 65000 - ton LNG fueled cruise ships

Source: Wang Feng, Lin Pu, (2011), The current situation and trend of development of LNG.

Wartsila LNG Pacs gas tank installed 3 465m3 gasholder on the ship; LNG daily consumption is 45t, endurance for 12 days. As the main diesel fuel in a backup, LNG has 2 8000kW electric motors. (Yang Jianghui, 2014) The fuel supply station is arranged near the stern storage tank, which can reduce the length of the pipeline and ensure the safety of the fuel supply station. Due to the large volume of LNG storage tanks, the replenishment of the ship will be completed by barge or small LNG carrier.

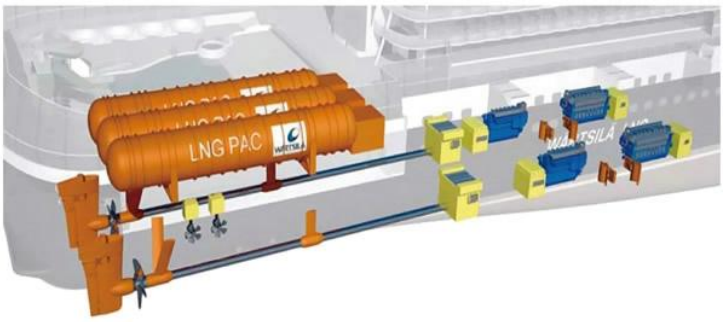


Figure 5 “Wartsila” LNG Pacs gas tank

Source: Yang Jianghui, (2014), Research of LNG dynamic ship filling technology, Marine engineering equipment and technology.

### *3.5.5.3. LNG fueled VLCC*

In December 2010, DNV announced the design concept of a type of environmental

VLCC ship "Triarity". The ship is 361 meters in total length, 70 meters in width, 27.52 meters in depth, and 291300 t in capacity. The VLCC can be reduced by 24% of CO2, 80% of NOX, 94% of SOX emissions during the period of 20 years. It is understood that a VLCC in each voyage will loss 0.2% of liquid cargo. In order to reduce the air steam leakage, the VLCC installed steam recovery unit by cargo oil pump with steam power. (Jin ling, 2011)

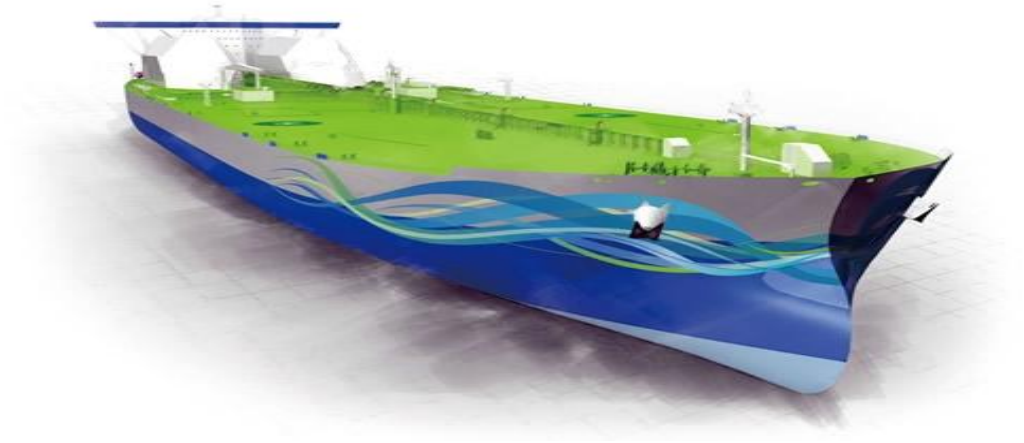

Figure 6 VLCC ship -"Triarity"

Source：Jin ling, (2011)，Advantages of LNG hybrid ship，CHINA SHIP SURVEY

From the point of view of the development of the ship, among the European countries in terms of LNG ship fuel development in the leading position, especially Norway has a leading edge and a good demonstration effect in the LNG infrastructure, the LNG fueled ship technical specifications, and the government's push for the LNG fuel.

And from the point of view of LNG fueled ships technology and equipment development, the development of the LNG fueled ships is not just limited to design company and shipyard, the ship-owner, classification society, equipment manufacturers, design company and shipyard joint research project also received a grant from the government in terms of technical development.

In addition to the above, some of the major European shipbuilding and design companies are developing LNG fueled technology. For example, Japan and South Korea shipbuilding companies are currently working on the development of LNG fueled ship. Mitsubishi Heavy Industry is one member of main LNG fueled ship engine suppliers. In 2009, Japan's Mitsui OSK lines announced the design of LNG fueled environmental ferry "ISHIN-II". Daewoo shipbuilding and marine company is currently developing the large LNG fueled container ship, and the company along with MAN is developing ME - GI engine and DSME high pressure fuel supply system applied for 14000 TEU container ships.

LNG industry can be described as a new industry with great development potential and greater uncertainty, but the present stage has not yet achieved a large range of promotion and application. At present, main factors influencing the rapid development of LNG fueled ships include the lack of infrastructure, ship technology constraints, the lagged development of specifications, different attitudes of governments and the public lack of knowledge for natural gas, and so on. Therefore, there will be a lot of joint efforts to solve in the long time.

### *3.5.6. The feasibility of LNG technology under the new system of IMO*

The International Maritime Organization (IMO) and the European Commission recently launched a meeting on carbon emissions and energy efficiency for maritime transport in order to reduce the impact of shipping on global warming by setting guidelines.

According to this regulation, all new ships with a gross tonnage of 400 tons or more must meet new energy efficiency design index (EEDI),and reduce carbon emissions by 10% from 2013; reduce by 10% from 2020 to 2024; reach 30% emission reduction target by 2024 . The vessels that have been launched are also in accordance with the guidelines set out in the ship energy efficiency management plan (SEEMP). (Hou Zhongsen, 2013)

This new rule has been applied among both developed and developing countries for the first time. There are 48 countries in favor of the resolution, 5 countries in oppose, and 12 countries abstained from voting. (Hou Zhongsen, 2013) China, Brazil and India opposed this decision. They asked IMO to provide 6 years of grace; so that they have plenty time to improve technology to meet the requirements. The implementation of the standards in India, China and other developing countries will be delayed, but other countries are retained rights. In order to prevent the entry of vessels in countries, the relevant emission reduction standards have not been implemented.

In addition, the European Commission also proposed to develop a plan to reduce emissions of sulfur dioxide emissions by 90% or 80%. On the basis of the IMO index and the European law, the European Commission established a limit of the sulfur and particulate emissions standards. Since 2015, some sensitive areas, such as the Baltic Sea, the North Sea and English have limited Channel fuel sulfur emissions from 1.5% to 0.1 %. Since 2020, the provisions in other parts of the sulphur emissions have become from 4.5% to 0.5%. (Qi Kunyuan, 2010)

According to IMO limitation, if the owner continues operating ships in ECA after 2015, they must make the final decision in three options: firstly, using low sulfur fuel oil; secondly, installing gas scrubber; thirdly, using liquefied natural gas (LNG).

DNV analyzed that if the ship and Marine diesel fuel sulfur content reduced to below 0.1%, the first solution just needs adjusting fuel oil system, but low sulfur fuel supplies are limited and an increase in demand will lead to price increasing. The second scheme, which used chemicals or water to remove sulfur that exhausted from the engine, needs large-scale renovation. However, installation of flue gas scrubber will increase energy consumption and CO2 emissions. However, LNG is used as fuel and is the best route of low cost, safe and environmental protection. As a marine fuel,

LNG whose environment efficiency is very significant can reduce almost 100% of sulfur oxide emissions, 85% - 90% nitrogen and 15% - 15% CO2 emissions. (Li Zhenghong, 2002) Moreover, the application of LNG also brings considerable economic benefits, because it is much cheaper than oil and rich natural gas reserves in the world.

### *3.5.7. The idea of offshore LNG stations planning in our country*

At present, China has become one of the world's major LNG (LNG) importing countries; China's LNG industry has entered into a period of rapid growth. According to estimates, in 2020, China's total demand for LNG will reach 3000 cubic meters, while the total output of LNG will reach 2400 cubic meters. It can be predicted that in following 10~20 years, quite a number of LNG will transfer to stop the users from the oil and gas stations. (Yu Xiaoli, 2012) In view of this, with the rapid development of LNG industry in China and the promulgation of international maritime regulations, a considerable part of the boat will become LNG fueled ships. Therefore, the construction of LNG receiving station should synchronize with the planning and construction the offshore LNG supply station, in order to ensure the healthy development of LNG and shipping industry in China.

Because of the influence of international oil prices and restrictions on emissions, the world shipping industry must seek new clean energy so as to substitute conventional fossil fuels. As oil and other non-renewable energy dried up and the international situation goes through the ups and downs, the further rising of international oil prices brings increasing risks to owners. In accordance with the provisions of the international maritime organization (IMO) the ship sulfide emission limits of U.S. emissions control area and the part of the European waters have been reduced from 1% now to 0.1%, and since 2020, and ship sulfur emissions limit value has also dropped from the current 4.5% to 0.5% since January 2015. (Liu Xiancheng, 2012) It can be said that these two factors will put forward new requirements in future. There

is no doubt that looking for real ship of energy conservation and emissions reduction will become one of the important works of shipping industry in the future.

Due to the characteristics of LNG, it is destined that ships which use LNG as fuel will be more widely accepted and loved by the shipping industry. LNG is environmental friendly without any sulfur emissions and dust. In addition, LNG has the quite high economic efficiency in terms of the current proven reserves. LNG reserves can be described as the "very rich", but the price is cheaper than oil. And with the increase in the number of LNG fueled ships, the demand for LNG filling stations will increase rapidly.

According to the relevant provisions of the IMO, LNG fuel will not be directly supplied in LNG fueled ships in the loading and unloading terminal, where means of LNG supply station can only be built in the sea. Therefore, the planning and construction of LNG in our country receiving station should also be synchronized with the planning and construction of offshore LNG gas supply station. Not only is it beneficial to resource sharing, but also can save construction investment and maintenance cost. So the market competitiveness will be greatly improved in the future.

## *3.6. Summary*

Through the analysis and comparison of several kinds of new energy sources, we find that although the use of LNG as the ship fuel has shortcomings such as high initial cost, occupy a large area, weak durability and infrastructure is not complete. But it is more economical and secure than wind, solar and nuclear power. In terms of technical feasibility, with the gas engine technology is increasingly mature and gradually promote the use of small LNG boat filling, the successful case of using LNG as ship’s fuel are more and more. LNG will definitely stand out in many new energy, is widely accepted and recognized by the shipping companies.

# CHAPTER 4 ECONOMIC EVALUATION ON LNG FUELED SHIP: BASED ON THE VESSEL REPLACEMENT IN COMPANY A

The international shipping industry is a based business industry. The ship investment is an important part of the development strategy of shipping company, which is also related to the fleet overall structure optimization, fleet transportation economic benefit, thereby affecting the shipping enterprise competition ability and survival and development ability. All the large shipping companies in the world have to face the reality and get involved in this research. The scientific and reasonable shipping investment is an important issue for the shipping companies.

Not only does the investment of LNG fueled ships contribute to spending a lot of money and a variety of other related resources in the big project without the exception, but also should be done more seriously, more systematic, and more scientific. Not only is there qualitative analysis, but also quantitative analysis.

In the economic activities of shipping, the economic indicators are the tools to evaluate the economic efficiency and to assess the economic performance of LNG fueled ships. The need of using the ship investment evaluation indicators becomes an important basis for scientific decision-making of the project.

## *4.1. Brief introduction of Lianyungang Haitong Shipping CO., LTD*

The company now has 118 transport cargo ships and the capacity of 65000 tons. There is main scope of the company including the middle and lower reaches of the Yangtze River and its tributaries of the provincial ordinary cargo transport.

In order to promote the structural adjustment of inland waterway transportation, the

saving energy and emission reduction from the state to the local. The standardization of inland waterway, energy saving and emission reduction is very serious and has contributed to a series of promoting policies becoming an issue.

According to the relevant provisions of the state, combined with the actual situation and development trend of Lianyungang inland waterway transport, Lianyungang Haitong Shipping Co., Ltd. intends to build a 160k-cbm LNG fueled ships. The company chooses bank loans, and the proportion of loans is 80% times as the ship price. And the loan period is 10 years, the bank interest rate being 6.55%. Operating days need 350 days.

By choosing the NPV as the main evaluation index, and using the ship investment model to verify the LNG fueled ships investment decision-making, finally we can obtain the investment decision-making results.

## *4.2. Data collection*

**1) Vessel price: From Clarkson's ship annual price list**

Table 1 LNG carrier new building price

| | A | B |
|---|---|---|
| 1 | **Shipping Intelligence Network Timeseries** | |
| 2 | Created 26 October 2015 13:31 | |
| 3 | | nb |
| 4 | | 70754 |
| 5 | | LNG Carrier 160k cbm (DFDE, Atlantic Max) Newbuilding Prices |
| 6 | Date | $ Million |
| 7 | 2015-Jan | 211.50 |
| 8 | 2015-Feb | 211.50 |
| 9 | 2015-Mar | 211.50 |
| 10 | 2015-Apr | 208.00 |
| 11 | 2015-May | 200.00 |
| 12 | 2015-Jun | 200.00 |

Source：Clarkson

**2) LNG fueled ships financing data:**

Loan aim: Finance 80% of the capital cost ($211.5million) required for the purchase of a LNG vessel (built in 2010) in February 2015.

Loan amount：$169,200,000 (80%*$211.5million)

Loan duration (term): 10 years after the purchase of the vessel

Interest rate: 6.55% (Refer to China Bank benchmark interest rate in 2015)

Revenue per day: According to the data before 2015 to forecast the following ten years (the data before 2015 from Clarkson website)

Operating expenses: $12000/day (the data is predicted according to textbook)

Table 2 Data collection

| | |
|---|---|
| Vessel Price | 211500000 |
| % Financing | 75% |
| Loan amount | 158625000 |
| Interest rate | 6.55% |
| Daily OPEX | 12000 |
| OPEX days | 365 |
| Operating days | 350 |
| OPEX escalation | 3% |
| loan term | 10 |

Source：Own presentation

On the basis of the operating income of LNG fueled ships before 2015, we can predict the enterprise income in the following ten years through move average method; weight more average model and liner analysis method and exponential smoothing model, and the selected method which has smallest MES. Therefore, the best method is weight more average model. And we can get the forecasting average revenue is 68733.45 per year.

Table 3 forecast average revenue

| | YEAR | YEAR NUMBER | LNG Carrier 160k cbm AVERAGE EARNINGS USD/day | FORECAST VALUE(MOVE AVERAGE) | FORECAST VALUE(WEIGHT MORE AVERAGE) W1=0.1 W2=0.2 W3=0.7 | FORECAST VALUE(WEIGHT MORE AVERAGE) | LINEAR | EXPONETIAL |
|---|---|---|---|---|---|---|---|---|
| | 2008 | 1 | 68542 | | 1.0 | 0.639852804 | 15001.9 | 13897.62 |
| | 2009 | 2 | 45621 | | | 0 | 17945.8 | 15830.17 |
| | 2010 | 3 | 43574 | | | 0.360147196 | 20889.7 | 18031.46 |
| | 2011 | 4 | 105486 | 52579.00 | 46480.2 | 59549.84 | 23833.6 | 20538.84 |
| | 2012 | 5 | 140000 | 64893.67 | 87117.1 | 67181.21 | 26777.5 | 23394.90 |
| | 2013 | 6 | 98457 | 96353.33 | 123454.6 | 78301.55 | 29721.4 | 26648.10 |
| | 2014 | 7 | 74655 | 114647.67 | 107468.5 | 102954.53 | 32665.3 | 30353.68 |
| | 2015 | 8 | 43561 | 104370.67 | 85949.9 | 116466.18 | 35609.2 | 34574.55 |
| Forecast | 2016 | 9 | | 72224.33 | 55269.4 | 78686.36 | 38553.1 | 39382.36 |
| | 2017 | 10 | | 63480.11 | 54866.28 | 76106.88 | 41497 | 44858.72 |
| | 2018 | 11 | | 80025.04 | 53816.38 | 55282.31 | 44440.9 | 51096.60 |
| | 2019 | 12 | | 71909.83 | 54171.66 | 70257.46 | 47384.8 | 58201.90 |
| | 2020 | 13 | | 71804.99 | 54170.06 | 74000.23 | 50328.7 | 66295.23 |
| | 2021 | 14 | | 74579.95 | 54135.01 | 62023.51 | 53272.6 | 75513.99 |
| | 2022 | 15 | | 72764.92 | 54145.69 | 67292.03 | 56216.5 | 86014.67 |
| | 2023 | 16 | | 73049.96 | 54145.99 | 71584.29 | 59160.4 | 97975.55 |
| | 2024 | 17 | | 73464.94 | 54144.83 | 65466.80 | 62104.3 | 111599.65 |
| | 2025 | 18 | | 73093.27 | 54145.15 | 66634.68 | 65048.2 | 127118.27 |
| | MSE | | | 2748353263 | 1955342035 | 2786995381 | 4213870682 | 4538218479 |
| | | | | | average earning= | | 68733.45 | |

Source：Own calculation

## *4.3 Analysis*

### 1）Break-even analysis

The purpose of break-even analysis is to find out the critical value between cost and profit. Through the balance of cost and profit analysis, it can be founded that the value of the shipping companies does not lose, so as to determine whether the company can make a profit or loss.

Table 4 Break-even rate calculation

| | | BREAK-EVEN RATE CALCULATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Amounts in US$ | year1(2010) | year2(2011) | year3(2012) | year4(2013) | year5(2014) | year6(2015) | year7(20 | year8(2017) | year9(2018) | year10(2019) |
| Starting balance | 158625000 | 142762500 | 126900000 | 111037500 | 95175000 | 79312500 | 63450000 | 47587500 | 31725000 | 15862500 |
| Capital | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 |
| Interest | -10389937.5 | -9350943.75 | -8311950 | -7272956.25 | -6233962.5 | -5194968.75 | -4155975 | -3116981.25 | -2077987.5 | -1038993.75 |
| Instalment amount | -26252437.5 | -25213443.75 | -24174450 | -23135456.25 | -22096462.5 | -21057468.75 | -20018475 | -18979481.25 | -17940487.5 | -16901493.75 |
| Ending balance | 142762500 | 126900000 | 111037500 | 95175000 | 79312500 | 63450000 | 47587500 | 31725000 | 15862500 | 0 |
| | | | | | | | | | | |
| Loan repayment | -26252437.5 | -25213443.75 | -24174450 | -23135456.25 | -22096462.5 | -21057468.75 | -20018475 | -18979481.25 | -17940487.5 | -16901493.75 |
| OPEX | -3650000 | -3759500 | -3872285 | -3988453.55 | -4108107.157 | -4231350.371 | -4358291 | -4489039.609 | -4623710.797 | -4762422.121 |
| Total expence | -29902437.5 | -28972943.75 | -28046735 | -27123909.8 | -26204569.66 | -25288819.12 | -24376766 | -23468520.86 | -22564198.3 | -21663915.87 |
| Daily break even | -85435.53571 | -82779.83929 | -80133.52857 | -77496.88514 | -74870.19902 | -72253.76892 | -69647.9 | -67052.91674 | -64469.13799 | -61896.90249 |
| | | | | | | | | | | |
| Average break-even | 73603.66 | < | 79628 | | | | | | | |

Source：Own calculation

It can be seen from the chart above, the average break-even point is US$73603.66 lower than the daily revenue (US$79628). This means that the shipping companies can make a profit by the investment in the LNG fueled ships.

**2) Loan cash-flow analysis**

The cash flow statement is a table that can reflect the changes of enterprise's financial statements. It can comprehensively reflect the enterprise in a certain period of cash inflows and outflows of information which is helpful to understand the profitability and the debt paying ability of the enterprise.

Table 5 Cash flow

| | | CASH FLOW CALCULATIONS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year number | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Operating days | | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 |
| Operating revenue | | 27869800 | 27869800 | 27869800 | 27869800 | 27869800 | 27869800 | 27869800 | 27869800 | 27869800 | 27869800 |
| Operating expense | | -3650000 | -3759500 | -3872285 | -3988453.55 | -4108107.157 | -4231350 | -4358290.882 | -4489039.609 | -4623710.797 | -4762422.121 |
| Gross profit | | 24219800 | 24110300 | 23997515 | 23881346.45 | 23761692.84 | 23638450 | 23511509.12 | 23380760.39 | 23246089.2 | 23107377.88 |
| Capital | | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 | -15862500 |
| Interest | | -10389937.5 | -9350943.75 | -8311950 | -7272956.25 | -6233962.5 | -5194969 | -4155975 | -3116981.25 | -2077987.5 | -1038993.75 |
| Net cash flow | | -2032637.5 | -1103143.75 | -176935 | 745890.2 | 1665230.344 | 2580980.9 | 3493034.118 | 4401279.141 | 5305601.703 | 6205884.129 |
| Acuumulated cash flow | -15500000 | -17532637.5 | -18635781.25 | -18812716.25 | -18066826.05 | -16401595.71 | -13820615 | -10327580.71 | -5926301.569 | -620699.8659 | 5585184.263 |
| Estimate of sale of asset | | | | | | | | | | | 105750000 |
| | | | | | | | | | | | |
| Total net cash flow | -15500000 | -2032637.5 | -1103143.75 | -176935 | 745890.2 | 1665230.344 | 2580980.9 | 3493034.118 | 4401279.141 | 5305601.703 | 111955884.1 |
| IRR | 23% | | | | | | | | | | |
| PBT | 2.100 | | | | | | | | | | |

Source：Own calculation

From the picture above, we can find accumulated cash flow from -620699.8659 in

9th years and to 5585184.263 after the investment in 10th year, and the number changing from the negative to the positive. So we can calculate the IRR (Internal Rate of Return) and PBT (payback time)

●IRR

IRR reflects the profitability of the investment project; it is an important dynamic indicator. In fact, it is a specific discount rate, and forces that NPV=0, then we can calculate the IRR is equal to 23%.

●PBT

The payback time is a period of time from the date of the project to the cumulative net cash flow value exactly equal to 0.

Payback time=2+620699.8659/6206884.129=2.1. So the payback time for LNG fueled ship is about 2 years, proved to be a quick return project.

**3) Estimation of beta(β )**

We find the levered beta and then plug this into the CAPM formula so as to find the levered beta we use and the unlevered beta of the firm.

Suppose the systematic risk of the business area (**β** asset**)** is 1.5,we can solve for**β** equity use formula: $\beta \text{ equity} = \beta \text{ asset} * (1+D/E)$, D refers to debt, E refers to equity. Therefore, **β** equity=1.5*(1+80/20)=7.5

**4) Cost of equity (COE)**

Usually, COE is calculated by CAPM also. It known as required return rate.

The formula is： $Re=Rf+\beta *(Rm-Rf)$

Suppose the Risk-free rate (Rf) is 4%, Suppose the Risk-free rate (Rf) is 4%,

So the Re: Re=4%+7.5*10%=79%

**5) Weighted average COC (WACC)**

If we can determine the weight of every capital components, we will calculate the WACC. We assume that the company's debt rate be 错误！未找到引用源。11% ($r_D$) and the company's marginal tax rate be 20% ( Tc)

$$r_{WACC}=\frac{Equity}{Equity+Debt}*r_{Equity}+\frac{Debt}{Equity+Debt}*r_{Debt}*(1-Tc)$$

WACC=20/100*79%+80/100*11%*80%=0.158+0.0704=22.84%<23%

WACC (22.84%) < IRR (23%), therefore, shipping company can invest LNG ships. Because WACC<IRR, this means the profit of investment is bigger than the cost, so these companies can earn money in the future.

**6) Net present value (NPV)**

The NPV is total cash inflow value minus all the cash outflow value. If NPV is more than 0, it means the project is profitable, higher than the NPV, superior to the project, and greater than the return on investment.

$$NPV=\sum_{t=0}^{n}\frac{CFt}{(1+k)^t}$$ (k=WACC)

NPV=15500000+2032637.5/(1+22.84%)+1103143.75/(1+22.84%)^2+176935/(1+22.84%)^3+745890.2/(1+22.84%)^4+1665230.344/(1+22.84%)^5+2580980.9/(1+22.84%)^6+3493034.118/(1+22.84%)^7+4401279.141/(1+22.84%)^8+5305601.703/(1+22.84%)^9+111955884.1/(1+22.84%)^10=**10004939.56>0**

Table 6 Results of IRR/ NPV /PBT

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total net cash flow | -15500000 | -2032637.5 | -1103143.75 | -176935 | 745890.2 | 1665230.344 | 2580980.9 | 3493034.118 | 4401279.141 | 5305601.703 | 111955884. |
| IRR | 23% | | | | | | | | | | |
| PBT | 2.100 | | | | | | | | | | |
| NPV | ¥10,004,939.56 | >0 | | | | | | | | | |

Source: own calculation

Therefore, we can see that the shipping companies can make a profit by the investment in the LNG fueled ships.

## *4.4. Suggestions to Lianyungang Haitong shipping Company*

Although the LNG fueled ship is very clean, it can also meet the needs of energy conservation and emission reduction, whose economic efficiency is also good. However, there are still some problems:

①"Oil to gas" technology is also not very mature now, and difficult to rapid popularization;

②Infrastructure is still not perfect, and very difficult to ship refueling;

③LNG fueled ship's endurance is generally not high, and the short distance sailing ship is more suitable, but the long-distance sailing ship cannot be very good application;

④LNG transport and transfer and so on are not convenient for gasoline and diesel;

⑤There is no unified standard LNG technology, while there is a difference between the classification society.

To solve these problems, firstly, we should increase the "oil to gas" efforts to popularize this technology rapidly; secondly, developing new technology faster contributes to carrying on the ship refueling to the ship; finally, the government needs to increase the construction of LNG infrastructure and investment in this area.

Generally speaking, on the one hand, the application of clean liquefied natural gas with high efficiency and quality in the modern shipping industry can meet the rules

and regulations of the international maritime organization. On the other hand, it is beneficial to maintain the good ecological environment. Therefore, the use of natural gas can bring considerable economic benefits and significant social benefits, which is very feasible and necessary.

# CHAPTER 5 CONCLUSION

It is all known that global emission reduction and low carbon trend have brought great pressure to the shipping industry. According to the relevant provisions by the International Convention and the prevention and control of marine pollution by the Marine Environmental Protection Committee of the IMO (International Maritime Organization): It is required that the sulfur content of the fuel used by the (emission control area) in the ECA (emission control area) shall not exceed 1% in the future, and no more than 0.1% in January 1, 2015.

Actually, according to the shipping green energy development trends, the world has begun to pay attention to a variety of energy researches, such as the use of low sulfur fuel oil, coal cleaning, use of nuclear energy and other renewable energy. However, as the ship energy, LNG has quite obvious advantages.

The major advantage is that the world has proven that natural gas reserves are very rich. Non-conventional sources of energy such as shale gas have been currently used to calculate natural gas for 250 years. (Zhang Fuxing, 2012) The spot price of liquefied natural gas is only equivalent to diesel 1/4. Deputy Director of the national energy board admitted that as oil fuel in the future of alternative energy, the LNG utilization rate among the developed countries in Europe and the United States has reached 25%, while China is only 3.9%. And the LNG's annual growth rate has reached the advanced level in the world. Up to now, China has become the world's leading LNG importing country. It is expected that by 2015, LNG's annual supplies will reach 2800-3350 billion cubic meters. (Chen Wei, 2013)

In summary, LNG Marine technology will gain the rapid development in the near future, and we will soon usher in the era of LNG.

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