Future perspective of the ship alternative fuels in Indonesia

F M Felayati¹, Semin², B Cahyono², U Prayogi¹, A Winarno¹

¹Department of Marine Engineering, Faculty of Engineering and Marine Science, Hang Tuah University, Surabaya, Indonesia 60111
²Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia 60111

E-mail: frengki@hangtuah.ac.id

Abstract. Ship operation has a huge demand due to the ability to achieve a low-cost operation with big cargo density worldwide. Meanwhile, the ship fuel is the highest cost of the operational spending thus increasing the fuel consumption efficiency is required. Alternative fuels have been proposed to achieve it over decades of research. Indonesia, as a maritime country, also encourages the shipowner to accept the alternative fuel application. However, apply a new type of fuel directly to the existing ships is very complicated. This study aims to contribute the future direction with the author's perspective of the implementation of the alternative fuel in Indonesia. Gas fuel type is chosen as the main case on this point of view. There are several gas fuels that are evaluated based on the maturity level of the research study case, such as natural gas and hydrogen. Moreover, the possibility of gas fuel type implementation in Indonesia is also studied. In the last, the future of natural gas and hydrogen fuels is discussed.

1. Introduction
Over the years, the ship's existence is very important to deliver big cargo volume overseas. However, the low delivery cost is very interesting to achieve due to the high demand for shipping without country boundaries. Fuel cost is dominated by the operating cost which is the main cost of shipping [1]. The fuel type is one factor in fuel cost which affects the ship powering system and operational complexity. Thus, choosing the fuel type for the ship in design is a crucial decision. Besides, the ship fuel type has to comply with the stringent rule for the very low emissions target or has the potential toward zero emissions in the future [2].

Several types of fuel are proposed to be a solution to optimize the fuel combustion emissions such as natural gas and hydrogen. Natural gas fuel complies with the latest emissions rules on ships such as IMO Tier III which has a high maturity level of research for the application [3]. Natural gas fuel reduces NOx emissions significantly than conventional diesel fuel on a combustion engine [4]. Moreover, the combustion engine which can use natural gas as the main fuel is available in the market. Meanwhile, hydrogen as an engine fuel is less mature than the natural gas on the application. Many institutions initiate to bring hydrogen fuel applied to ships [5]. Two perspectives come on hydrogen fuel application on ships, hydrogen fuel for combustion engines [6] and electric generators [5]. Both of the perspectives are still in the study. However, Indonesia, as a maritime country, should be prepared to apply this type of fuel due to the global trend. A short to long-term plan should be overviewed due to the feasibility of many factors such as cost, infrastructure, availability, etc.
Thus, this study presents the author's perspective on the future implementation of alternative fuels in Indonesia, especially natural gas and hydrogen. These two types of gas fuel are briefly evaluated and discussed based on the possibility of implementation in Indonesia. Moreover, the future of natural gas and hydrogen fuel is discussed. This study aims to contribute the future direction with the author's perspective of the implementation of the alternative fuel in Indonesia. Gas fuel type is chosen as the main case on this point of view. There are several gas fuels that are evaluated based on the maturity level of the research study case, such as natural gas and hydrogen. Moreover, the possibility of gas fuel type implementation in Indonesia is also studied. In the last, the future of natural gas and hydrogen fuels is discussed.

2. Natural gas and hydrogen as ship fuels

Natural gas and hydrogen are proposed to be the fuel main fuel source for the operation (Figure 1). Natural gas and hydrogen have a promising opportunity to be dominating the fuel market. Those fuels can be used independently or combined [7]. Besides, on ship operation, the diesel engine is still superior due to the high power and efficiency output with high maintainability. Natural gas and hydrogen can be used as fuel using diesel engines combined with diesel fuel as dual-fuel. Natural gas and hydrogen are used as the main fuel with the largest fuel energy substitution and diesel fuel is used as the pilot fuel for the ignition source [8]. Natural gas and hydrogen have a high cetane number thus it is hardly self-ignite using compression on diesel engine [9].

![Figure 1. Most of the recent fuel and prospected fuel for ships](image)

Natural gas fuel in ships can be stored in two conditions, as a liquid or as a gas. In liquid conditions, natural gas is stored as liquid natural gas (LNG) which is stored in very low-temperature conditions. Moreover, natural gas can be stored as compressed natural gas (CNG) which is stored in a high-pressure chamber. However, natural gas is still used in gas conditions in the combustion process. Based on the recent studies, natural gas can be used by premixed with the air in the intake port or directly injected in the cylinder [10].

There are some superior conditions for using natural gas as fuel in diesel engines. A dual-fuel engine can reduce the NOx and PM emissions significantly than the dedicated diesel fuel engine [11]. It allows low combustion temperature to thus reduce NOx emissions significantly [12]. Moreover, it reduces the PM emissions due to the less carbon in the total fuel energy [13]. Diesel fuel has lower energy substitution in the combustion process. Nevertheless, there is a lower thermal efficiency on the dual-fuel engines than conventional diesel, especially at low load conditions [14]. The unburned hydrocarbon emissions also increase significantly at low load conditions [15]. However, a lot of research has been conducted to overcome the optimum combustion process at certain engine conditions.

Moreover, hydrogen can be used in ship operations in several conditions. The hydrogen can be coupled with the diesel fuel thus also performed as a dual-fuel engine as diesel/natural gas dual-fuel engine [16]. Hydrogen also can be coupled with natural gas and diesel in the combustion process. It increases engine performance and emissions [7]. Besides, hydrogen also can be used to generate electricity with the hydrogen fuel cell and the electricity is used for electric propulsion [5]. A
dedicated hydrogen engine was also developed by several manufactures but it used spark ignition. The main idea is to avoid complex electric development but also lowers carbon-based fuel utilization in combustion.

3. Implementation of the gas fuel type in Indonesia
The gas fuel type of ships in Indonesia has a less attention to be applicable. Besides, there are some small ships such as harbor tugboats is used LNG fuel as the main fuel for the operation. Moreover, some LNG carriers also used boiled gas for engine fuel. In this case, the very high-cost investment is the most of the top problem to achieve the massive implementation. Only few institution initiates to use gas type fuel for the ship in case of green campaign on lower the greenhouse gas (GHG) emissions [17]. There is a lot of work to do to implement gas type fuel for the ship operation in Indonesia such as mentioned in Figure 2.

Figure 2. Implementation perspective of gas fuel type for ship in Indonesia

Gas fuel availability is the most important scenario for the implementation. The feasibility study on the availability should be considered as a top priority due to the massive impact aims. Without any study on the availability, the government has lacked decision making to choose the gas fuel type priority to lower the emissions target with affordable price on the business. It should be studied where is the priority location which has the busiest ship traffic. It turns to calculate the GHG emissions contribution from the ship and decides when the implementation should be started to avoid the bigger GHG emissions contribution.

In the next possibility, the fuel distribution can be developed by prioritizing the high impact location on the GHG emissions contribution. Thus, the lower price of the implementation can be performed. The parties also can be determined thus collaboration can be made between the government and shipping industry. If it necessary, a subsidy in the implementation can be proposed due to the high investment cost in turns the old ship power to the new one. It should be a very high cost in the implementation but if the stakeholders gather in one vision it should be very feasible to realize.

4. The future of natural gas and hydrogen fuel
Natural gas and hydrogen becomes popular in recent years in targeting low GHG emissions. Some manufacturers have proposed a new type of power plant that can be applied to the ship by using gas fuel type [18]. It indicates that there is a demand in the market which is forcing the manufacturer to answer the challenge. It is opened the opportunity for natural gas and hydrogen to survive in the future with very high demand. Other technology in the utilization of natural gas and hydrogen also proposed to expand the possibility for the high demand (Figure 3).

Natural gas has a huge availability all over the world and is still in exploration at an affordable price. Methane is the main component of natural gas which can be converted to be fuel and another possibility. Nowadays, some of the hydrogens are also developed by methane [19]. The methane has carbon and hydrogen atoms thus it can be separated and produced hydrogen. It is due to the availability of methane and as an alternative on cost-effectiveness to produce hydrogen. However, hydrogen is a free carbon fuel type than natural gas. Since the carbon issue has a huge impact on the emissions target, thus hydrogen has the potential to overcome the problem.
Figure 3. Future demand expansion on natural gas and hydrogen utilization

Hydrogen may have excellent potential in the future as a fuel. However, it only will be potential if there is a lack in utilization, it is the same on the other gas fuel type; thus, an action should be executed. A clear stringent rule should be formulated and executed. On the other hand, clear steps on the implementation are needed thus the stakeholder can be prepared for the next action without any uncontrolled problems in the future.

5. Conclusion
A brief study on the future perspective of the ship's alternative fuels in Indonesia is presented. Gas fuel type is chosen for the main discussion on the ship's alternative fuel. Natural gas and hydrogen are chosen to be discussed at the highest maturity level in recent studies. Natural gas and hydrogen have attractive characteristics as ship fuel candidates. Serious attention should be considered to implement this type of fuel in Indonesia. Thus, the demand can be developed and it will increase the utilization of natural gas and hydrogen in the future.

6. Reference
[1] Ghaderi H 2020 Wider implications of autonomous vessels for the maritime industry: Mapping the unprecedented challenges Advances in Transport Policy and Planning vol 5 (Elsevier B.V.) pp 263–89
[2] Doukas H, Spiliotis E, Jafari M A, Giarola S and Nikas A 2021 Low-cost emissions cuts in container shipping: Thinking inside the box Transp. Res. Part D Transp. Environ. 94 102815
[3] Theotokatos G, Stoumpos S, Lazakis I and Livanos G 2016 Numerical Study of A Marine Dual Fuel Four-Stroke Engine
[4] Yang B, Wei X, Xi C, Liu Y, Zeng K and Lai M-C 2014 Experimental Study of The Effects of Natural Gas Injection Timing on The Combustion Performance and Emissions of A Turbocharged Common Rail Duel-Fuel Engine Energy Convers. Manag. 87 297–304
[5] Ortiz-Imedio R, Caglayan D G, Ortiz A, Heinrichs H, Robinius M, Stolten D and Ortiz I 2021 Power-to-Ships: Future electricity and hydrogen demands for shipping on the Atlantic coast of Europe in 2050 Energy 228 120660
[6] Shin B, Cho Y, Han D, Song S and Min Chun K 2011 Investigation of The Effects of Hydrogen on Cylinder Pressure in A Split-Injection Diesel Engine at Heavy EGR Int. J. Hydrogen Energy 36 13158–70
[7] Ouchikh S, Lounici M S, Tarabet L, Loubar K and Tazerout M 2019 Effect of natural gas enrichment with hydrogen on combustion characteristics of a dual fuel diesel engine Int. J. Hydrogen Energy 44 13974–87
[8] Cheenkachorn K, Poompipatpong C and Ho C G 2013 Performance and Emissions of A Heavy Duty Diesel Engine Fuelled with Diesel and LNG (Liquid Natural Gas) Energy 53 52–7
[9] Liu J, Yao A and Yao C 2015 Effects of diesel injection pressure on the performance and emissions of a HD common-rail diesel engine fueled with diesel/methanol dual fuel Fuel 140 192–200
[10] Wei L and Geng P 2016 A Review on Natural Gas/Diesel Dual Fuel Combustion, Emissions and Performance Fuel Process. Technol. 142 264–78
[11] Yousefi A, Guo H and Birouk M 2018 An Experimental and Numerical Study on Diesel Injection Split of A Natural Gas/Diesel Dual-Fuel Engine at A Low Engine Load Fuel 212 332–46
[12] De Simio L and Iannaccone S 2020 Dataset for Comparison Between Single and Double Pilot Injection in Diesel-Natural Gas Dual Fuel Engine *Data Br.* 28 104963

[13] Yang B, Ning L, Liu B, Huang G, Cui Y and Zeng K 2021 Comparison study the particulate matter characteristics in a diesel/natural gas dual-fuel engine under different natural gas-air mixing operation conditions *Fuel* 288 119721

[14] Felayati F M, Semin, Cahyono B, Bakar R A and Birouk M 2021 Performance and emissions of natural gas/diesel dual-fuel engine at low load conditions: Effect of natural gas split injection strategy *Fuel* 300 121012

[15] Felayati F M, Semin and Cahyono B 2021 Methane Emissions Evaluation on Natural Gas/Diesel Dual-Fuel Engine during Scavenging Process *IOP Conference Series: Earth and Environmental Science* vol 698 (IOP Publishing Ltd) p 012036

[16] Sharma P and Dhar A 2018 Compression Ratio Influence on Combustion and Emissions Characteristic of Hydrogen Diesel Dual Fuel CI Engine: Numerical Study *Fuel* 222 852–8

[17] Pan P, Sun Y, Yuan C, Yan X and Tang X 2021 Research progress on ship power systems integrated with new energy sources: A review *Renew. Sustain. Energy Rev.* 144 111048

[18] Mavrelos C and Theotokatos G 2018 Numerical Investigation of A Premixed Combustion Large Marine Two-Stroke Dual Fuel Engine for Optimising Engine Settings Via Parametric Runs *Energy Convers. Manag.* 160 48–59

[19] Balcombe P, Staffell I, Kerdan I G, Speirs J F, Brandon N P and Hawkes A D 2021 How can LNG-fuelled ships meet decarbonisation targets? An environmental and economic analysis *Energy* 227 120462