LNG as marine fuel within Indonesia shipping sector, a literature review

R Butarbutar¹, R O Saut Gurning², and Semin²

¹Candidate Doctor, Marine Engineering Department, Marine Faculty, ITS, Kampus Keputih Sukolilo
²Marine Engineering Department, Marine Faculty, ITS, Kampus Keputih Sukolilo

Abstract. The objective of this study is to review the state of art and the opportunity on LNG development as marine fuel for Indonesian shipping sector. Liquid Natural Gas (LNG) as one of source energy has become one progressing on research and development by several research company, classification society and shipping company. The research that has been done focused on the environmental benefit to the country. This was as a result of increasing quantity of pollutions due to marine fuel used by vessels. The interesting part from the study that LNG will reduce sulphur (SOₓ) until 90-95 % and reduce the carbon until 25 % which it causes for other alternative energy will develop and progress slowly. The use of natural gas as alternative energy is one of the goals to find the potential solution for ship owner to follow the IMO requirement for the stakeholder to implement the limitation on sulphur content from marine vessel exhaust gas. Annex VI mandated the ship operator to use marine fuel which contain 0.5 % sulphur or install the scrubber which it will expensively cost for the ship owner. LNG from some of literatures shown the most advance compare to other alternative fuel and it will provide benefit from environmental protection and cost efficiency.

1. Introduction
Nowadays, the development of marine industry in Indonesia in particular is still influenced by shipping sector as it uses the most economical means of transportation. Indonesia as one of largest island country in the world are connected using sea transportation mode. The development of marine industry in Indonesia in particular is still influence by shipping sector as it uses the most economical means of transportation. The need of energy in Indonesia will depend on the need of energy globally. BP Energy Outlook 2019 provide two challenges for the usage of energy which they are the increasing demand of energy every year and the challenge to reduce carbon content of the energy that use on all sector including factory, land transportation, aviation and marine transportation. The use of fossil fuel for almost all marine vessel brings about the increase of pollution, that is, greenhouse effect. Significant effort needs to be done in order to reduce the use of some fossil fuel, such as, Heavy Fuel Oil (HFO), Marine Fuel Oil (MFO) and Marine Gas Oil (MGO), unless potential climate crisis will happen in the future. Figure 1 illustrates procedure to overcome the crisis in which energy options should be obtain as well as regulation should be developed.
Figure 1. Rational of energy management and alternative with certain impact to climate

This literature review will provide clear picture for ship owner especially in Indonesia to understanding on how important this change. Ship operator or ship owner in Indonesia are still struggle with the operating cost (Opex) for their day-to-day fleet operation. Every single change on their strategy will impact overall cost overview. The implementation of limitation sulphur and carbon content on shipping sector, it will require costly effort such as modification, additional equipment or even to reduce their cargo space. The development of fuel from fossil is an important source and the composition of the heavy fossil hydrocarbon which it can transform to natural gas that environmentally friendly [1]. The fossil fuel will cause the high-cost impact to the government including the potential impact on economy, social protection, air pollution and even for the education. The usage of fossil fuel is very critical to change to alternative energy. The energy innovation will provide the balance between the social readiness and technology development [2]. Some literatures about the development oil and gas will provide context on why the important of transition on utilisation conventional fossil fuel to other potential alternative fuel as shown in Table 1:

| Author             | Development oil and gas time to time                                                                                                                                                                                                 |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Norbert Berkowitz 1997 | Fossil hydrocarbon formed heavy oil, bitumen and coal as important source for light conventional fuel. Furthermore, from Norbert explanation that heavier fossil hydrocarbon will transform to the natural gas which environmentally friendly. This literature provides the basic concept on how the natural gas come from and it will be aligned with concept to have alternative fuel from natural gas which it has the composition and capability for emission reduction. |
| John Oakey 2015    | The flexibility of fuel is very important for terminate the dependency to conventional fossil fuel [3]. It’s important view from this journal because its intention to terminate the dependency on fossil fuel, which many countries are not yet start to develop renewable energy. The challenge is the willingness to protect the earth from climate change. |
| N Abas et al 2015   | The peak production of fossil fuel and reducing production will depend on the fuel consumption and exploration. Oil and gas including coal, will exist until several decades, however the increasing the usage of fossil fuel will impact to climate change. The renewable energy source and alternative fuels are the key to energy development and climate change [4]. |
| Sunyoung Yun et al 2015 | Fossil fuel as an energy has consume the expensive cost to government including the impact to country economy, social life protection, welfare, |
air pollution and even the impact to education in overall. The utilisation of fossil fuel should be change to renewable energy. Energy innovation should create the balance between the social readiness and technology development.

Laura Merril et al 2017  The research for renewable energy to replace fossil fuel with the good highlight that government provided high subsidies and it cause the government lose the opportunity to develop renewable energy [5].

Daniel Soeder, Scyller Borglum 2019  Fuel revolutionary that the shale of gas is significant invention in the history of oil and gas industry [6].

Daniela Momete 2020  The rapid population growth should require the high consumption of energy where the existing source of conventional fossil fuel is not sufficient in term of number and it will require other development of renewable energy to ensure there is a balancing from economic, social and environmental protection aspects. European Union has close to the goal of renewable energy development [7].

The table 1 provided some journal review on development of fossil fuel into natural gas. Most of authors, they explained how critical to look for alternative source of fuel consider the rapid population globally. Rapid population will impact on increasing consumption for fossil fuel. Furthermore, it will cause expensive cost to government including the cost impact to environmental.

The key of earth protection from climate change impact is the mindset from government to provide framework and support for shipping sector. The shipping sector shall to do transition to alternative fuels immediately, it will significantly impact for future decades to economy, social and environmental.

### 1.1. Environmental consideration for energy selection

Globally, the fossil fuel is the major source of energy and the demand of fossil fuel every year is increasing however the capacity resource of exploring for fossil fuel is reducing around the world. In accordance to 2016 Indonesia Energy Council for Business as usual (BAU) scenario, the provision of oil including oil source, fuel and refinery product will increase from 72 million Ton Oil Equivalent (TOE) on 2015. Furthermore, it will become 284 million TOE on 2050 or the growth demand around 4% per year. From the description for increasing the need of oil in Indonesia, there are two challenge which they are the limitation of oil reserves as the raw material for producing HFO, MFO, MGO and IFO and other challenge is the carbon emission to atmosphere which it can cause the global emission or Green House Emission (GHG). Jack Sharples from The Oxford Institute for Energy Study in 2019 [8] mentioned in his journal LNG Supply Chains and The Development of LNG as Shipping Fuel in Northern Europe explained the major source of carbon emission (CO\textsubscript{2}) is the transportation including the air pollution that cause of human health impact especially from SO\textsubscript{x}, NO\textsubscript{x} and particulate emission. At 2015, the global emission for CO\textsubscript{2} from exhaust gas emission around 32,3 billion ton which 7.7 billion is coming from transportation emission. The land transportation is the biggest source of emission with total number of emissions around 5.8 billion ton followed by sea transportation around 657 million ton of emission and aviation provide 530 million ton of emission. When the land transportation contributes for CO\textsubscript{2}, NO\textsubscript{x}, and particulate emission, in other hand the sea transportation contributes around 90% in transport sector for SO\textsubscript{x} emission and it has impacted to contribute the emission to local port. One factor that cause for high emission from vessel due to the cheap price of fuel and filtering technology of fuel. The bigger portion of government subsidies for fossil fuel or conventional fuel also one contributing factor from government to lose the opportunity in developing alternative energy. The fossil fuel should immediately to replace with other alternative energy. However according to N Abbas that the fossil fuel is the energy that needed until future and it cannot be replaced in overall with the alternative energy.
1.2. Alternative fuel for shipping sector

There are several alternatives for fuel in marine sector that most of them are still in research or study by the fuel energy research company, classification society, engine manufacturing, government and ship owner. DNV has a study to identify the alternatives of fuel for shipping such as LNG, LPG, methanol, biofuel and hydrocarbon. DNV believed that battery system, fuel cell system and wind-assisted propulsion to harbour will be potential energy to shipping sector however it’s still on research stage. So far, the other energy source that used as an alternative for fuel in shipping sector is LNG because it has proven in term of reducing emission and sufficient source of LNG. Battery is one of potential source of energy in the future, it will provide direct store of electrical energy especially for propulsion system. The growth of electrical vehicle will impact to the use of battery for vessel as well, however in the development of the technology is still not yet meet demand from shipping sector. Other potential energy alternative such fuel cell system will provide good opportunity for engine manufacturing due to this fuel cell convert the chemical energy to electrical and thermal through electrochemical oxidation and minimise the noise emission and vibration. Again, this potential energy development is still slowly on progress for technology development together with the last potential alternative energy in shipping which is wind-assisted propulsion. In addition to three of potential alternative fuel in shipping sector, there are some of energy that it already used in some industry in the world. Biofuels that developed from biomass which converted to liquid or gaseous fuels also commonly used in shipping sector in Indonesia. Government of Indonesia has established the requirement for vessel to have biodiesel as fuel for shipping sector however for future it will challenging due to the requirement for replanting the sources of this biodiesel such as palm oil. Other alternative energy is methanol which it can produced from natural gas, coal, biomass, CO$_2$ and hydrogen. Hydrogen as another alternative energy is used as fuel on some land transportation such as car, buses, train and truck. The other alternative energy which also used in shipping sector is LPG (Liquid Petroleum Gas) as mixture from propane and butane however no progress so far for LPG as alternative energy in shipping sector because the development of LPG technology is not in advance compare to LNG.

2. LNG as shipping alternative fuel

LNG is natural gas with the main component is methane (CH$_4$) with the composition the lowest content of carbon and this natural gas has potential to reduce CO$_2$ emission. The LNG that produced mostly used for households, power plant and other industry sector. With the characteristic of LNG, in practically will have free sulphur. As a fuel in shipping, LNG has used since 1950 and nowadays the LNG carrier has using LNG as fuel. The question on usage of LNG whether using this type of fuel will provide benefit to ship owner or shipping company? Some of study has provide some view in different angle about the benefit using LNG as marine fuel. Calderon [9] explained that LNG has got a good momentum with the fast-growing technology of LNG compare to other alternative fuel. In Technology Warming Potential (TWP) approach, LNG as source of energy should have incentive for stakeholder that use LNG as fuel including in shipping sector as align with the intention to reduce gas exhaust emission [10]. Byeong-Yong in his journal in 2017 provide the result of his research that using LNG for the CO$_2$ vessel provide cheaper prices for fuel compare to the same type of vessel but use conventional fuel such as HFO or MGO [11]. Other research in South Korea for the flour vessel that use LNG as fuel and with the willingness to pay by the customer due to important of reducing emission from vessel exhaust gas, the customer want to pay 36% higher from the average cost from the vessel use the conventional fuel [12]. Some of challenge from shipping sector in regard to usage of LNG as fuel from Jun Woo et al [13] research as follows:

- Higher investment cost for changing fuel from conventional to LNG
- Fuel prices

From another interesting study that stated, IMO in implementation the regulation with 2 decades used technical and operational approach in the implementation of IMO rules including on reducing exhaust gas emission however these approaches are not really successful and this research propose that IMO
should use the market-based measures or approach [14]. Commercial incentive will be a potential approach to promote LNG as fuel and it will give guarantee to the shipping sector to have a change. One approach that it can be used to show that investment on vessel to use LNG using Life Cycle Cost Analysis (LCCA) which give overall overview cost calculation for this alternative fuel [15]. This cost optimization by calculate all aspects and do the cost identification approach for future. Some of additional literatures also shown the benefit from using LNG for vessel as per table 2:

**Table 2. Literature review on benefit LNG as alternative fuels**

| Author           | The benefit LNG as alternative fuels |
|------------------|--------------------------------------|
| M Aymelek 2014   | Aymelek researched found the promising for container vessel if use LNG as fuel when the have a long voyage even there are some challenges including operational and safety however LNG offer the economical aspect and environmental protection and it will be a potential bunker option on 2030. |
| Masaki A 2014    | The low propulsion engine project using LNG as fuel shown the good investment cost compare to the vessel that use conventional fossil fuel using Selective Catalytic Reduction (SCR). |
| O Schinas et al 2015 | For shipping industry, the LNG fuel technology has a good momentum by the availability of overall technical solution to reduce carbon emission and all the stakeholder such as regulator, engine manufacture and shipping operator have a similar interesting to digging more detail about LNG as fuel for vessel |
| Olav A 2015      | China, South Korea and Japan are the customer which implemented the emission control that it requires all vessel to these countries to follow their regulation |
| Thomson et al 2015 | LNG as one of the rapid growths of technology development in alternative fuels compare to other alternative fuels. With the Technology Warming Potential (WTP), LNG should be a source of energy that required an incentive from government to the industry that use LNG as fuel including for shipping industry and in parallel to the demand from the customer to reduce emission from exhaust gas. |
| Bikram S 2019    | In the development of engine technology, some of shipping company has developed Dual Fuel Diesel Engine (DFDE) as combination between using LNG as main fuel source during voyage and using MGO during port manoeuvring |

Table 2 provided overview on literatures in regard to benefit of LNG as alternative fuel. In shipping sector, container vessel sector as mentioned by Aymelek in his paper in 2014 [16] that LNG is promising when it’s used for container vessel even there are some challenges in operational and safety. Masaki [17] on his paper also mentioned that LNG as marine fuel showed the good investment compare to another vessel that use conventional vessel. LNG has a fuel technology which overall technical solution to reduce carbon emission [18]. It will provide a good reference for shipping sector to start changing fuel management strategy consider the major customer for trading such China, South Korea and Japan have implemented the strict rules on emission control [19]. Other view on LNG benefit that some shipping company have used Dual Fuel Diesel Engine on their fleet which combine LNG as main fuel during voyage and MGO during port manoeuvring [20]. This combination has shown the significant reduction on conventional fossil fuel usage during voyage and it can reduce emission in overall.
3. Indonesia shipping sector opportunity to use LNG as fuel alternative

Some of the research show that LNG is most competitive alternative to substitute conventional fuel including cost efficiency in long term investment. One shipping sector in Indonesia that contribute to development national shipping trade whether international and domestic is container vessel. Container vessel’s ship owner that they have a route to international route especially to country that implemented strong emission control should start to think the long cost efficient on fuel management that contribute as one of the costly expenditures for vessel. The table below provide the expectation on LNG consumption until 2040 and expected that the increasing number of consumptions.

Table 3. Expectation on LNG consumption in maritime sector in million ton per annum (mpta). (Source Lloyd’s Register 2017)

| Year | 2025 | 2030 | 2035 | 2040 |
|------|------|------|------|------|
|      | 8-30 | 10-40| 15-45| 20-65|

UNCTAD in 2017 report shown the increasing trend for vessel use LNG as fuel but not LNG tanker including for vessel in operations or new build vessel. With this trend, Indonesia shipping sector should see the potential of LNG as fuel consider LNG is most competitive compare to other alternative fuels.

3.1. Challenge to Indonesia shipping sector

Indonesia shipping industry as one of Indonesia economical support in usage of LNG as fuel has some of challenge that it should be part of stakeholder including government to solve the problem and provide support to marine industry. Some of the challenge for Indonesia shipping industry as follow as below:

- support on providing incentive for shipping company to participate in using environmentally friendly fuel such as LNG
- provide the infrastructure for bunker LNG
- establish the national regulation in marine for alternative fuel such as LNG
- approach for this implementation alternative fuel LNG based on market as well

3.2. Variable success factor for implementation LNG as fuel in Indonesia

There are many contributing factors as describe from some research or journal and the variable that it can provide the success for Indonesia shipping industry to implement LNG as fuel such as the support from the government on providing problem solving on the challenge that facing by the Indonesia shipping industry. There are lot of research has been done by shipping company and engine maker to ensure that LNG can be one of competitive fuel in shipping industry. Each shipping company should understand on the potential alternative fuel and what the optimise fuel choose by the shipping sector in Indonesia including the understanding on market requirement for environment energy or fuel. The investment calculation by shipping company and support from the government in tax will give opportunity for shipping sector to see benefit in commercial for using LNG. Operational cost calculation that it should calculate all variable such as manning, port charges, technical and other operational cost. The important calculation is to determine the freight rate. With the good calculation of freight rate will help the shipping company on the convince the customer that the shipping sector has good willingness to provide the services that the impact on environment low even the freight rate could be higher than the conventional fuel.

4. Conclusion

As in the global picture, Indonesia shipping industry has suffered from the obligation to reduce emissions from their fleet. The level of CO₂ emission in still high because of the use of HFO and MGO.
As the biggest maritime country, Indonesia should participate to reduce emission by promoting the use of LNG. This source of clean energy is available in this country and has not yet been optimally utilised, particularly in shipping sector. Some studies show that LNG as alternative energy will give benefit in the long term. LNG will give cost efficiency to ship owner and provide good investment decision. Indonesia shipping sector should start to think that LNG can use in their fleet and give benefit on the implementation. Authors agreed that incentive to shipping company that participate to use LNG from government will really needed. Indonesia as one of largest country that depend on sea transportation in connectivity should participate in providing regulation on fuel management that required industry including shipping to use the environmentally friendly fuel such as LNG. The participation from shipping industry including local university to do the feasibility study for alternative fuel in shipping sector is important. It will give a reference for ship owner to change fuel management strategy from conventional fossil fuel to alternatives fuel such as LNG. In addition, government could make incentive program in order to promote its use.

5. References
[1] Norbert Berkowitz 1997 Fossil Hydrocarbon (Academic Press)
[2] Sunyoung Yun and Joosung Lee 2015 Advancing Societal Readiness Toward Renewable Energy Adoption with a Socio-Technical Perspective (Technological Forecasting & Social Change)
[3] John Oakley 2015 Fuel Flexible Energy Generation (Woodhead Publishing 1st Edition)
[4] N Abas and A Kalair and N Khan 2017 Review of Fossil Fuels ad Future Energy (Future)
[5] Laura Merrill et al 2017 Making the Switch from Fossil Fuel Subsidies to Sustainable Energy (Nordic Council of Minister)
[6] Daniel Soeder and Scyller B 2019 Shale Gas and Tight Oil, The Fossil Fuel Revolution 1st Edition (Elsevier Science)
[7] Daniela Cristina Momente 2020 A Unified Framework for Assessing the Readiness of European Union Economies to Migrate to a Circular Modelling (Science of Total Environment)
[8] Jack Sharples 2019 LNG Supply Chains and Development of LNG as a Shipping Fuel in Northern Europe (The Oxford Institute for Energy Studies)
[9] M Calderon and D Illing and J Veiga 2016 Facilities for Bunkering of Liquefied Natural Gas in Port (Transport Research Arena)
[10] H Thomson and J Corbett and J J Winebrake 2015 Natural Gas in Marine Fuel (Energy Policy)
[11] Byeong-Yong Yoo 2017 Economic Assessment of Liquefied Natural Gas (LNG) as Marine Fuel for CO2 Carriers Compared to Marine Gas Oil (MGO) (Energy) p 772-780
[12] Hye Jeong Lee and Seung Hoon Yoo and Sung Yoon Huh 2020 Economic Benefit of Introducing LNG Fueled Ship for Imported Flours in South Korea (Transportation Research)
[13] Jun Woo Jeon and Gi Tae Yeo 2017 Study of Optimal Timing of Container Ship Order Considering the Uncertain Shipping Environment, The Asian Journal of Shipping Environment (Science Direct)
[14] Jan Eise Fokkema and Paul Buijs and Iris FA 2017 An Investment Appraisal Method to Compare LNG Fuelled and Conventional Vessel (Transportation Research Part D 56) p 229-240
[15] Pao-Chi Hsu 2014 A Life Cycle Cost Analysis of Using Alternative Technologies on Short Sea Shipping Vessel in ECAs (University of Rostock)
[16] M Aymelek and EK Boulougouris and O Turan 2014 Challenge and Opportunities for LNG as a Shift Fuel Sources and Application to Bunkering Network Optimization (Maritime Technology and Engineering, Guedes Soares & Santos)
[17] Masaki A and Hirohiko K and Tetsugo F and Shota O and Kazuyoshi H 2014 Economic Analysis of Trans-Ocean LNG Fuelled Containership (JMarSci Technology) p 470-478
[18] O Schinas and M Butler 2015 Feasibility and Commercial Consideration of LNG Fuelled Ships (Ocean Engineering)
[19] Olav Akselsen 2015 Norwegian Regulatory Regime on Emission, ECA Zones and Use of LNG (Norwegian Maritime Authority)
[20] Bikram Singh 2019 LNG as Fuel for Shipping Industry (Marine Insight)