Methanol as a Marine Fuel for the Decarbonization of the Shipping Sector

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ABSTRACT

The maritime industry is vital to the global economy but significantly contributes to greenhouse gas emissions. Decarbonization strategies need to be developed to meet ever stringent emission standards. This study focuses on exploring methanol as an alternative fuel for cargo ships, addressing challenges and barriers. The environmental impact of methanol using various indexes is analysed and compared with traditional fossil-fuelled vessels. The study considers the retrofit of two cargo vessels and assesses the implications of using methanol on small- and medium-sized ships by using Tank-to-Wake and Well-to-Wake approaches. The importance of considering fuel emissions throughout the entire chain has been emphasised by comparing methanol produced from different sources. A specific index measuring CO2 emissions per transported cargo unit is also introduced. Results show that ship design and fuel production technology represent key factors to move toward a more sustainable shipping.

KEYWORDS

Decarbonisation; Eco-Delivery; Environmental Assessment; Greenhouse Gas Emissions; Methanol; Shipping Sector

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INTRODUCTION

The transportation sector is the backbone of modern society; it connects people, goods, and services and significantly shapes economic and social development. Over the last few decades, it has grown exponentially, and the forecasts continuously increase, leading to the need for a holistic change process [1]. The current transportation model is based on traditional fossil fuel-based propulsion, impacting the environment and human health [2]. The Paris Agreement highlighted the importance of international collaboration for reducing pollutants and setting targets to combat their effects on climate change. The shipping industry is one of the pillars of the transportation sector, and, focusing on air pollution in 2018, it was responsible for around 2.9% of the world's GHG emissions from human activities [3]. Lowering the carbon footprint of the maritime sector is one of the most pressing challenges for the research community and all stakeholders involved in sea transport. At a regulatory level, the International Maritime Organization (IMO) developed, in 2018, the first decarbonization strategy, which introduces rules and tools for evaluating the environmental efficiency of existing and newly built vessels. In 2023, the strategy was revised with more ambitious and challenging decarbonisation goals. Additionally, the European Union (EU) has set a local strategy for emission abatement, focusing on a Well-to-Wake (WtW) approach. Also, Navies are more than ever focussing attention on efficiency, operating costs, energy sources, and the environmental footprint of naval ships [4].

Several strategies and technologies at different stages of development are under scrutiny to achieve the objectives, including hull efficiency improvements and alternative power sources. Wind-Assisted Propulsion Systems (WAPS) are technologies investigated for limiting the polluting impact of the global fleet. WAPS uses wind force to produce thrust for the ship's propulsion to reduce fuel consumption and emissions [5]. Flettner rotors are rotating cylinders (usually spun by an electric motor) that generate aerodynamic lift and drag when immersed in a fluid stream; the working principle belongs to the so-called Magnus effect [5]. Articles and press releases report significant benefits in fuel consumption reduction using the rotor as an auxiliary propulsion device. In [6], different wind-assisted technologies (rotor, wing sail, and DynaRig) are compared, and the most significant fuel savings have been provided by the Flettner rotor, with an average value of 9%. On the contrary, Santoso et al. (2017) shows relatively low benefits, below 1%, when using the rotor on a DWT 4000-ton container ship [7]. The hybridization of the ship power plant is another possibility; this solution combines different technologies, such as engines, fuel cells, batteries and electric motors, enabling great flexibility in vessel design and optimization of consumption and polluting impact [8]. Belvisi et al. [9] proposed a novel hybrid propulsion plant architecture on a new-generation Destroyer ship. The proposed solution relies on battery storage as a backup power source to maintain reliability requirements in Minimum Generator Operation mode while reducing the CO2 emissions of the electric generation. Onboard Carbon Capture and Storage Systems (CCS) are also explored as after-combustion solutions; with this solution, the Carbon Dioxide (CO2) is extracted from exhaust gases, processed, and stored [10]. In [11], a new CC method is proposed using Molten Carbonate Fuel Cells (MCFCs) for retrofitting existing vessels. MCFCs allow for additional energy production while separating CO2 emitted by conventional vessel engines. The technology enables a 20% CO2 reduction using an MCFCs rated at 10% of the engine MCR. Despite the promising results, challenges related to weight and size need to be effectively addressed.

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Optimization and simulation are valuable tools for estimating the behaviour of technologies and also for crew training purposes [12]. Barone et al. [13] propose a dynamic simulation- and optimization-based approach for identifying energy-efficient systems and measures for ship applications, using a large cruise vessel as a case study. Regulators and stakeholders are evaluating and promoting also alternative fuels for the maritime sector; Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), methanol, biofuels, and hydrogen are identified as the most promising options [14]. An overview on cleaner alternative fuels is provided in the work of Al-Enazi et al. [15]. Karvounis et al. [16] evaluate the environmental and economic feasibility of using ammonia and LNG as alternatives to fossils in the maritime industry. Maloberti et al. [17] evaluate alternative fuels such as methanol and hydrogen and different hybrid propulsion layouts on a ferry boat operating in a marine protected area. The study proposes an optimization-based algorithm for minimizing GHG emissions. Dantas and Theotokatos [18] investigate the environmental and economic feasibility of autonomous vessels.

This study aims to analyse the use of methanol as marine fuel for the decarbonization of the maritime sector. The evaluation is based on the methodology proposed in [19], addressing the Pillar 2 of the above-mentioned methodology. Two dry cargo vessels of different size are compared by using the environmental Key Performance Indicators (KPIs) presented in [19]. The paper provides an overview of methanol conversion's issues and technology barriers on vessels of two different sizes.

The novelty of this study is represented by the application to the dry bulk sector, one of the backbones of the maritime economy due to its efficiency, and for this reason careful to accept breakthrough innovations. Results highlight the great contribution that bulk carrier conversion to more sustainable fuels can provide to lower the emissions associated to each unit of transported cargo, emphasizing the importance of transitioning to a more sustainable transportation.

The rest of the paper is organized as follows: the Section Methanol as a Decarbonisation Strategy for the Maritime Sector gives an overview of the use of this chemical onboard ships, the Materials and Methods section details the key performance indicators employed in the study and the relevant data. The Case Study section analyse the methanol conversion of two ship types and the Results section presents the findings. Finally, the Conclusions section summarizes the key outcomes and implications of the research.

METHANOL AS A DECARBONISATION STRATEGY FOR THE MARITIME SECTOR

Methanol is the simplest alcohol and its chemical-physical characteristics have led to a growth of interest in its use as an alternative fuel. The interest in this chemical as an alternative fuel onboard ships has grown exponentially since 2015, when the RO-PAX Stena Germanica was retrofitted to use methanol fuel. Several shipping companies have started to enlarge their fleet with methanol-ready and methanol-enabled vessels. This section gives an overview of the use of this chemical as a decarbonization tool for the maritime sector.

Methanol is a widely traded chemical, with an annual production of almost 100 million tonnes worldwide [20]. It can be efficiently produced from various sources and is classified as Fossil-based or renewable/green methanol. Fossil-based methanol is mainly produced from coal (brown methanol) and natural gas (grey methanol), and it represents almost the total amount of available methanol. Green methanol includes the production from biological sources (bio methanol) and

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synthetic pathways (e-methanol) [20]. The various production chains influence the product's carbon footprint on a well-to-wake (WtW) basis [21], as well as availability and costs. Methanol is also a sulphur-free chemical; thus, it could be a viable option for vessels traveling in the regions included in the Sulphur Emission Control Area [22]. Nitrogen Oxide (NOx) emissions are reduced compared to traditional marine fuel and comply with Tier II regulation [21]. Blending methanol with water in the pre-combustion phase further reduces NOx to comply with the more stringent limits, avoiding installing expensive after-treatment systems [23]. Compared to traditional marine fuels, methanol combustion reduces particulate matter by about 95% [24].
Methanol retains a liquid state under atmospheric conditions, facilitating transportation and storage in conventional fuel tanks. However, this advantage is counterbalanced by the relatively low Lower Heating Value (LHV 19.9 MJ/kg [25]) compared to fossil marine fuels. This characteristic represents a critical issue for onboard applications because more fuel is needed to store the same energy as fossil fuels. Moreover, methanol's volatility, colourlessness, extreme flammability, toxicity to humans, and notably low flashpoint (12°C [26]) underscore the imperative for stringent regulatory oversight. In response, the International Maritime Organization (IMO) promulgated the "Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohols as Fuel" in 2020, marking a shift towards a more prescriptive regulatory framework compared to the preceding IGF code (2015). This initiative prompted leading Classification Societies, including DNV, ABS, Lloyd's Register, and IRS, to develop guidelines for vessels employing methanol and ethanol fuels.

Navigating the complex landscape of methanol as a marine fuel requires a holistic approach, integrating various safety considerations to ensure operational efficiency and crew welfare. Managing fire and explosion risks inherent to methanol's unique properties is at the forefront of these concerns. Methanol boasts a notably low flashpoint, making it susceptible to ignition under certain conditions. To mitigate this risk, requirements prescribe protective cofferdams around integral methanol tanks. These cofferdams are a crucial barrier, providing a buffer zone against potential fire and explosion hazards.
Furthermore, the choice of material for methanol storage tanks is paramount due to its corrosive nature. Stainless steel emerges as the preferred option due to its exceptional corrosion resistance. However, in large structural tanks or retrofitting projects, alternative solutions such as silicate coatings on structural steel may offer a viable compromise, balancing durability with regulatory compliance. Adequate ventilation and inerting systems are pivotal in maintaining safe operating conditions onboard methanol-fuelled vessels. Implementing nitrogen-inert systems displaces oxygen within storage tanks, minimizing the risk of combustion or explosion. Such systems are integral components of a comprehensive safety strategy, working with other protective measures to safeguard personnel and assets.
Strategic positioning of bunkering stations is another critical consideration, necessitating meticulous planning to mitigate the risk of fuel exposure during routine operations. Proper ventilation and spillage containment measures are paramount, ensuring compliance with stringent safety protocols while facilitating efficient fuelling procedures.

Methanol’s characteristics, such as the high-octane number and compression tolerance, enable its utilization in conventional compression ignition engines with specific injection and feeding systems modifications. Additionally, a minimum amount of Diesel Oil (DO) as pilot oil is needed to ignite -the methanol-air mixture. Leading marine engine manufacturers have recognized the potential of methanol as a marine fuel and have expanded their portfolio to include methanol dual-fuel solutions and retrofitting options. In the current practice of utilizing dual-fuel engines, it is customary to carry a quantity of diesel oil as a precautionary measure [27]. This provision ensures a safe return to port using fuel oil propulsion in the event of a

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malfunction in the methanol system. Due to the lack of experience with methanol as fuel, this safety measure is implemented to enhance reliability. However, this requirement further exacerbates the challenge of accommodating methanol storage on board, particularly during retrofitting.

MATERIAL AND METHODS

Assessing the environmental implications of an innovative solution is crucial; in this study, particular emphasis has been placed on evaluating the GHG footprint associated with cargo shipping. It is important to note that various metrics are employed to quantify the environmental impact of an industrial process, such as ship transportation. Specifically, emissions are categorized into Well-to-Tank and Tank-to-Wake. WtT emissions encompass the production, transportation, and onshore storage phases, while TtW signifies the pollutant emissions during combustion onboard. WtW emissions include the polluting impact over the entire chain.
IMO has introduced several tools to estimate, monitor, and limit the carbon footprint of ships. In this work Carbon Intensity Indicator (CII) has been selected as environmental parameter to compare the proposed conversion to methanol with the original vessels. This indicator measures the amount of CO2 emissions produced per unit of cargo transported over a distance, typically expressed as grams of CO2 per tonne-mile (Equation 1) [28]. This indicator helps assess the efficiency and environmental performance of vessels, allowing for comparisons between different shipping routes, vessel types, and operational practices.

$$CII = \frac{FC_j \; CF_{j\,TtW}}{C \;\; D_t} \tag{1}$$

In Equation 1, FCj represents the fuel consumption of type-j in the considered period, and CFj is the conversion factor for the fuel j. For bulk carriers, C (Capacity) means deadweight, and Dt is the distance travelled in nautical miles (nm) [29]. The CII of the vessel under scrutiny must be compared with the required value imposed by IMO, which becomes more stringent yearly [29]. The carbon intensity indicator considers only the CO2 emissions produced onboard, the TtW emissions.
Based on the EU's approach to decarbonisation, another index has been introduced as a novelty: the Well-to-Wake Operational Index (WOI) (Equation 2)

$$WOI = \frac{FC_j \; CF_{j\,WtW}}{C \;\; D_t} \tag{2}$$

It has the same formula as CII, but the conversion factors consider GHG emissions over the entire fuel chain. Considering WtW emissions, the concept of Equivalent Carbon Dioxide (CO2eq) needs to be introduced. CO2eq serves as a tool to assess and compare the climate impact of different greenhouse gases by expressing their warming potential relative to carbon dioxide over a specified period. Table 1 summarizes the conversion factors needed for CII and WOI calculation.

Table 1. Conversion Factors [30]

	Tank-to-Wake [gCO2/gfuel]	Well-to-Wake [gCO2eq/gfuel]

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HFO	3.114	3.716
MGO	3.206	3.876
Grey Methanol	1.375	2.053
Bio-Methanol	1.375	0.324

Another environmental KPI assessed is the Eco-Delivery Index (Equation 3) [19], which evaluates the GHG emissions per cargo ton attributable to the primary fuel consumption. This index considers the fuel's overall GHG emissions using the WtW factor.

$$EDI = \frac{\sum FC_j \, CF_{j\,WtW}}{Transported\ Cargo} \quad (2)$$

This index enables the evaluation of the GHG footprint associated with goods transport, which is crucial in the logistics chain given the increasingly stringent global emission limits.

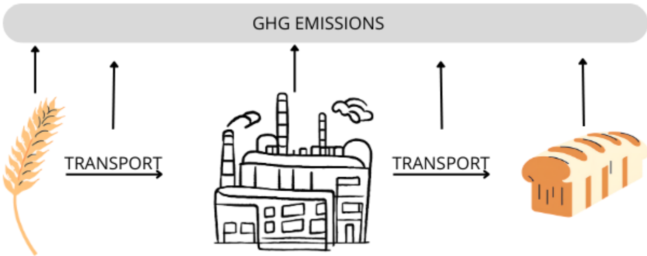

Figure 1. Example of Emissions Related to a Production Chain.

Moreover, the international trend is to estimate, regulate, and limit the total emissions associated with goods and services. Figure 1 presents a simplified logistics and production chain, highlighting the crucial role of transportation and its significant contribution to GHG emissions.
The EDI index in the case study has been calculated using a grain shipment from Canada to Italy, with an estimated duration of 35 days.

CASE STUDY

The proposed case study analyses the environmental impact after a methanol conversion of two bulk carrier vessels of different size; their main characteristics are summarized in Table 2. The original vessels are fossil-fuelled (HFO and DO) and the conversion study to methanol is only focused on the main propulsion engine.

Table 2. Original Vessels Characteristics

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	Vessel A	Vessel B	
Length Overall, max	180.00	199.98	[m]
Breadth	30.00	32.26	[m]
Depth	14.70	18.45	[m]
Deadweight (DWT)	34000	60245	[mt]
MCR Main Engine	7600	7520	[kW]
Rpm Main Engine	110	99	[rpm]
SFOC Main Engine	170 (at 80%MCR)	165.1 (at 75%MCR)	[g/kWh]
Speed	14	14	[kn]
Auxiliary Generators (3 sets) Power	600	570	[kW]
Rpm Auxiliary Generators	900	900	[rpm]
SFOC Auxiliary Generators at 50% MCR	2 [t/day]	253.3	[g/kWh]

Operational data are based on recorded data of Vessel B, the data of its operativity during 2023 are summarised in Table 3. The same operational data have been used for Vessel A.

Table 3. Operativity Data

Operativity Data Over a Year		
Number of Voyages	19	
Days Spent During Operation	146	[days]
Hours of Operativity	3561.5	[hours]
Distance Travelled	43892	[nm]
Average Observed Speed	12.42	[kn]
Total Reported Consumption (LSHFO)	3112.76	[mt]
Total Reported Consumption (LSMGO)	211.72	[mt]

Methanol Tank Layout and Main Engine Selection

The conversion to methanol for a ship has an impact on the overall layout, arrangement, and performance. Although the technical aspects are not the primary focus of this work, some insights and data are provided. Vessel A has been singled out to assess the implications of the methanol conversion on the general arrangement and propulsion system layouts due to the smaller dimensions. Powered by Heavy Fuel Oil (HFO), Vessel A features tanks situated aft within the engine room. The maximum amount of HFO storable onboard is about 1700 cubic meters (m3) while the storage capacity for diesel amounts to 210 m3. The hypotheses for this conversion seek to uphold the vessel's main dimensions while prioritizing adopting the least invasive solution to reduce costs, avoid cargo capacity losses and minimize downtime during docking procedures.
The ship layout was analysed in accordance with the specifications outlined in the American Bureau of Shipping's "Requirements for Ethanol and Methanol Fueled Vessels" which incorporates IMO’s MSC.1/Circ.1621 [31]. The conversion strategy entailed positioning the methanol tanks within the spaces initially designated for HFO tanks, prioritizing the efficient utilization of available volumes while minimizing structural changes. Figure 2 highlights in light blue the area selected for the fuel storage and supply system positioning.

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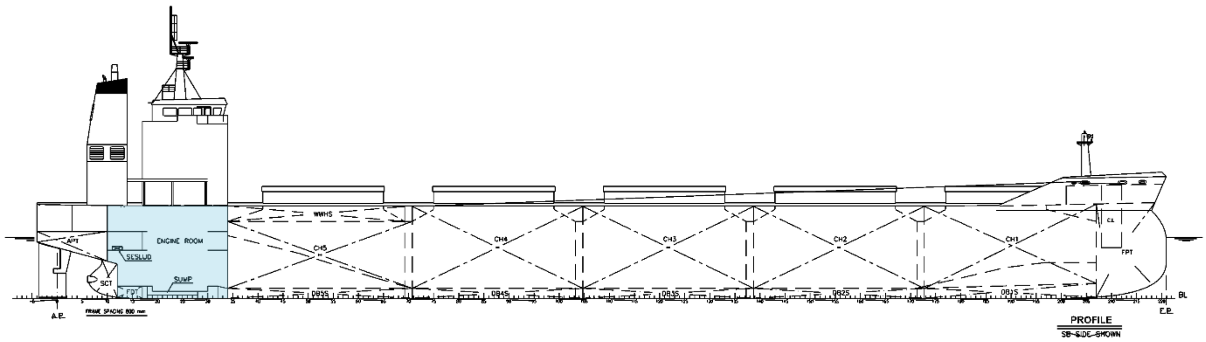

Figure 2. Vessel A - Area selected for the positioning of fuel tanks and supply system.

As previously mentioned, the installation of safety cofferdams to protect the methanol tanks represents the most significant alteration in the retrofitting process, the obtained layout is represented in Figure 3.

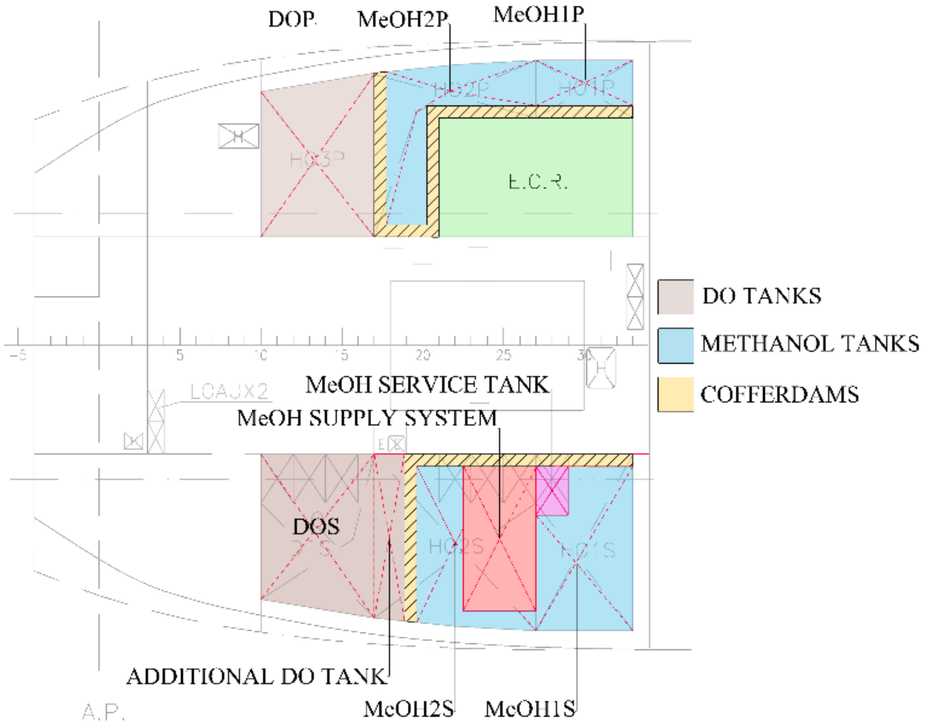

Figure 3. Vessel A Tank Layout After Methanol Conversion [32]

Vessel B is briefly discussed from a technical standpoint due to the particular positioning of its HFO tanks in the original layout. Following MARPOL regulations, these tanks are located in the double bottom. When converting the ship to methanol, these tanks can be reused by installing cofferdams only towards the other compartments of the ship, as the regulation allows direct contact between methanol and shell plating. Figure 4 b shows the proposed safety cofferdam for Vessel B highlighted with yellow areas, and the methanol volumes blue coloured.

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For both vessels, it has been hypothesized that the modifications implemented in the fuel system to accommodate methanol utilization do not necessitate alterations to the power requirements for propulsion. As such, the main engine power of 7600 kW has been retained. As previously mentioned, dual fuel solutions are the most available solutions for methanol propulsion; thus, this type of engines has been selected for the case study analysis. Methanol propulsion parameters include a Specific Gas Consumption (SGC) of about 325.3 g/kWh at 75% MCR, representing methanol consumption, and a Specific Pilot Oil Consumption (SPOC) of approximately 11.24 g/kWh. The lower LHV of methanol compared to fossil fuels, combined with the need to allocate volumes for DO to meet safety and operational requirements and the loss of methanol volume due to safety cofferdams inevitably leads to a reduction in the ship's endurance of about 70%.

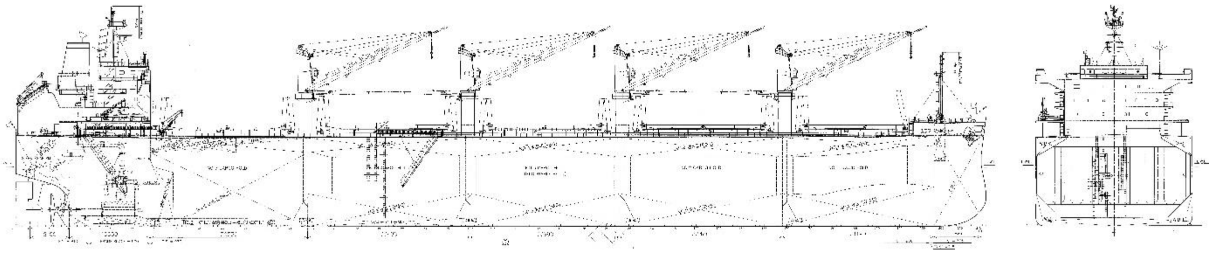

Figure 4 a. Vessel B-Longitudinal and Transversal View

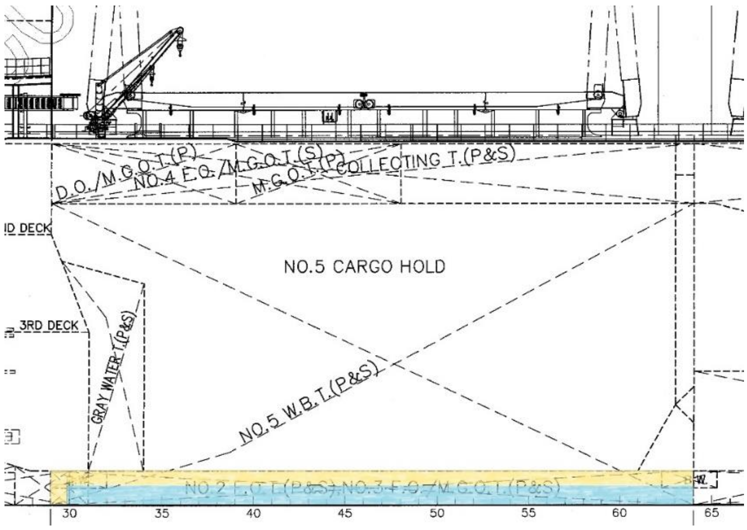

Figure 4 b. Vessel B-Example of Cofferdam Installation

RESULTS

This section summarises the results obtained from this work. The preliminary analysis concentrated on technical and design aspects, utilizing vessel A as the benchmark for the retrofitting assessment. The outcomes reveal that the allocated storage space for methanol is constrained to minimize structural modifications and adhere to safety regulations. The primary fuel tanks after conversion accommodate 1120 m3 of methanol and an additional diesel tanks volume of about 280 m3 is allocated for pilot oil and safety purposes. The loss of 34% of storage volume results in a decrease in the autonomy of almost 70% due to the low calorific value of

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methanol. This could be a drawback for cargo vessels that could be mitigated by frequent bunkering.

Table 4 shows the results of the environmental assessment for the two vessels. Vessel A represents a theoretical case, while Vessel B is based on real operational data, this leads to differences between the two options. The findings of this study indicate that when focusing on TtW emissions, using the IMO's approach does not offer a significant advantage in utilizing methanol onboard ships. In the best scenario, it is only a short-term measure for decarbonisation. Shifting the analysis considering GHG emissions over the entire chain, it is evident that grey methanol is not a sustainable option with a significant increase in carbon footprint compared to fossil fuels. Differently, using methanol from biological and renewable sources effectively abates GHG emissions and can be considered a mid/long-term solution to more ecologically friendly shipping. In general terms, the medium-sized vessel, referred to as Vessel B, appears to be less advantaged by a conversion to methanol compared to Vessel A.

Table 4. Environmental Results

	CII Original	CII Methanol	WOI Original	WOI Grey Methanol	WOI Bio-Methanol
Vessel A	8.33	-8%	9.95	+12%	-71%
Vessel B	3.92	≈ 0%	4.68	+31%	-67%

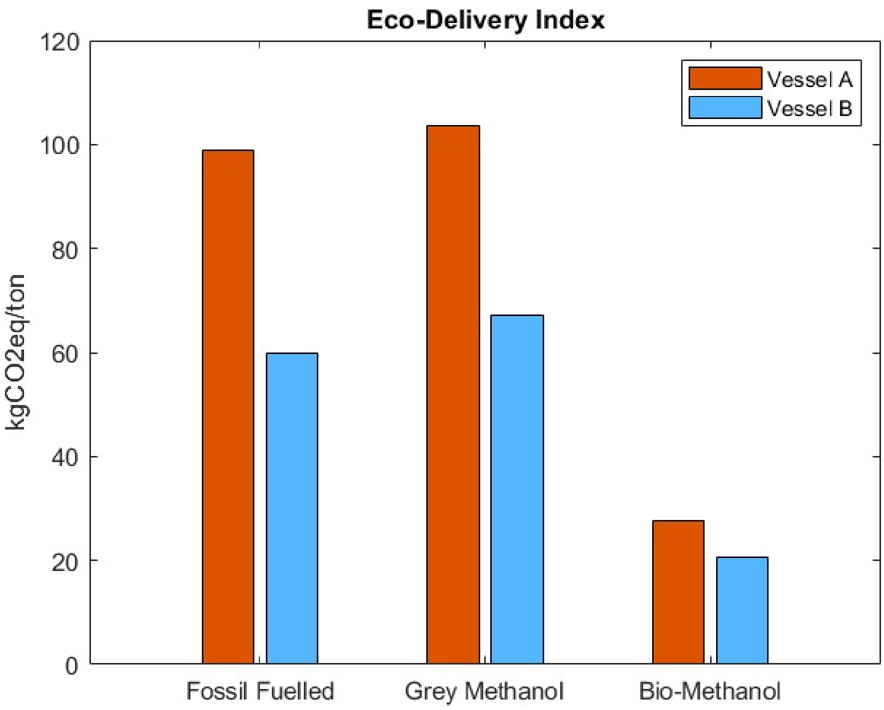

Figure 5. Eco-Delivery Index Results

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Figure 5 highlights the EDI results; this index shows the GHG emissions attributable to the entire fuel chain associated with the unit of cargo transported. With this analysis, vessel B appears more ecologically friendly in every proposed scenario.

Discussion

The conversion of small-sized bulk carrier ships is a niche topic in the relevant literature, as finding the necessary space for methanol storage poses a significant challenge. This study proposes to use original HFO tanks spaces for methanol tanks, installing the required safety cofferdams. The reduction in endurance found in this study for Vessel A is considerable, about 70%. This aligns with predictions in the literature, which estimate that methanol requires 2.5 times more space than traditional fuels [32]. Additionally, the impact of cofferdams and diesel as a backup fuel further complicates the space requirements. The CII evaluation is not influenced by the different types of methanol production and feedstocks but reveals a significant difference between the two considered vessels. The CO2 emissions associated with using methanol as the primary onboard fuel vary depending on the engine type and operating load. Studies have shown a reduction in Tank-to-Wake CO2 emissions by approximately 7-10% [33,34], and the CII findings corroborate this data.
The WOI results highlights the CO2 polluting impact over the entire fuel chain, from production to onboard combustion. In this context the various types of methanol have a different footprint. Natural gas-based methanol worsens the WtW polluting impact while, according to literature [21] the Bio-Methanol shows an improvement of about 70%.
The Eco-Delivery Index is an innovative parameter and, as such, is not directly comparable to existing literature. This index evaluates the global CO2 emissions attributable to each ton of effectively transported cargo, providing a valuable metric for assessing optimal strategies to reduce the carbon footprint of final market products. The analysis indicates that the cargo transported by Vessel B has a lower carbon footprint. Additionally, the gap with Vessel A is slightly reduced when green methanol is used as fuel onboard.

CONCLUSIONS

This work has investigated the use of methanol as an alternative fuel onboard cargo ship from an environmental perspective. The analysis follows the methodology presented in [35] and has been applied to a small-size and a medium-size dry cargo vessel to evaluate the retrofitting option. Preliminary considerations indicate that, from a fuel-storage perspective, methanol is a feasible option. However, barriers exist, mainly concerning safety and inherent characteristics of methanol that limits fuel space and ship's range. Additionally, methanol can be produced following different technological paths and using different feedstocks and the various product-chains have different carbon footprints. The environmental KPIs selected allows to have a comprehensive overview on the atmospheric impact of converting ships to methanol. Following the IMO's approach, which considers only onboard emissions, the GHG footprint is not affected by the type of methanol production. The low LHV of methanol and the need to use diesel as pilot oil limit the benefits of a lower emission conversion factor compared to HFO. In the most optimistic scenario, with a reduction of about 8%, the CII results make methanol a short- to medium-term solution, given the increasingly stringent limits imposed by regulatory bodies. The introduction of the Well-to-Wake Operational Index (WOI) enables to highlight the overall impact of the different types of methanol. Using natural gas-based methanol, the only currently available option on large scale, the WOI indicates an increase in global emissions compared to the same vessel powered directly by fossil fuel. This aspect is more evident for the medium-sized ship with an increase in GHG emissions of more than 30%. The use of methanol from

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renewable sources has emerged as the only viable solution, however its availability in ports and costs still represent an important barrier to its massive use as fuel onboard ships. From CII and WOI assessment, it is evident that vessel B is slightly less advantaged in the case of a methanol retrofit. The Eco-Delivery Index (EDI) provides valuable data for comparing various investments and logistic chains. As shown in Figure 5, the EDI results indicate that transporting cargo in Vessel B has a lower environmental impact than transporting the same cargo in Vessel A. This analysis, undertaken in a sector facing stringent GHG limits and carbon taxation, underscores the critical importance of a Well-to-Wake assessment to prevent hidden emissions. Furthermore, this study emphasizes the necessity of considering emissions per cargo ton when making investment decisions or selecting transport vectors, thereby advancing ecologically sustainable options.

NOMENCLATURE

ABS	American Bureau of Shipping
CCS	Carbon Capture and Storage
CII	Carbon Intensity Indicator
CO2	Carbon Dioxide
DNV	Det Norske Veritas
DO	Diesel Oil
EDI	Eco-Delivery Index
EU	European Union
GHG	Greenhouse Gas
HFO	Heavy Fuel Oil
IGF	International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels
IMO	International Maritime Organization
IRS	Indian Register of Shipping
KPI	Key Performance Indicator
LHV	Lower Heating Value
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MARPOL	Maritime Pollution Regulation
MCFCs	Molten Carbonate Fuel Cells
MCR	Maximum Continuous Rating
MGO	Marine Gas Oil
NOx	Nitrogen Oxides
SGC	Specific Gas Consumption
SPOC	Specific Pilot Oil Consumption
TtW	Tank-to-Wake
WAPS	Wind Assisted Propulsion Systems
WOI	Well-to-Wake Operational Index
WtT	Well-to-Tank
WtW	Well-to-Wake

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