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ANALYSIS OF EXISTING PRACTICES OF USE OF METHANOL AS A MARINE FUEL

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Abstract. *The energy transitions the maritime industry faces today is distinct from those earlier evolutions. It is not driven by technological advances or economics, but by an environmental imperative – increasingly underscored by social pressure, policy and regulatory demands to reduce emissions. The maritime industry, therefore, needs to explore all available technological and operational options which can deliver emission reductions, starting with energy efficiency. These technologies and the improvement of energy efficiency on board can help reduce emissions in the short term while acting as a great enabler for faster adoption of low-carbon fuels in the long term.*

This article provides a comprehensive overview of all energy efficiency options available today. All options for methanol as a marine fuel are discussed and presented in detail, covering key cost factors and suitability for specific vessel types. The article also addresses port infrastructure readiness and methanol availability.

Key words: *methanol, port infrastructure, marine fuel, bunkering, fuel system*

Introduction.

The global economy continues to grow, driven in part by global population growth. At the same time, over 80% of growth is driven by the increasing influence of a large and growing middle class in emerging economies on the global economy [1]. The latest version of DNV's «Shipping Outlook 2050 report» [2] calculated that energy efficiency could deliver fuel savings and emissions reductions of up to 16%. That's a significant number, equivalent to decarbonising 55,000 of the smallest or 2,500 of the largest ships in the world fleet. If achieved, it could make a major contribution to the emissions reductions needed to meet the first of the IMO's decarbonisation targets, namely a 20% reduction by 2030, easing the urgency of the transition to alternative fuels and giving these markets vital time to develop.

Increasing the efficiency of using energy resources potential in combination with minimizing damage to the environment is the paradigm of designing energy equipment in the modern world. In this regard, the requirements of IMO legislative acts strictly regulate emissions of harmful substances from shipping facilities. According to IMO resolutions, for each new ship with a gross tonnage $\leq$ 400 t it is necessary to determine the required (Required) and achievable (Attained) design energy efficiency index of the ship EEDI, as well as the operational index EEOI during the design, construction and operation of the ship [3].

IMO requirements are directly related to increasing the efficiency of fuel energy use in ship power engineering and the use of alternative fuels. This creates a practical demand aimed at adapting energy-saving technologies to ship power engineering, developing promising schemes for transport energy complexes, and studying processes in ship power equipment.

Modern low-speed diesel engines are the basis of marine power engineering. They have high efficiency, exceeding 50%, and high aggregate power, which has made it possible to use such engines on most types of marine transport vessels [4].

It is this category of engines that has been decided to be adapted to operate on alternative fuels, and in particular, methanol. Methanol has potential as an alternative fuel due to its environmental friendliness, easy storage and transportation of methanol, and low production costs. However, its technical features and limitations related to safety and efficiency of use must be taken into account. Development of technologies and further research will help to optimize the use of methanol in marine engines and increase its attractiveness as an alternative fuel.

Main text.

Environmental aspects of the transition to methanol. Deploying methanol as a marine fuel dramatically lowers emissions of SO_x, NO_x and PM compared to HFO or MGO. Methanol combustion itself does not generate any SO_x or PM emissions, and what little emissions do occur come from a small amount of diesel (3-5 percent) deployed as pilot fuel. Ship operators can immediately comply with the IMO's most stringent SOx and PM emissions regulations by switching to methanol. According to tests carried out by MAN Energy Solutions [5], operators can reduce NOx emissions below Tier III levels by deploying a mixture of methanol with 25 to 40 percent of water, and 3-5 percent of diesel as a pilot fuel (Fig.1).

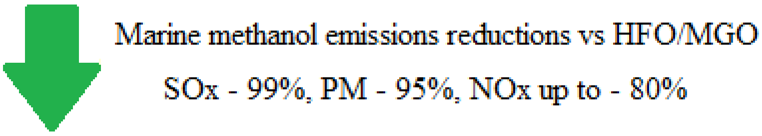


Figure 1 - Marine methanol emissions reductions vs HFO/MGO

Authoring: [5]

At first, since 2005, it was the fight against nitrogen oxides and sulfur oxides. The nitrogen standards were achieved by improving the technology - marine diesel engines (Tier I, Tier II), as well as the use of catalysts (Tier III), and for sulfur - first by reducing its content in conventional marine fuel, then from January 1, 2020 - either scrubbers or the use of low-sulfur fuel oils, or other types of fuel, such as LNG and methanol, which practically do not emit sulfur oxides. Since 2011, the stage of combating one of the greenhouse gases - carbon dioxide, has begun, through the introduction of phases to limit the amount of CO_2 emitted per unit of transport work (tons per mile), which was called the energy efficiency coefficient. This tool further increased interest in alternative fuels [6].

The influence of fuel characteristics on the energy efficiency index of a vessel. For most transport vessels, the main component of CO_2 emissions is produced by the engine or group of engines of the propulsion system. As can be seen from the analysis of formula (1), the reduction of CO_2 emissions can be achieved both by reducing fuel consumption (Engine power × SFC) and by using fuel with a low carbon content (accounted for by the CF index). Under the assumption that the propulsion power, deadweight and speed of the vessel can be taken constant, only the specific fuel consumption SFC and the carbon content factor in the fuel CF have an impact on the design index of the vessel's energy efficiency EEDI.

$$EEDI = K \times SFC \times C_F, \quad (1)$$

In the Formula:

K - Engine power / DWT×speed, kW/t-mile

Specific fuel consumption is inversely proportional to the lower available calorific value of the fuel LCV. Thus, under the accepted assumptions, the EEDI index is a function of the fuel characteristics:

$$EEDI = f\left(C_F / LCV\right) \tag{2}$$

Along with the use of low-sulfur fuel oils or retrofitting the ship's exhaust system with special catalysts (scrubbers), one of the promising ways to reduce the content of harmful substances in the exhaust gases of ship power plants is the use of alternative fuels: liquefied natural gas, methanol and ethanol. The characteristics of the main marine fuels are presented in Table 1.

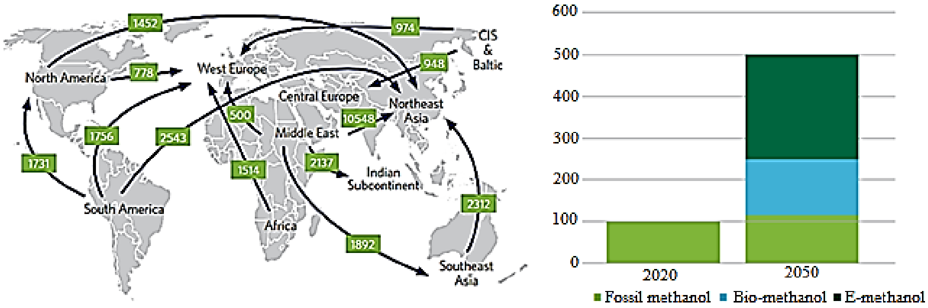
Table 1 - Characteristics of the main marine fuels

Fuel type	Fuel designation	Carbon content	C_F, t CO_2/t fuel	Lower calorific value, MJ/kg
MDO	ISO 8217	0,8744	3,206	42,700
LFO	ISO 8217	0,8594	3,151	41,200
HFO	ISO 8217	0,8493	3,114	40,200
LPG	Propane	0,8182	3,000	46,300
	Butane	0,8264	3,030	45,700
LNG	LNG	0,7500	2,75	48,000
Methanol	Methanol	0,3750	1,375	19,900
Ethanol	Ethanol	0,5217	1,913	26,800

Authoring: [3]

When dual-fuel low-speed engines operate on gaseous fuel, about 3-5% falls on the ignition dose of liquid fuel ("pilot" fuel), which is MDO. Gaseous fuel is supplied to the engine under high pressure. Power consumption for driving the compressor unit for supplying gaseous fuel can be up to 2.8–3.0% of the engine power [7]. Taking these factors into account, the use of butane as a marine fuel instead of traditional HFO provides a reduction in the EEDI index of up to 13%, propane – up to 15%, and liquefied natural gas – up to 24%.

Availability of methanol and technical readiness of port infrastructure. Ship operators who run methanol fleets would be able to procure methanol with relative ease. Methanol is available at over 120 ports worldwide and shipped globally. Today, there are more than 90 methanol production facilities all over the world, with annual supply of nearly 100 million tons of methanol (33 billion gallons or 125 billion liters) (Fig. 3a) [8].



a b

Figure 3 - Availability of methanol:

a - Main Methanol Interregional Trade Flows (Thousand metric tons per annum);

b - Methanol Production by 2050

Authoring: The Methanol Industry. 2022

According to the IRENA, by 2050 e-methanol and bio-methanol – "green" methanol – are expected to make up about 80 percent of total production, which could reach 500 million tons per year (Fig. 3b) [9]. The availability of feedstocks for bio-methanol and e-methanol production are likely to limit most individual production facilities to capacities ranging from 50,000-250,000 tons per year. Whether produced from gray, blue or green feedstocks, the methanol molecule will have the same physical properties, facilitating the transition of marine methanol over time as more low carbon and net carbon neutral methanol enters the global supply chain.

Current Fuel Costs. According to S&P Global Commodity Insights figures, methanol traded at lower prices, on a dollar per ton basis, than MGO, HFO and LNG at the Rotterdam bunkering hub from November 2023 to November 2024 (Fig. 4).

Natural gas prices spiked towards the end of 2021, amid supply tightness ahead of winter, and more spikes emerged after the Russian invasion of Ukraine in February 2022. The surging natural gas price impacted the LNG price, but also had a placed upward pressure on methanol prices, as most methanol is made from natural gas [10].

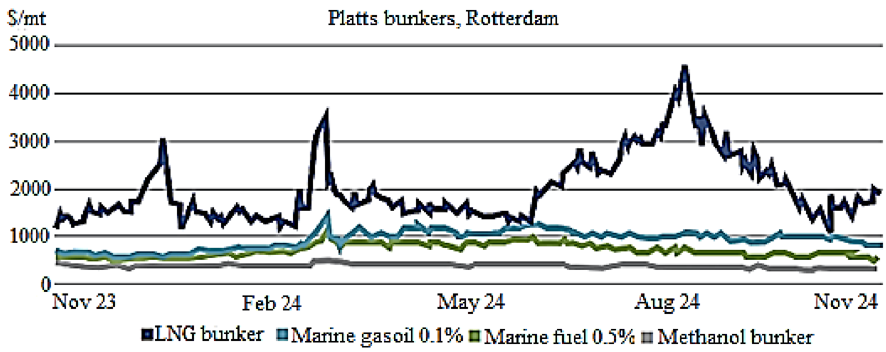


Figure 4 - Bunker Prices of Methanol, HFO, LNG, and MGO at the Rotterdam

Authoring: Muchira, N.2024

However, when incorporating the relevant energy density factor to compare the different fuels on a like-for-like basis, HSFO typically becomes the cheapest, although methanol often traded at lower prices than LNG and MGO in the Rotterdam bunkering hub (Fig. 5).

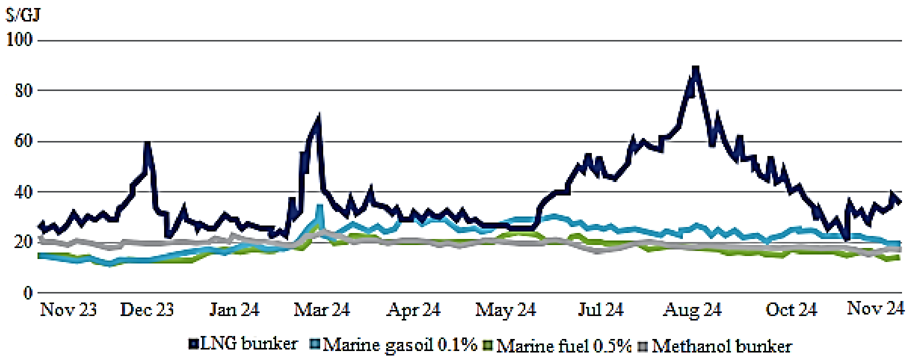


Figure 4 - Fuel Prices Considering Calorific Value – Rotterdam Bunker Fuel Prices

Authoring: Muchira, N.2024

Technical readiness of infrastructure. Fuel supply, infrastructure, and bunkering of methanol remain as challenges for its widespread adoption. Lessons can be learned and adapted from the use of LNG as marine fuel while developing bunkering infrastructure for methanol.

Bunkering facilities, onboard containment systems, fuel supply systems, and marine engines are the key aspects that need to be assessed for the use of methanol as a marine fuel.

The available bunkering option for methanol will vary depending on the port and the amount of fuel demanded. Initially, new fuels will likely be delivered truck-to-ship or ship-to-ship. Although the properties of methanol (i.e. such as its flammability, toxicity and corrosivity) present risks for the bunkering of the fuel, ports already have a lot of experience in safely handling methanol [11] and the fuel is available in over 100 ports globally [12]. Fig. 6 provides an overview of the available methanol storage capacity available at ports across different countries.

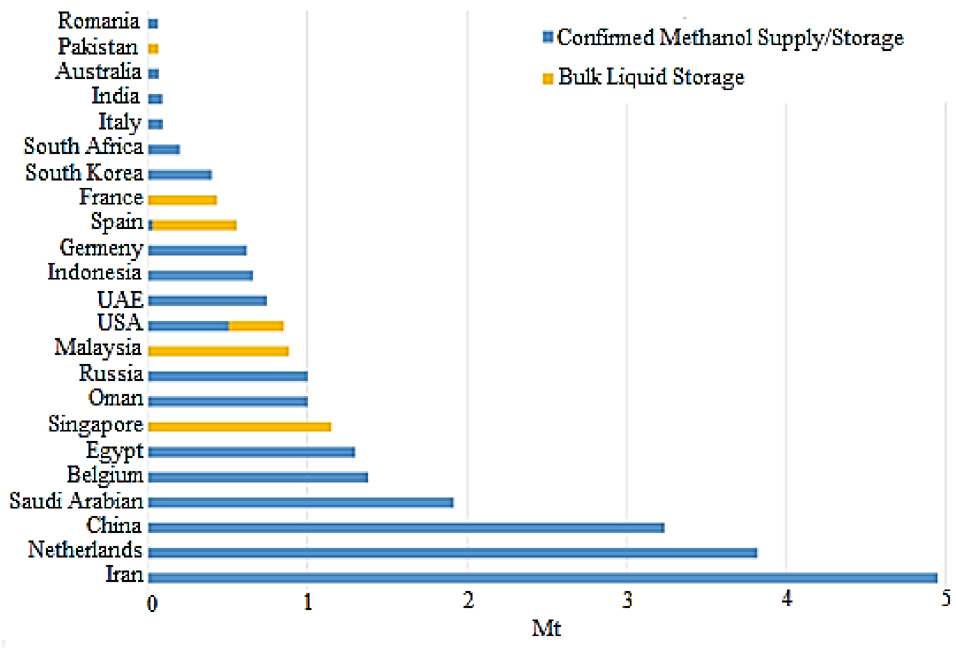


Figure 6 - Ports with available methanol storage capacity in 2023

Authoring: https: //www.methanol.org/marine/

In total, the research identified a total methanol storage capacity at ports of approx. 25 Mt. Iran, the Netherlands, China, Saudi Arabia and Belgium collectively account for 60 % of the global methanol storage capacity at ports identified.

Conclusions.

Fuel availability, retrofit costs and carbon prices will play a key role in determining the viability of engine conversions. In some segments, they are already becoming a viable prospect. The analysis found that research and industrial projects are aimed at scaling up methanol so that it becomes available for use in wider transport sectors. Methanol, being a clean fuel, significantly reduces SO_x, PM, CO_2 and NO_x emissions and will be used more widely due to the increasing availability of methanol. The study found the total methanol storage capacity at ports to be around 25 Mt. Iran, the Netherlands, China, Saudi Arabia and Belgium together account for 60% of the world's methanol storage capacity at specific ports. The use of methanol as a marine fuel has reduced CO_2 emissions by more than 1.5 times during the operation of a marine power plant based on a diesel engine.

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