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Fuel options for the future: a comparative overview of properties and prospects

As the maritime industry seeks to reduce its impact on the environment, the search for alternative fuel options is becoming increasingly important. Various fuel options are being studied, including biofuels, hydrogen, and ammonia, which are considered to be more environmentally friendly than traditional fuels extracted from the Earth's depths. The choice of fuel depends on various factors, including the size, speed, and distance of the ship, as well as the availability and cost of fuel. In the future, a combination of different fuel options may be necessary to achieve emission reduction goals. This article compares different alternative fuel types for ships, including low-sulfur fuel, LNG, electricity, methanol, hydrogen, and ammonia. Research shows that low-sulfur fuel is expensive but still cheaper than LNG, and the process of transitioning a ship to this type of fuel is relatively simple. LNG is the most expensive type of fuel and requires a complete overhaul of the ship's fuel system, which reduces its profitability. The article provides a table comparing the properties of different fuel types and concludes that methanol is likely to be the most promising alternative fuel in the near future.

Keywords: safe energy policy, ecology, environmental protection, pollution of atmosphere, low sulphur.

Introduction. Environmental pollution has become an increasingly concerning issue in modern times, with human progress being a major contributor. Various sources, including factories, vehicles, airplanes, and ships, emit a significant amount of harmful gases that have a detrimental impact on the environment. To address this, the International Maritime Organization (IMO) has taken steps to regulate air emissions from ships, with an amendment to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) adopted in 2020. This requires ships to use fuel that contains less than 0.5% of sulfur or utilize a scrubber to clean heavy fuel oil. However, scrubbers are not a complete solution as they simply transfer pollution from the air to the ocean. The biggest challenge is to find an economically viable and environmentally friendly fuel. While very low sulfur fuel oil can reduce sulfur pollution, it still contributes to nitrogen oxides (NO_x) and carbon dioxide (CO₂) emissions. Liquid natural gas (LNG) is a promising option, but its high cost is a concern for ship-owners. Another potential solution is fully electric-powered vessels, but they are only practical in regions where electricity is both cheap and environmentally friendly. Overall, methanol is the most promising alternative fuel due to its ecological benefits and relatively low cost. However, its utilization requires significant attention from ship-owners.

Despite its benefits, methanol as a fuel option has not been widely adopted by ship-owners due to the need for additional attention in handling and utilization. However, ongoing research and development in the field of alternative fuels for ships are leading to new innovations and solutions that could make methanol a more viable option in the future. The shipping industry is also exploring the use of new technologies such as wind-assisted propulsion and hydrogen fuel cells to reduce emissions. However, these technologies are still in the early stages of development and require significant investment and infrastructure.

Reducing air pollution from ships is crucial for protecting the environment and human health. The use of alternative fuels and new technologies can play a significant role in achieving this goal, but further research and development is needed to make these solutions more widely available and economically viable for the shipping industry.

Analysis of recent research and problem statement. Different types of scrubbers exist, including open-loop and closed-loop systems, which operate on similar principles. Open-loop scrubbers draw water from the ship's kingston box and use it to purify the air of sulfur before discharging it overboard [1]. Closed-loop scrubbers work similarly, but the water used for scrubbing is retained on board and discharged as sludge in ports [2]. Hybrid systems are also available, which can use both open and closed-loop cycles.

In order to make a decision regarding the installation of a scrubber on a vessel, a shipowner must carry out a comprehensive analysis [3]. One of the important factors to consider is the age of the vessel. It should also be noted that retrofitting an operational vessel with a scrubber system can result in the vessel being out of commission for a minimum of 30-40 days, leading to substantial loss of profit for the shipowner [4].

Purchasing and using Very Low Sulfur Fuel Oil (VLSFO) is an alternative approach to comply with the IMO 2020 regulations. However, it should be noted that transitioning a vessel from heavy fuel to VLSFO requires a thorough cleaning of the entire fuel system, which results in a prolonged downtime at the berth and loss of profits for the shipowner. Additionally, recent studies have found that VLSFO may produce higher emissions of soot than its predecessor, High Sulfur Fuel Oil (HSFO). This is attributed to the high percentage of aromatic compounds in new mixtures of marine fuels with a sulfur content of 0.50%, which directly contribute to the production of soot [5].

The purpose and tasks of the study. Based on data from ship & bunker's website, the mean global cost of heavy fuel per metric ton was \$520 in October 2021 (Figure 1a), while the price of low-sulfur fuel was \$620 per metric ton (Figure 1b) [6]. In a few years, the difference in the cost of using low-sulfur fuel instead of heavy fuel may outweigh the cost of installing a scrubber, although the calculations were made assuming vessels were operating at low speeds [7]. However, it should be noted that fuel consumption may be twice as high when a vessel is traveling at full speed [8].

Thus, it can be inferred from sources [9, 10] that the benefits of utilizing low-sulfur fuel in lieu of installing a scrubber are not immediately clear. The primary reason being that the conversion process from heavy fuel to low-sulfur oil is both costly and complex. Furthermore, in the long-term, this option is significantly more expensive. Additionally, some research suggests that even low-sulfur fuel may have detrimental effects on the environment. Therefore, it is worthwhile to explore alternative fuels that can be used for shipping [11].

When considering alternative fuels, it is important to evaluate them based on three critical factors: cost-effectiveness, environmental impact, and safety in fuel usage. Among the most promising alternative fuels for shipping are liquefied natural gas, electricity, and methanol. Figure 2 provides a useful comparison of these fuels' characteristics on ships, as of 2021.

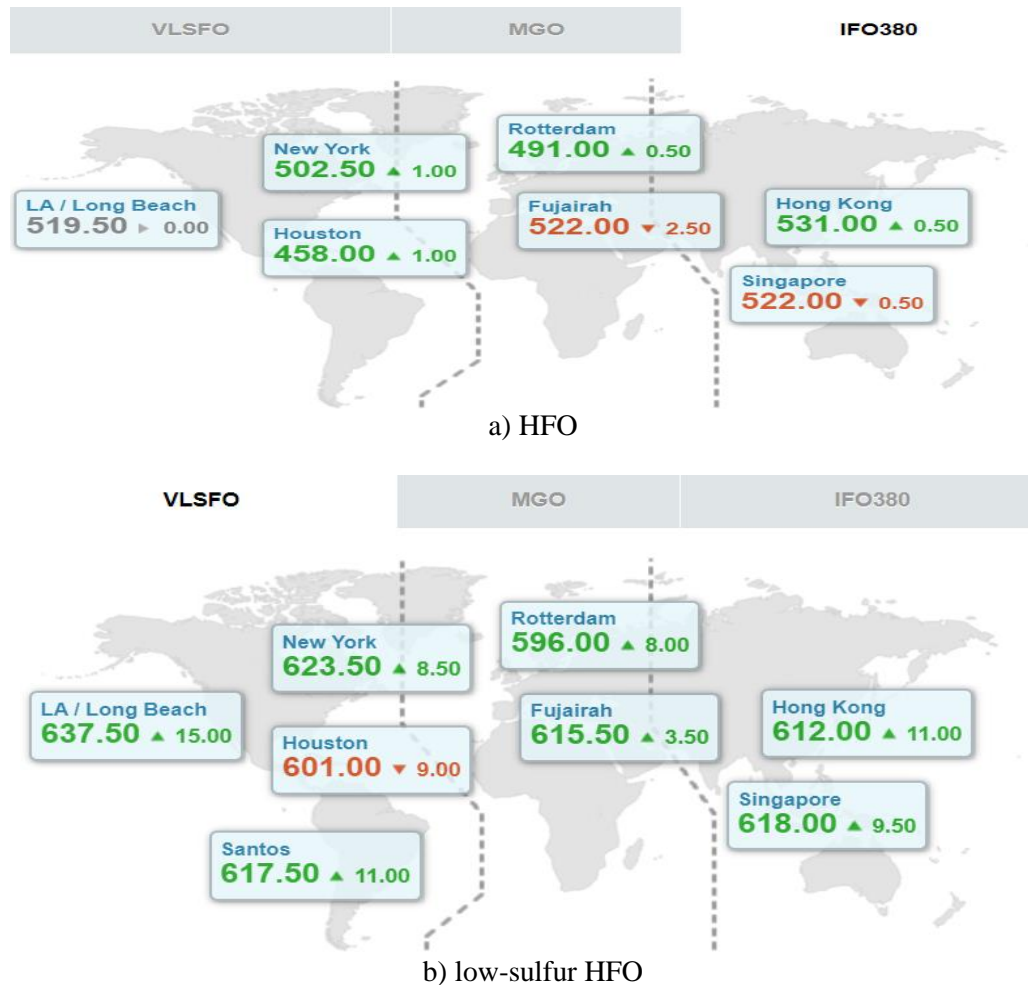


Fig. 1. Fuel prices in different countries

Comparing the prices of low-sulfur fuel and gas can be challenging, as it depends heavily on trends in the global market, which can change rapidly. For example, in February 2021, the energy efficiency price per unit of measure for gas (mmBTU) was \$6.85, while for the same unit of measure for low-sulfur fuel, it was around \$12, indicating that using gas was twice as profitable. The fuel market has experienced significant changes since then, with gas prices increasing threefold compared to February of the same year. While the price of low-sulfur fuel has also increased, it has not increased as much as gas. Currently, gas is 1.5 times more expensive than low-sulfur fuel. Given these circumstances, it is difficult to determine which fuel will be more profitable for future use. The obvious disadvantage of gas usage over low-sulfur fuel is manifested in the following. The cost of installing a gas or two-fuel engine, LNG tanks, relevant pipelines and related equipment can increase the cost of a new vessel by up to 30% compared to a traditional propulsion system. Another disadvantage of LNG is the very time-consuming and expensive re-equipment of marine bunkering terminals [12].

Consideration will now be given to the impact of gas on the environment. Firstly, it should be emphasized that sulfur emissions are markedly reduced, by up to 90%, when utilizing gas as opposed to heavy fuel. Furthermore, natural gas is widely promoted due to its comparatively lower CO₂ emissions relative to coal or oil. However, it is important to note that methane, which comprises a significant component of natural gas, is a greenhouse gas with a potency 25 times greater than that of CO₂ [13]. The overall environmental benefits of liquefied natural gas (LNG) depend on the level of emissions occurring during its production and usage. According to calculations by DNV GL (Det Norske Veritas

and Germanischer Lloyd), a total methane leak rate of 5.5% (incorporating both production and transportation stages, as well as combustion) would result in greenhouse gas emissions from LNG equivalent to those arising from diesel. Consequently, the issue necessitates the implementation of measures to reduce emissions from both production and combustion in engines [14]. Presently, a range of techniques and ideas exist for mitigating these leaks, and their implementation may yield tangible reductions in greenhouse gas emissions by a range of 10-20% when compared to conventional petroleum-based fuels.

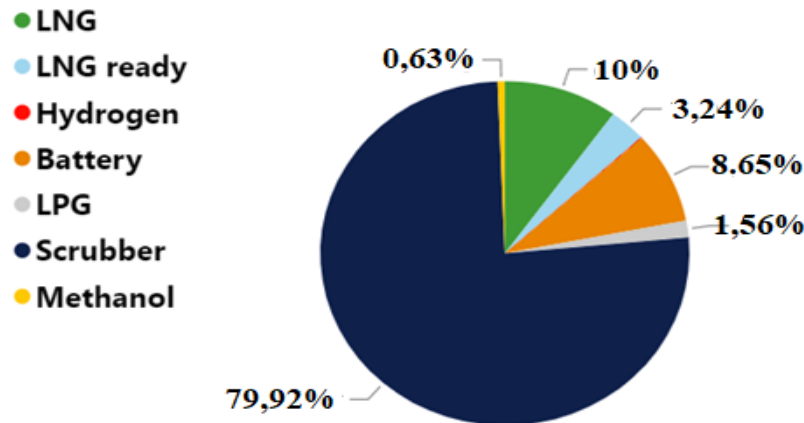


Fig. 2. The total number of vessels operated and under construction that use different types of fuel

It is imperative to consider the environmental impact of utilizing gas as a fuel source in shipping. The reduction in sulfur emissions by up to 90% when using gas, as opposed to heavy fuel, is a significant advantage. Additionally, natural gas has been touted for its relatively lower CO₂ emissions in comparison to coal or oil. However, it is crucial to acknowledge that methane, a major component of natural gas, is a greenhouse gas with a potency 25 times greater than that of CO₂. Therefore, the environmental benefits of liquefied natural gas (LNG) are contingent on the level of emissions occurring during its production and utilization. The total methane leak rate, incorporating both production and transportation stages as well as combustion, is estimated by DNV GL to be 5.5%. Such a leak rate would result in greenhouse gas emissions from LNG equivalent to those emitted from diesel fuel. As such, measures to reduce emissions from both production and combustion are necessary, and a variety of techniques and ideas exist for mitigating these leaks. Implementation of these measures may yield tangible reductions in greenhouse gas emissions of 10-20% when compared to conventional petroleum-based fuels.

Materials and methods of research. When considering the cost-effectiveness of alternative fuels, it is important to not only analyze current market trends but also take into account the long-term cost implications of investing in new propulsion systems and infrastructure. It is also worth noting that environmental regulations, such as the International Maritime Organization's (IMO) sulfur cap, can greatly impact the demand and supply of different types of marine fuels, further affecting their cost-effectiveness. The environmental impact of alternative fuels is another critical factor to consider. As discussed earlier, methanol has the advantage of emitting low levels of sulfur, NO_x, and greenhouse gases during combustion, making it a promising option for reducing marine pollution. However, the production and transportation of methanol also have their own environmental impacts, such as carbon emissions from its production process and potential leaks during transportation. Thus, a comprehensive assessment of the environmental impact of different fuels should take into account the entire supply chain, from production to combustion.

Safety is another important factor to consider when evaluating alternative fuels. While LNG and methanol have been used safely in some vessels, there are still concerns about the risks associated with

their use, such as the potential for leaks or fires. The development of safe and reliable technologies for handling and using alternative fuels is crucial to ensuring their safe implementation.

The choice of alternative fuels for shipping must take into account a variety of factors, including cost-effectiveness, environmental impact, and safety. While LNG, electricity, and methanol are among the most promising options, each has its own advantages and disadvantages that must be carefully weighed. Ultimately, the development and adoption of sustainable and environmentally friendly marine fuels will require continued research, investment, and collaboration among industry stakeholders, policymakers, and researchers.

The issue of whether to use gas or low-sulfur fuel remains a subject of discussion, particularly in terms of cost-effectiveness and eco-friendliness. While gas may be a more affordable option at present, fluctuations in the global market make it difficult to predict which fuel will be more profitable in the long-term. In terms of environmental impact, while gas is known to emit significantly lower levels of sulfur than heavy fuel, the issue of methane leaks must be addressed to fully realize its potential as an eco-friendly alternative.

In addition to the aforementioned criteria of cost-effectiveness, environmental impact, and safety, the selection of alternative marine fuels is influenced by the availability and associated infrastructure for each fuel type. For instance, while liquefied natural gas (LNG) possesses the potential to significantly diminish emissions, its production and transportation infrastructure is still in its nascent stage. On the other hand, electric-powered ships necessitate substantial investments in charging infrastructure and battery technology to become a feasible option for long-haul shipping.

It's important to note that the adoption of alternative fuels in shipping is not only driven by environmental concerns but also by regulatory requirements. The International Maritime Organization's (IMO) regulations, such as the sulfur cap implemented in 2020, are pushing the industry towards cleaner fuels. This has led to a surge in research and development of new fuels, such as biofuels and hydrogen, which have the potential to significantly reduce emissions and meet the IMO's targets for decarbonization.

The shift towards alternative fuels in shipping is a complex and multifaceted issue that requires a holistic approach. While gas and low-sulfur fuel are currently the most popular options, continued research and investment in emerging technologies will be necessary to achieve a sustainable and environmentally friendly future for the shipping industry.

Other alternative fuels are also being considered in the shipping industry. Liquefied natural gas, electricity, and methanol are among the most promising options, and each has its own unique advantages and disadvantages. For example, while LNG has the potential to significantly reduce greenhouse gas emissions, its production and transportation must be carefully managed to avoid methane leaks. Meanwhile, electric-powered vessels produce no direct emissions, but their batteries require frequent recharging, which can limit their range and require significant infrastructure investments.

The shipping industry is exploring a range of options for reducing its environmental impact, including the use of alternative fuels and improved technologies for reducing emissions from existing vessels. By carefully weighing the cost-effectiveness, eco-friendliness, and fuel usage safety of each option, it may be possible to develop a sustainable and profitable model for the shipping industry in the years to come.

Another alternative fuel for vessels is electricity, stored in batteries. However, the potential for emission reductions largely depends on the structure of electricity: in regions with a high level of usage of renewable sources or nuclear energy, emissions of both greenhouse gases and other pollutants will be low (Fig. 3).

Figure 3 shows the carbon intensity of the electricity structure in different countries, expressed in grams of CO₂ equivalent emitted per 1 kWh of electricity produced.

The cost of operation may be low, provided that the price of electricity is competitive with the prices of marine fuel. The main obstacle to the introduction of batteries in transportation is their high capital cost, which exceeds \$ 1,000/kWh. Despite this, using batteries is one of the best long-term solutions for addressing environmental problems, as long as shore-based electricity production can meet or surpass

emissions from conventional fuel-powered ships. significant investment will be required to develop port infrastructure and equip ships with batteries, and the varying electricity prices in different countries may affect the economic feasibility of battery-powered ships. Safety considerations also need to be addressed, and current battery capacity is insufficient for long voyages. At present, electricity is mainly used in hybrid vessels in combination with conventional fuel to reduce emissions and improve efficiency. However, as technology improves and battery capacity increases, using batteries as a standalone fuel for ships could become a viable option in the future.

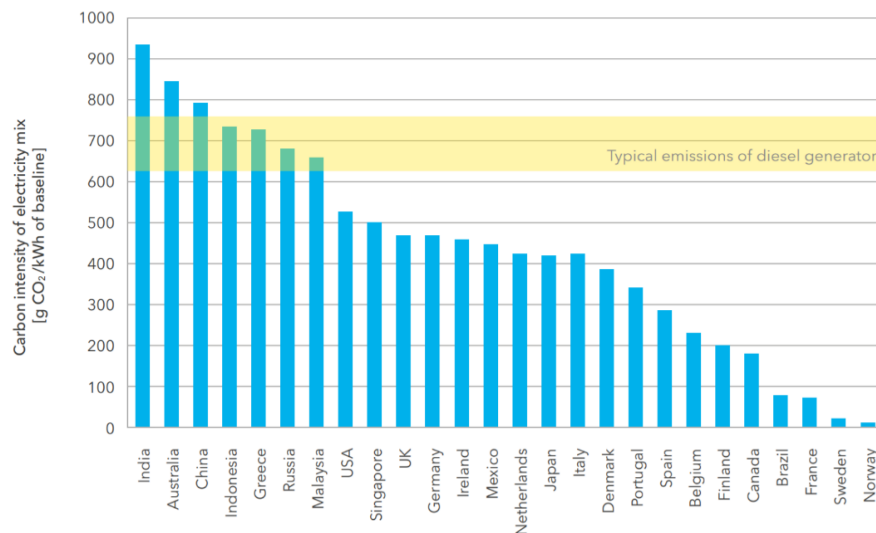


Fig. 3. Specific carbon emissions in electricity production in different countries

In the long run, this is one of the best solutions to environmental problems, provided that the production of electricity on shore will not cover or even exceed the emissions of ships running on conventional fuel [15]. Another important aspect is the financial side of the idea. First of all, a large amount of money should be invested in ports infrastructure and ships equipment. Also, all countries have different electricity prices, so when calling at one port, the ship can save very well compared to the cost of conventional fuel, and in another port, it can cost several times more and exceed the cost of conventional fuel. It is also necessary to pay attention to the development of safe technology for the use of batteries on ships. Another important issue is the fact that now the battery capacity is far from what is needed to conduct long voyages. Nowadays, electricity is used mainly on hybrid vessels in combination with conventional fuel to reduce emissions and increase efficiency. It will take a long time before electricity can be used on ships as a stand-alone fuel.

The use of electricity as a primary fuel source on ships raises concerns regarding the capacity and cost-effectiveness of the necessary battery technology. Currently, battery capacity is insufficient for long voyages, limiting the application of electric power in shipping to hybrid vessels that combine conventional fuel and electricity. The development of battery technology that can meet the energy demands of long voyages is crucial to the adoption of electric power in the shipping industry. The financial aspect of electric power usage is also a significant consideration. Investment in port infrastructure and ship equipment is necessary to enable electric power usage, and the cost of electricity can vary significantly between countries, potentially making it more or less cost-effective compared to conventional fuels in different regions. Ensuring the safety of battery usage on ships is another critical issue that requires attention. While electric power has great potential to reduce emissions and improve efficiency in shipping, it will take significant time and investment to develop the technology and infrastructure necessary for its widespread adoption.

Methanol is an alternative fuel called methyl or wood alcohol, which is a liquid, that means that the existing infrastructure for fuel storage and refueling will require only minor changes for methanol

processing [16], which will require low infrastructure investment costs compared to the large investment required to build liquefied gas terminals or electricity supply systems.

Methanol can be produced from a variety of feedstocks, including natural gas, coal, and biomass. The production of methanol from renewable energy sources such as wind and solar power is also being developed [17]. Methanol is considered a clean fuel due to its low emissions of particulate matter, sulfur oxides, and nitrogen oxides. Methanol also has a higher octane rating than gasoline, which makes it a potential replacement for gasoline in the transportation sector [18].

Methanol is a polar liquid that combines with water, other alcohols, esters, and most organic solvents. This means that methanol, which is released into the environment, will decompose quickly [19]. A large spill will have only local consequences and will decompose in water. Methanol is highly toxic and flammable, which poses safety risks during storage and transport. Methanol also has a lower energy density than conventional fuels, which means that more fuel is required to produce the same amount of energy. In addition, the production of methanol from fossil fuels is a significant source of greenhouse gas emissions, which undermines its status as a clean fuel. The development of renewable methanol production methods could mitigate this issue, but further research is needed to assess the feasibility and scalability of these methods.

The availability of methanol on a large scale is main problem. To be able to supply a large fleet, more methanol has to be produced. To cover 25-30% of the maritime market it is necessary to significantly increase production capacity [20].

In terms of environmental impact during combustion, methanol does not emit sulfur, and the levels of NO_x and greenhouse gases are even lower than in LNG (Fig. 4).

However, the production of methanol can be energy-intensive and may lead to emissions of CO₂ and other pollutants if fossil fuels are used as the primary source of energy. Additionally, the transportation and storage of methanol require specialized infrastructure, which may pose a challenge for widespread adoption.

The safety aspects of methanol as a fuel should also be considered. Methanol is highly flammable and toxic, which requires strict safety protocols for its handling and storage. The risk of leaks and fires must be minimized through appropriate design and operational procedures.

Methanol is considered a promising alternative fuel for shipping, with several pilot projects and demonstration vessels already in operation. Ongoing research and development efforts aim to further improve the cost-effectiveness, environmental performance, and safety of methanol as a marine fuel.

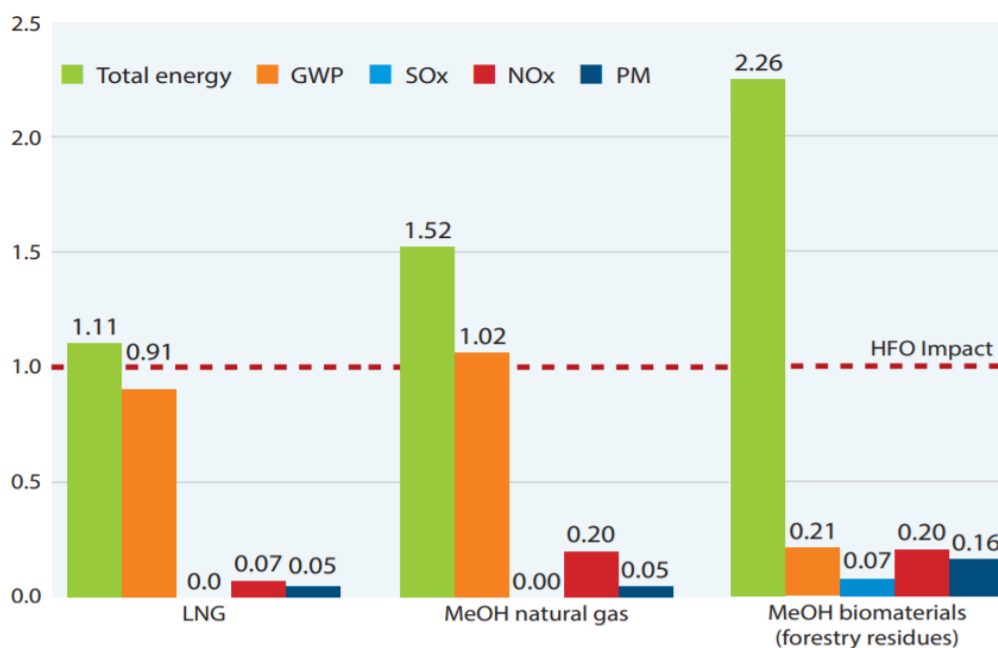


Fig. 4. Comparison of emissions during LNG and methanol production

This makes methanol a highly attractive alternative fuel option for environmentally-conscious industries and governments. The production of methanol is relatively easy and cost-effective, and it does not require a complete overhaul of a ship's fuel system, unlike LNG. As a result, the adoption of methanol as a fuel source has the potential to significantly reduce the shipping industry's carbon footprint and mitigate the negative impacts of climate change. However, further research and development are necessary to address the remaining technical and regulatory challenges associated with the widespread adoption of methanol as a marine fuel.

Methanol is a renewable fuel source that can be produced from a variety of feedstocks, such as natural gas, coal, and even carbon dioxide. This makes it a highly versatile and sustainable alternative to traditional fossil fuels. Moreover, methanol has a high energy density, which means it can be stored and transported more efficiently than some other alternative fuels. It's worth noting that methanol does have some drawbacks. For example, it has a lower energy density than gasoline or diesel, which means that more fuel is needed to achieve the same level of power. Also, the production of methanol requires a significant amount of energy, which can lead to increased greenhouse gas emissions if the energy is not derived from renewable sources.

While methanol may not be a perfect solution to our energy needs, it does offer a promising alternative to traditional fossil fuels, especially in terms of its low environmental impact and potential for renewable production.

Conclusions and prospects for further work in this area. As a conclusion, the general table of an estimation of various properties of all considered kinds of fuel is presented (tab. 1). The table shows that the scrubber is the most profitable in the long run, because paying only several millions the shipowner gets the opportunity to supply the ship with the cheapest fuel, which pays off in just a few years. It is also easy to install on a ship and can be done in most docks around the world. However, the scrubber does not solve the problem of pollution at all and has no long-term prospects taking in consideration that the IMO plans to further increase the requirements for environmental pollution prevention by ships. A heavy fuel spill is a terrible natural disaster that destroys all the flora and fauna nearby.

Table 1. Estimates of various types of fuel parameters

	Scrubber/ heavy fuel	Low sulfur fuel	LNG	Electricity	Methanol
Profitability	+	+/-		+/-	+/-
Ease of installation	+	+	-	-	+
Availability	+	+	+/-	-	-
Environmental impact	-	+/-	+	+/-	+
Safety during accident	-	-	+	-	+
Prospects	-	+/-	+	+/-	+

Low-sulfur fuel is quite expensive, but still cheaper than LNG. For a complete transition of the vessel to this type of fuel requires washing all tanks and systems, however, compared with the installation of systems for other alternative fuels, this is a much easier process. Low-sulfur fuel has been widely adopted as a means to comply with the International Maritime Organization's sulfur emissions regulations. However, the transition to this fuel comes with its own set of challenges. One of the biggest hurdles is the cost, as low-sulfur fuel is more expensive than traditional heavy fuel oil. This has led to concerns about the financial impact on shipping companies, especially during periods of economic downturn.

Another challenge is the need to clean tanks and systems before switching to low-sulfur fuel, to prevent contamination and ensure proper operation. While this is a simpler process compared to installing new infrastructure for other alternative fuels, it still requires significant time and resources.

Despite these challenges, low-sulfur fuel remains a promising option for reducing emissions in the shipping industry. Ongoing research and development efforts are aimed at improving its cost-effectiveness and performance, as well as exploring other alternative fuels with potential benefits for both the environment and the industry as a whole.

Liquefied natural gas today is the most expensive of all fuels compared in this paper. In order to equip a ship with LNG power supply system, the ship's fuel system must be completely redesigned, and it should be borne in mind that LNG occupies a larger volume with the same energy efficiency as other fuels, which further reduces its profitability. Not all ports in the world can supply vessels with gas and it will take some time before LNG bunkering systems will be available everywhere.

The implementation of a liquefied natural gas (LNG) power supply system on a vessel requires a complete redesign of the ship's fuel system, and it should be noted that LNG occupies a larger volume with the same energy efficiency as other fuels, which further diminishes its profitability. Moreover, LNG is presently the most expensive fuel compared to other alternatives, thus making it a less attractive option for commercial shipping. The availability of LNG in ports is another limiting factor, as not all ports are equipped with the necessary infrastructure to supply vessels with gas. The implementation of LNG bunkering systems worldwide will require significant investments in infrastructure and may take some time to be fully realized.

Electricity is a very controversial type of alternative and depends on the place of its production. In some countries, such as Norway, this is the best choice for ships sailing locally, as it is cheap there and electricity generation causes minimal damage to the environment. Electricity itself does not affect the environment during usage.

Continuing the discussion on alternative fuels for shipping, it is important to note that electricity is a complex and location-dependent option. The suitability of this fuel depends on the electricity production method used and its availability at ports. In countries like Norway, which produce electricity from renewable sources, electric-powered ships may offer a cost-effective and environmentally friendly option for local shipping. However, in other countries where electricity is generated primarily from non-renewable sources, electric power may not be a feasible alternative. It should also be noted that the production and disposal of batteries used to store electricity raise environmental concerns. Once in use, however, electric propulsion does not contribute to air pollution or greenhouse gas emissions, making it an attractive option for clean transportation.

Methanol is the most promising but still underestimated type of fuel. It is cheaper than LNG and takes up less space for the same energy efficiency, which makes it more competitive with low-sulfur fuel than gas. To convert a vessel to methanol, shipowner needs to do the same as to convert it to low-sulfur fuel, which is not such a complicated process. Furthermore, methanol is a liquid at room temperature and atmospheric pressure, which simplifies storage and transportation compared to LNG. Methanol is also widely available, as it is a commodity chemical and can be produced from various feedstocks, including natural gas, coal, and biomass. Methanol has a lower greenhouse gas emission profile than conventional fossil fuels, but its production still generates CO₂ emissions. However, the use of renewable energy sources in methanol production, such as biomass and carbon capture and storage (CCS) technologies, can significantly reduce its carbon footprint. Methanol also has a higher octane rating than traditional fuels, which can lead to better engine performance and efficiency. However, methanol is still a relatively new fuel in the shipping industry, and its infrastructure for bunkering and distribution is not yet fully developed, which presents a challenge for its widespread adoption.

Energy sources such as hydrogen and ammonia were also considered during the search and information was analyzed for this report. However, at the moment they cannot compete with the types of fuel described in this work, because their production and price are much higher, they take even more space for storage than LNG, during the accident they pose a great danger to the ship's crew and the environment. Hydrogen and ammonia are energy sources that have been studied for their potential use

as fuels for shipping, but they currently face significant challenges. The production and price of hydrogen and ammonia are higher than other alternative fuels described in this report, making them less competitive. Additionally, the storage of hydrogen and ammonia requires even more space than LNG, which is a significant disadvantage for ships where space is limited. Furthermore, both hydrogen and ammonia pose safety risks during transportation and handling, as they can be highly flammable or toxic in certain conditions, which can endanger both the crew and the environment. Therefore, despite their potential advantages, hydrogen and ammonia remain less feasible options for the shipping industry, at least until technological and infrastructural developments occur.

The table 1 presented in this study provides an overview of various properties of different types of fuels. The most profitable option in the long run is the scrubber, but it does not solve the problem of pollution and has no long-term prospects. Low-sulfur fuel is expensive but still cheaper than LNG, and the process of converting a vessel to this type of fuel is relatively easy. LNG is the most expensive fuel and requires a complete redesign of the ship's fuel system, which reduces its profitability. Electricity is a viable option in some countries, but its effectiveness depends on the place of production. Methanol is the most promising alternative fuel due to its low cost and space requirements, making it competitive with low-sulfur fuel and more attractive than gas. While hydrogen and ammonia were also considered, their production and price are much higher, and they pose a significant danger to the environment during an accident. Thus, methanol is likely to be the most promising alternative fuel in the near future.

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Паливні опції майбутнього: порівняльний огляд властивостей та перспектив

Оскільки морська галузь прагне зменшити свій вплив на довкілля, пошук альтернативних варіантів палива стає все важливішим. Вивчаються різні варіанти палива, включаючи біопаливо, водень та амоніак, які вважаються більш екологічно чистими, ніж традиційні палива, які добуваються з недр Землі. Вибір палива залежить від різних факторів, включаючи розмір, швидкість та дальність корабля, а також від наявності та вартості палива. У майбутньому, для досягнення цілей зменшення викидів, може знадобитися комбінація різних варіантів палива. Ця стаття порівнює різні альтернативні види палива для кораблів, включаючи низькосульфатне паливо, СПГ, електрику, метанол, водень та аміак. Дослідження показує, що низькосульфатне паливо є дорогим, але все ж дешевшим, ніж СПГ, і перехід корабля на цей вид палива - досить простий процес. СПГ є найбільш дорогим видом палива і вимагає повної переробки системи палива судна, що зменшує його прибутковість. У статті надана таблиця, що порівнює властивості різних видів палива, і заключено, що метанол ймовірно буде найбільш перспективним альтернативним паливом в найближчому майбутньому.

Ключові слова: безпечна енергетична політика, екологія, охорона довкілля, забруднення атмосфери, низькосульфатне паливо.