Analysis initiated by
Methanol Institute

Analysis made by Dr. Jeroen Dierickx,
Energy & Fuel Expert

iDefossilise

ECONOMIC VALUE OF METHANOL FOR SHIPPING UNDER FUELEU MARITIME AND EU ETS

CONTENTS

EXECUTIVE SUMMARY

This white paper presents an economic analysis of bio-methanol and e-methanol as a marine fuel within the frameworks of the FuelEU Maritime regulation and the recently applied extension of EU's Emissions Trading System (ETS) to maritime transport. It aims to evaluate the economic viability of bio- and e-methanol under these regulations compared to the continued use of fossil diesel, with VLSFO used as reference, and to provide an estimate of their value in relation to these regulatory frameworks.

Structure of the white paper

The white paper is divided into four sections:

1. Regulatory Landscape: A brief review of FuelEU Maritime and the EU ETS extension to maritime transport
2. Non-Compliance Costs: Calculation of additional regulatory costs under FuelEU Maritime and EU ETS for using VLSFO.
3. Compliance Pathways: Explanation of the pathways to achieve FuelEU Maritime compliance with sustainable methanol.
4. Economic Value of Methanol: Calculation of the maximum price of bio- and e-methanol to achieve cost parity with VLSFO including its non-compliance costs.

Key Findings

- Regulatory Penalties: FuelEU Maritime and EU ETS impose substantial penalties on fossil fuel use, such as VLSFO.
- Rising Costs: Additional regulatory costs for non-compliance with FuelEU Maritime targets increase each five years, for example from 39 euro/ton in 2025 to 353 euro/ton in 2035 and 1,997 euro/ton in 2050.
- EU ETS Implementation: Regulatory costs under EU ETS are phased in from 40% in 2024 to 100% in 2026. With a 100 euro market price for EU emission allowances, the additional cost for VLSFO is 321 euro/ton.
- Compliance Pathways: Options include using bio- or e-methanol, blends of fossil and sustainable methanol, and wind propulsion (only up to certain GHG reductions). Pooling ships to balance GHG intensity reductions is also possible.
- Pathway Analysis: Both the use of pure bio- and e-methanol and blends with fossil methanol are viable compliance pathways. This supports the sustainable methanol supply chain and leverages existing fossil methanol capacity during the transition.
- Economic Viability: Bio- and e-methanol have significant economic value under FuelEU Maritime and EU ETS, suggesting that the regulatory frameworks could effectively encourage the transition to sustainable fuels in maritime shipping.
- Maximum Prices: Based on the assumptions made in this analysis, the average maximum price for bio-methanol under FuelEU Maritime is 1,193 euro/ton from 2025-2050. For e-methanol, this is 2,238 euro/ton from 2025-2033 and 1,325 euro/ton from 2034-2050, reflecting a reduction in the reward for using RFNBO after 2033. Including EU ETS, these prices increase by 150 euro/ton for both bio-methanol and e-methanol.

Conclusions

The analysis concludes that the FuelEU Maritime and EU ETS regulations create a level playing field for sustainable fuels like bio- and e-methanol. With significant penalties for using fossil fuels, vessel operators are incentivized to switch to sustainable methanol. For fuel producers, these regulations provide a stable, long-term framework from 2024 to 2050, facilitating secure investment opportunities.

BACKGROUND ON THE ANALYSIS: UNDERSTANDING THE REGULATORY LANDSCAPE

The maritime industry is under increasing pressure to reduce its environmental impact, particularly concerning greenhouse gas (GHG) emissions. In response, both international and regional regulatory frameworks have been developed to encourage emissions reductions and promote sustainable shipping practices.

Introduction to FuelEU Maritime Regulation

The FuelEU Maritime regulation is a cornerstone initiative of the European Union aimed at reducing GHG emissions from the maritime sector[1]. This legislative framework sets specific targets and measures to defossilise shipping and promote cleaner fuels. It applies to all ships above 5000 gross tonnage, covering all energy used on board when the ship is at an EU port, on voyages between EU ports, and 50% of the energy used on voyages departing from or arriving at an EU port. Key elements include:

1. GHG Intensity Reduction Targets: Yearly average (well-to-wake) GHG intensity reductions of 2% by 2025, 6% by 2030, 14.5% by 2035, 31% by 2040, 62% by 2045, and 80% by 2050.
2. RFNBO Sub-target: A 2% sub-target for renewable fuels of non-biological origin (RFNBO) starting in 2034, with incentives for RFNBO use until then (through a reward factor in the calculations of the GHG intensity of ships until 2034).
3. On-shore Power Supply: Mandatory use in major European ports.

This analysis describes the penalties for not meeting the GHG intensity reduction targets and the 2% RFNBO sub-target for 100% EU voyages, and uses these penalties for calculating the economic value of bio-and e-methanol.

Introduction to EU Emission Trading System (ETS)

The EU Emissions Trading System (ETS) is a cap-and-trade system that limits the total CO_2 emissions from certain sectors, including the maritime sector since 2024. The scope of maritime emissions covered by the EU ETS increases from 40% in 2024 to 70% in 2025 and 100% in 2026[2]. The regulation applies to cargo and passenger ships of 5000 gross tonnage and above from 2024, and to offshore ships of 5000 gross tonnage and above from 2025. Smaller offshore and general cargo ships (between 400 and 5000 gross tonnage) are subject to monitoring, reporting, and verification from 2025, with potential inclusion in the EU ETS in 2027[3]. Covered greenhouse gases include CO_2, CH_4, and N_2O, with the latter two included from 2026 onwards[4].

Shipping companies must buy emission allowances, each covering one tonne of CO_2 or the equivalent of other powerful greenhouse gases such as methane (CH_4) or nitrous oxide (N_2O). Allowances are auctioned, and companies can trade them on secondary markets. The price of allowances fluctuates, with forecasts suggesting a gradual increase. In the period from May 2021 to May 2024, the minimum price and maximum price for an EU ETS allowance was 50.45 euro and 104.81 euro, respectively[5]. In January 2024, Reuters forecasted an average price of 74 euro for 2024, 83 euro for 2025 and 100 euro for 2026[6]. This analysis assumes a constant price of 100 euro per ton of CO_2 between 2024-2050.

Rationale for Analysis

The complex and evolving regulatory landscape around GHG emissions in the maritime sector necessitates comprehensive analysis to assess its impacts. This analysis provides stakeholders with insights into the potential effects of the FuelEU Maritime regulation and the EU ETS on shipping operations, fuel choices, and compliance strategies. By understanding the regulatory context and its implications, stakeholders can make informed decisions and navigate the transition towards a more sustainable maritime future.

NON-COMPLIANCE COSTS

This section explores the implications of the FuelEU Maritime regulation and the EU Emissions Trading System (ETS) under a "business as usual" scenario, where shipping companies continue to use fossil fuels such as VLSFO, HFO, MDO, or LNG. Although each fossil fuel has different well-to-wake greenhouse gas intensities[1], VLSFO (distillate marine grade) is used as the reference fuel in this analysis.

The FuelEU Maritime regulation imposes two types of penalties:

1. GHG Intensity Reduction Penalties: For not meeting the greenhouse gas (GHG) intensity reduction targets.
2. RFNBO Sub-target Penalties: For not meeting the sub-target for renewable fuels of non-biological origin (RFNBO).

To calculate the penalties, the method described in Annex I, II, and IV of the regulation was used[1].

FuelEU Maritime GHG Intensity Penalty

The penalty for not meeting the FuelEU Maritime GHG intensity reduction targets increases every five years, starting at 39 euro/ton VLSFO in 2025 and rising to 1,997 euro/ton VLSFO after 2050. This increase corresponds with the stricter GHG intensity reduction targets over time. When the cost of an EU emission allowance is 100 euro, the FuelEU Maritime GHG intensity penalty surpasses the EU ETS cost by 2035 and more than doubles it after 2040.

FuelEU Maritime RFNBO Sub-target Penalty

The penalty for not meeting the RFNBO sub-target was calculated using an assumed price difference of 1,000 euro between RFNBO and VLSFO, resulting in a penalty of 21 euro per ton of VLSFO used. For context, if the price difference between RFNBO and VLSFO were 500 euro or 2,000 euro, the penalties would be 10 euro and 42 euro per ton of VLSFO, respectively.

EU ETS Penalty

The EU ETS costs are tied to the price of one EU emission allowance. Assuming a fixed price of 100 euro per ton of CO_2 equivalent, and knowing that 1 ton of VLSFO emits 3.21 tons of CO_2, using VLSFO would incur under EU ETS in 2026 an additional cost of 321 euro per ton. Given that EU ETS is gradually introduced to the maritime sector, covering 40% of emissions in 2024 and 70% in 2025, this results in costs of 128 euro and 224 euro per ton of VLSFO in 2024 and 2025, respectively. By 2026, all emissions are in scope. This cost does not include methane (CH_4) and nitrous oxide (N_2O) emissions, which come into effect in 2026 and add about 5.5 euro per ton of VLSFO. For fossil LNG, this additional cost can reach 74 euro per ton of LNG used due to methane slip.

Figure 1 shows the non-compliance costs for using VLSFO under FuelEU Maritime and EU ETS. It highlights the individual contribution of each regulation as well as their combined effect.

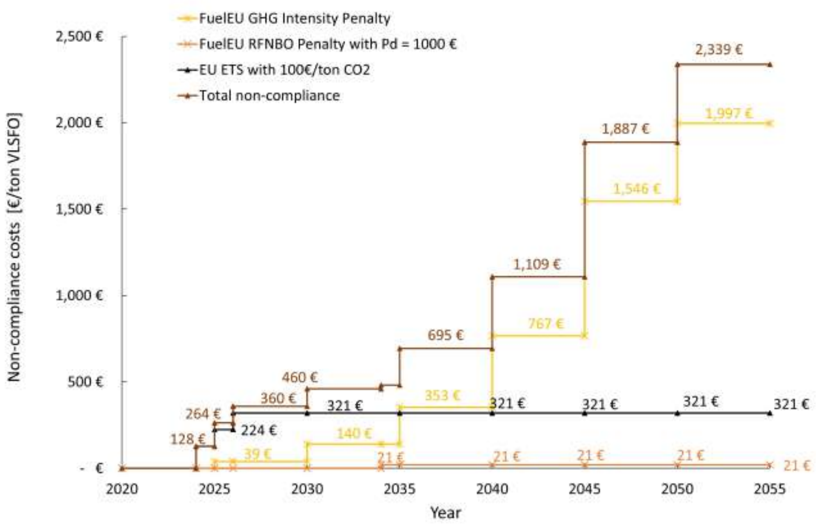

Figure 1: Non-compliance costs for using VLSFO under FuelEU Maritime and EU ETS.

Financial Impact for Vessel Operators

Figure 2 illustrates the total cost development for continued use of VLSFO for propulsion between 2025 and 2050, assuming a constant VLSFO price of 500 euro per ton. The cost of using VLSFO increases by about 50% in 2025 and quadruples from 764 euro in 2025 to 2,839 euro in 2050 due to the increasingly burdensome costs of non-compliance. This significant increase incentivizes ship operators to switch to sustainable technologies.

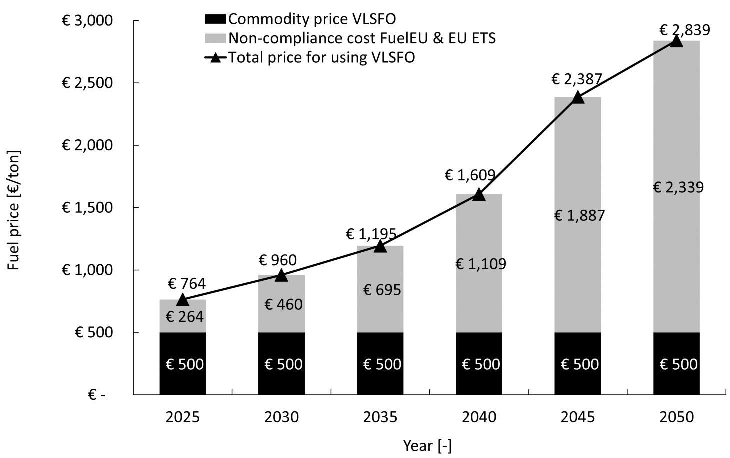

Figure 2: Example of the total price for using VLSFO when the VLSFO commodity price is at 500 euro per ton.

Table 1 presents an example of the additional daily costs of non-compliance with FuelEU and EU ETS for a typical 8000 TEU container ship sailing at 21 knots with a fuel consumption of 150 tons of VLSFO per day. The additional daily costs range from 39,572 euro to 104,192 euro in the period 2025-2039, and from 166,323 euro to 350,832 euro beyond 2040. These substantial costs of non-compliance incentivize the transition to sustainable fuels such as bio- and e-methanol.

Case: Container ship 8000TEU	2020	2025	2030	2035	2040	2045	2050
FuelEU GHG Penalty [€/day]	- €	5,909 €	20,971 €	52,978 €	115,108 €	231,838 €	299,617 €
FuelEU RFNBO Penalty [€/day]	- €	- €	- €	3,124 €	3,124 €	3,124 €	3,124 €
EU ETS (@ 100€/ton CO2) [€/day]	- €	33,663 €	48,090 €	48,090 €	48,090 €	48,090 €	48,090 €
Total additional costs [€/day]	**- €**	**39,572 €**	**69,061 €**	**104,192 €**	**166,323 €**	**283,053 €**	**350,832 €**

Table 1: Example of the additional costs for using VLSFO under FuelEU Maritime and EU ETS for a container ship of 8000 TEU.

ACHIEVING FUELEU MARITIME COMPLIANCE WITH SUSTAINABLE METHANOL

Given the significant non-compliance costs for the continued use of VLSFO, shipping companies are looking at regulatory compliance strategies. While several pathways exist, including the use of bio-fuels, e-fuels, wind propulsion, or pooling of vessels, this section focuses on mitigating non-compliance costs by the use of sustainable methanol. This can be done for individual vessels or for a pool of vessels, where one sustainable vessel offsets the greenhouse gas emissions of another group of vessels. In determining the compliance pathway, it is important to note that ship operators are currently favouring dual-fuel internal combustion engine (ICE) technology with methanol. This is due to the key features of dual-fuel methanol engines for the shipping industry's transition to sustainable fuels, as briefly detailed in Information Box 1.

INFORMATION BOX 1: DUAL-FUEL TECHNOLOGY

Dual-fuel technology involves an internal combustion engine (ICE) that simultaneously combusts two fuels to generate propulsion energy. Derived from diesel engine technology, its goal is to replace as much diesel as possible with a more sustainable fuel like methanol. One key advantage of dual-fuel technology is its ability to switch to pure diesel operation at any time. This flexibility minimizes the availability risk of sustainable fuels like methanol in ports, allowing ships to continue their voyages on pure diesel if methanol is unavailable. This feature also supports a gradual buildup of the sustainable fuel production and infrastructure.

However, complete replacement of diesel is impossible with this technology, as it always requires a certain amount of diesel for proper combustion. The minimum diesel requirement varies by engine type and manufacturer but typically targets a minimum diesel energy percentage of 5%. This means that 5% of the energy is derived from diesel, and the remainder from methanol. When sustainable methanol (bio- or e-) is used, tank-to-wake GHG reductions of about 95% are achieved compared to diesel-only operation, assuming equal efficiency in both operating modes. The engine can also operate at any diesel energy percentage between 5% and 100%. This allows precise adjustments to meet specific GHG intensity reduction targets.

While there are several pathways possible to be compliant with FuelEU Maritime, this analysis explores two pathways for using sustainable methanol:

1. Pathway 1 uses on an annual basis the average required (and minimum) amount of sustainable methanol to be compliant. The results of this pathway can be used for individual vessels or for a pool of vessels (or even hypothetically at an EU level, i.e. assuming that sustainable methanol would be the only solution to achieve compliance).
2. Pathway 2 uses methanol blends, i.e. a mixture of fossil-based and sustainable methanol. The results of this pathway can be used for individual vessels or for a pool of vessels. This pathway is interesting to investigate as it allows the existing methanol supply to be used and fossil-based methanol to be gradually replaced by sustainable methanol.

The two pathways are analysed as if they were two independent solutions to become compliant with FuelEU Maritime. In reality, the two pathways will co-exist and interact with each other, as well as with other solutions to achieve compliance.

Pathway 1: Using Non-Blended Sustainable Methanol

The Annex lists the assumptions that were used for calculating the results of Pathway 1. Figure 3 illustrates the results of this pathway: the energy shares of VLSFO and sustainable methanol to meet on an annual basis the FuelEU Maritime GHG intensity reduction targets. Two important aspects can be remarked from Figure 3. The first is that the shares of bio-methanol are higher than those of e-methanol. This is due to the lower GHG intensity reduction of bio-methanol compared to e-methanol (see Annex). The second is that the shares of e-methanol are proportionally lower compared to bio-methanol in 2025 and 2030, than in 2035 and thereafter. This is due to the reward factor for using RFNBO until 2034.

The results of this pathway serve several objectives:

- For vessels: although methanol dual-fuel vessels can run with a low energy share of diesel and a high energy share of methanol, the results presented in Figure 3 indicate the yearly averages of sustainable methanol that should be used at a minimum to be compliant with FuelEU Maritime. In the scenario that a vessel runs portions of its time on pure diesel (for economic or methanol fuel non-availability reasons), the value of the shares in Figure 3 is that it gives the minimum end goal for the vessel's yearly averages to be compliant with FuelEU Maritime. However, if a dual-fuel vessel continuously runs with higher methanol energy shares than those visualised on Figure 3, the vessel will be more compliant than required. This also enables the vessel to be used for pooling.
- For a pool of vessels: the results presented in Figure 3 are also valid for a pool of vessels. The percentages show the yearly average objectives for the pool. For example, if the pool uses bio-methanol to comply, the pool should use in 2030 on a yearly basis a minimum energy share of 7% of bio-methanol and maximum 93% of VLSFO. Combining these shares with the specifications of the vessels in a pool, the composition of a pool can be determined.
- For the European vessel fleet: in case that only sustainable methanol is applied for making vessels sustainable, Figure 3 indicates for the European vessel fleet the minimum percentage of bio- or e-methanol needed to be compliant with the GHG reduction targets of a certain year.

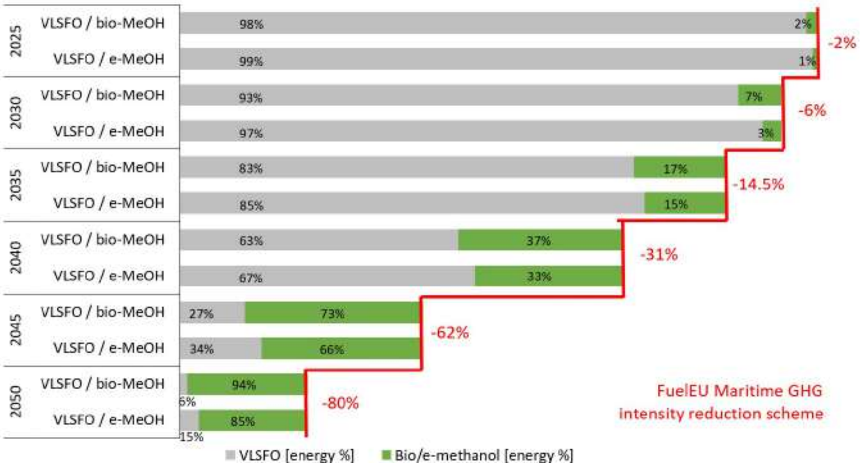

Figure 3: Energy shares of VLSFO and bio- or e-methanol in dual-fuel vessel operation to comply with the FuelEU Maritime GHG intensity reduction targets, based on the assumptions made this analysis.

Pathway 2: Using Blends of Fossil-Based and Sustainable Methanol

The Annex lists the assumptions that were used for calculating the results of Pathway 2. One key assumption taken in this analysis is that dual-fuel vessels run on an annual energy average with 5% of diesel and 95% of methanol blend (other annual energy averages give different blend composition results). For this 95% of methanol blend, Figure 4 displays the composition of the blend, i.e. the shares of fossil-based (FB) and sustainable methanol to comply with FuelEU Maritime. For example, in 2025-2029, the required shares are rather low (on a mass basis 14% bio-methanol and 7% e-methanol) due to the modest GHG intensity reduction targets of FuelEU Maritime. By 2035, the shares increase to 28% and 25%, respectively, and by 2050, they reach 100% for bio-methanol and 91% for e-methanol. This gradual increase allows for a steady ramp-up of renewable methanol supply, similar to the blending of bio-diesel and ethanol with respectively fossil diesel and gasoline in the road transport sector. The shares in Figure 4 can be used for individual vessels or for a pool of vessels (if all vessels in the pool are dual-fuel vessels).

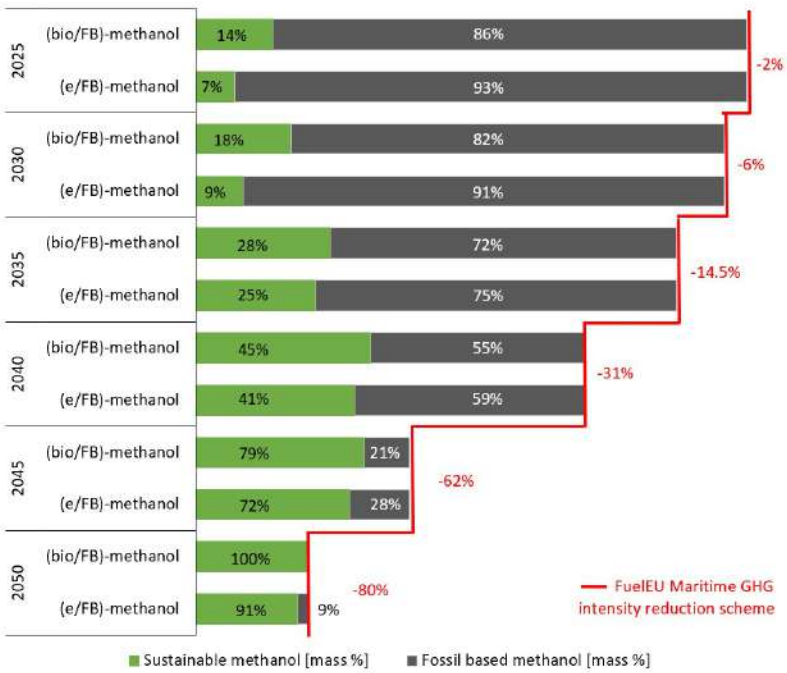

Figure 4: The composition of methanol blends to comply with FuelEU Maritime, based on the assumptions made in this analysis.

Comparison of Pathway 2 to Other Energy Carriers

Figure 5 visualises, in addition to the methanol blends to comply, the blends of fossil and sustainable LNG and ammonia to comply with FuelEU Maritime. The same main assumption has been used to calculate the shares of fossil component and bio- or e-component, i.e. dual-fuel vessels running on average with 5% of diesel and 95% blend fuel on an energy basis. Other assumptions, such as well-to-wake emissions factors, are listed in the Annex. It can be seen that e-ammonia blends require a slightly higher sustainable component than methanol blends, which is due to the higher well-to-wake emission factor of ammonia. LNG on the other hand requires a slightly lower sustainable component in the blend due its lower well-to-wake emission factor.

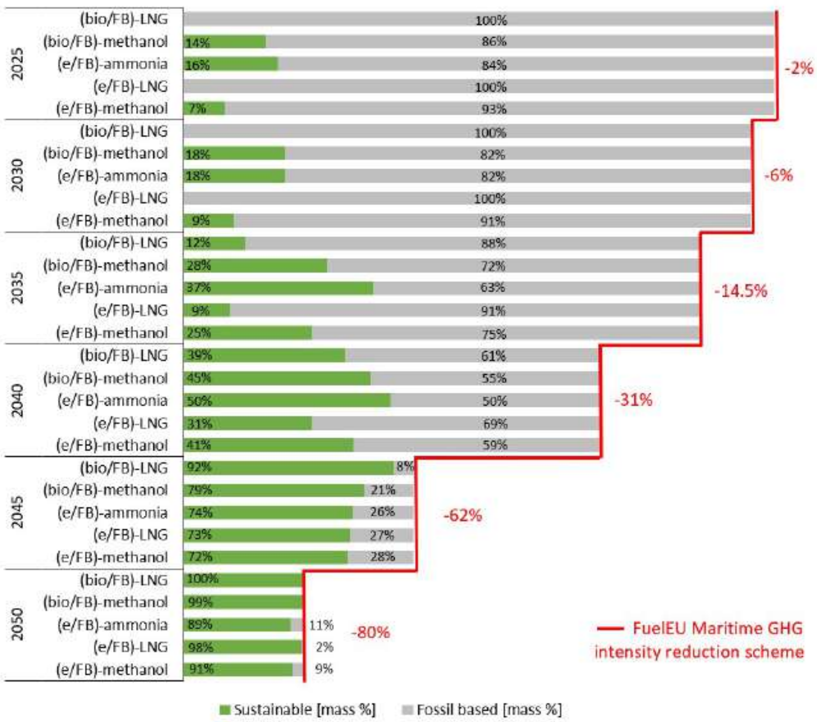

Figure 5: The composition of methanol, ammonia and LNG blends to comply with FuelEU Maritime, based on the assumptions made in this analysis.

ECONOMIC VALUE OF BIO- AND E-METHANOL

Understanding the economic value of methanol is crucial for both shipping operators and sustainable methanol producers. Therefore, this section examines the economic value of bio- and e-methanol, highlighting their viability and attractiveness within the regulatory landscape. It is important to note that the economic value of bio- and e-methanol is not "absolute" under FuelEU and EU ETS. Instead, their value is relative, depending on the comparison of the compliance pathway with the scenario where VLSFO is used, including the non-compliance costs under FuelEU and EU ETS. The key parameters determining the economic value are the VLSFO price, the EU ETS price and the well-to-wake emission factors of bio- and e-methanol. Therefore, it is important to emphasize that the economic values of bio- and e-methanol presented below are only valid under the assumptions made in this analysis. Additionally, note that the prices are applicable for intra-EU voyages, i.e. voyages between EU ports. For extra-EU voyages, i.e. voyages to or from an EU port, the maximum prices will be lower given that only 50% of the energy used on the voyage is accounted for in calculating the FuelEU Maritime penalty.

Figure 6 visualises the method used in this analysis to calculate the economic value of bio- or e-methanol. The left hand side of the equation shows the total fuel cost for using VLSFO under FuelEU Maritime and EU ETS. For calculating this total fuel cost, a VLSFO price of 500 euro per ton and a price for EU ETS allowances of 100 euro are assumed in line with the above sections. The cost for failing to meet the FuelEU RFNBO sub-target was not considered to reduce the number of variable parameters and given its negligible impact. While it is currently not yet sure how the tank-to-wake GHG emissions of bio- and e-methanol will be valued under EU ETS, it was assumed that both emission factors are zero. The right hand side of the equation in Figure 6 shows the total fuel cost of a certain compliance pathway, which is in this analysis the pathways explained in the previous section, i.e. Pathway 1 (using non-blended sustainable methanol) and Pathway 2 (using methanol blends). The economic value of methanol is expressed in this analysis as the maximum price of methanol for which the total fuel cost on both sides of the equation are equal. An example of this calculation method can be found in Information Box 2.

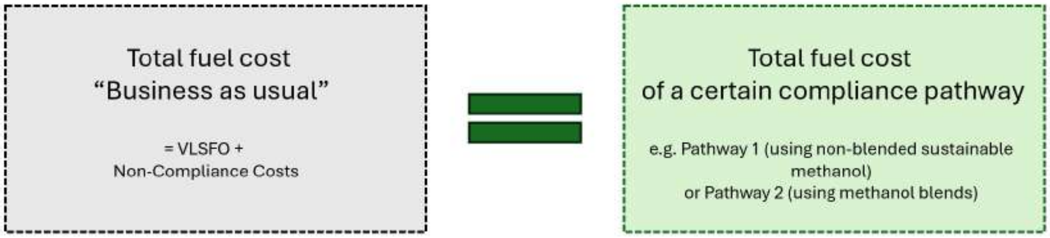

Figure 6: Method used in this analysis to calculate the economic value of bio- and e-methanol.

INFORMATION BOX 2: EXAMPLE OF CALCULATION METHOD DETERMINING THE ECONOMIC VALUE OF E-METHANOL IN 2025

In Figure 2, the total price of VLSFO is shown to be 764 euro per ton in 2025. To comply with FuelEU, Figure 4 indicates that a yearly average dual-fuel operation for one vessel or a pool of vessels with 1% e-methanol and 99% VLSFO (by energy) is sufficient. If the total fuel cost of this dual-fuel operation must equal 764 euro per ton of diesel equivalent energy, the price of e-methanol must be 2,174 euro per ton. If the price of e-methanol exceeds 2,174 euro per ton, the total fuel cost of the dual-fuel operation of the vessel or pool will be higher than in the business as usual case where only VLSFO is used. Conversely, if the price of e-methanol is lower, the total fuel cost to be compliant will be less.

Economic Value with Pathway 1 (Using Non-Blended Sustainable Methanol)

Figure 7 visualizes for compliance Pathway 1 (using non-blended methanol) the maximum prices for bio-methanol and e-methanol. It shows maximum prices from 2025 to 2050, distinguishing between prices considering only the FuelEU Maritime GHG intensity reduction target and those also including EU ETS. The price impact of EU ETS is constant from 2030 onwards, equal to 150 euro per ton for both bio-methanol and e-methanol. In 2025, the price difference is slightly lower because only 70% of shipping emissions are covered by EU ETS. The average maximum bio-methanol price from 2025 to 2050 is 1,193 euro per ton considering FuelEU Maritime and 1,335 euro per ton considering FuelEU Maritime and EU ETS. For e-methanol, the average maximum price from 2025 to 2033 is 2,238 euro per ton considering FuelEU Maritime and 2,364 euro per ton considering FuelEU Maritime and EU ETS. From 2034 to 2050, these prices decrease to 1,325 euro per ton and 1,475 euro per ton, respectively, due to the removal of the RFNBO reward factor.

The maximum prices in Figure 7 guide both bio-methanol and e-methanol producers and shipping operators. They represent the equilibrium price at which bio-methanol and e-methanol are competitive with VLSFO, given the assumptions made in this analysis. These maximum prices help determine the maximum premium for bio-methanol or e-methanol. For instance, if bio-methanol production costs 800 euro per ton, the maximum premium in the period 2035-2039 is 551 euro per ton. If e-methanol production costs 1,800 euro per ton, the maximum premium in 2025 is 374 euro per ton. Depending on the business case, these premiums might enable profitable production, stimulating bio-methanol and e-methanol producers.

As mentioned above, the maximum prices in Figure 7 apply to intra-EU voyages. For extra-EU voyages, only 50% of the energy used during the voyage should be taken into account for calculating the FuelEU Maritime penalty. In this case, the resulting maximum prices for bio- and e-methanol considering FuelEU Maritime are reduced by about 40% to 45%. Since approximately two-thirds of the CO_2 emissions reported under the EU Maritime MRV Regulation come from extra-EU voyages[7], it is important to note that this will significantly impact the market uptake potential of bio- and e-methanol.

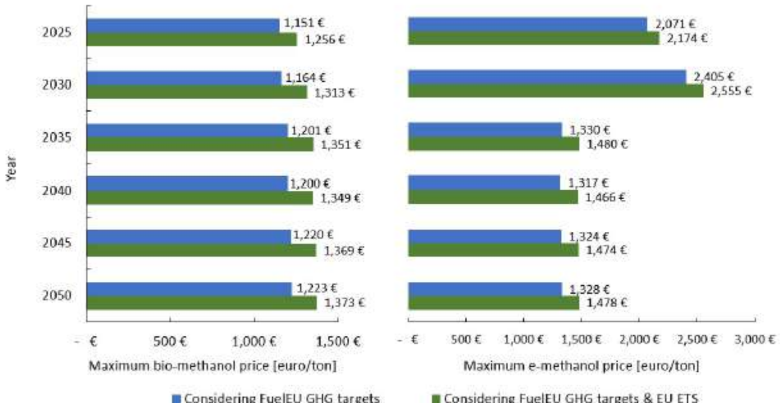

Figure 7: Maximum bio-methanol and e-methanol price using Pathway 1 to match with the total price for VLSFO under FuelEU Maritime and EU ETS, based on the assumptions made in this analysis.

CONCLUSIONS

This analysis focused on the stringent European regulatory framework for greenhouse gas emissions, particularly the FuelEU Maritime and EU ETS systems. These regulations impose significant penalties for non-compliance, driving the need for alternative fuels.

Rising Regulatory Costs for VLSFO

The non-compliance costs for using VLSFO will rise sharply due to regulatory penalties, from 264 euro per ton in 2025 to 2,339 euro per ton by 2050. This increasing cost supports the shift to alternative fuels like bio-methanol and e-methanol.

Compliance Pathways with Methanol

To comply with FuelEU Maritime, two pathways using methanol were examined:

1. Pathway 1: using on a yearly average the required (and minimum) amount of sustainable methanol to be compliant.
2. Pathway 2: using methanol blends, i.e. a mixture of fossil-based and sustainable methanol.

Economic Value of Bio-Methanol and E-Methanol

The economic value of sustainable methanol is expressed in this analysis as the maximum price of sustainable methanol for which the total fuel cost of VLSFO, including non-compliance costs, is equal to the total fuel cost with Pathway 1. The key parameters influencing the economic value of sustainable methanol are the VLSFO price, the EU ETS price and the well-to-wake emission factor of the sustainable methanol used. For example, with the assumptions taken in this analysis, the maximum price for bio-methanol considering FuelEU Maritime is 1,164 euro per ton in 2030 and 1,200 euro per ton in 2040. Considering as well the EU ETS, both maximum prices increases with 150 euro per ton. The reward factor for e-methanol from 2025 to 2034 also significantly impacts its maximum price, making it for example 2,405 euro per ton in 2030 but dropping to 1,330 per ton in 2035 when the reward factor ends. Including EU ETS results also for e-methanol in a maximum price increase of 150 euro per ton.

It is also concluded that the economic value of sustainable methanol depends on its potential to reduce greenhouse gases: the higher the well-to-wake GHG reduction, the higher the economic value under FuelEU Maritime. For example, the maximum price under FuelEU Maritime for a specific type of bio-methanol will be higher than those presented in this analysis if the producer can provide greater and validated well-to-wake GHG reductions than those assumed in this analysis. Additionally, it is important to emphasize that the presented maximum prices are valid for EU voyages. For extra-EU voyages, the maximum prices will be approximately 40% to 45% lower under FuelEU Maritime, as only 50% of the energy used during the voyage is taken into account for calculating the FuelEU Maritime penalty. This will have an impact on the market uptake potential of bio- and e-methanol.

Market Incentive for Sustainable Fuels

FuelEU Maritime and EU ETS provide strong incentives for the adoption of sustainable fuels in the maritime sector. The non-compliance costs for VLSFO are substantial, making bio- and e-methanol attractive alternatives. With average maximum prices under FuelEU Maritime of 1,193 euros per ton for bio-methanol (from 2025 to 2050) and up to 2,238 euros per ton for e-methanol (from 2025 to 2034), these regulations may create a supportive market environment for bio- and e-methanol fuel producers. This suggests that the regulatory frameworks could effectively encourage the transition to sustainable fuels in maritime shipping.

ANNEX

Methodology and Assumptions

All calculations in this analysis follow the methods described in FuelEU Maritime[1]. All key assumptions used are outlined below.

Assumptions in the Section “Non-Compliance Costs”

For calculating the non-compliance costs for using VLSFO:

- The penalty for not meeting the RFNBO sub-target was calculated with a price difference of 1,000 euro between RFNBO and VLSFO.
- The EU ETS allowances were set at 100 euro.
- The VLSFO price was set at 500 euro per ton.

Assumptions in the Section “Achieving FuelEU Maritime Compliance with Methanol”

For calculating the results of Pathway 1 and 2, the energy densities and well-to-wake emission factors (based on [1] unless otherwise stated):

Fuel	Energy density [MJ/kg]	WtW emission factor [gCO_2eq/MJ]
VLSFO (type Distillate Marine grade)	42.7	90.77
fossil methanol	19.9	100.4
bio-methanol	19.9	13.3 [8]
e-methanol	19.9	4.9 [9]
fossil ammonia	18.6	121
e-ammonia	18.6	n/a
fossil LNG	49.1	83.2 (incl. methane slip)
bio-LNG	49.1	27.0 (incl. methane slip)
e-LNG	49.1	12.7 (incl. methane slip)

Additionally, it was assumed that dual-fuel vessels run on average with 5% of diesel and 95% of second fuel (methanol, ammonia, or LNG) on an energy basis.

Assumptions in the Section "Economic Value of Bio- and E-Methanol"

For calculating the economic value of bio- and e-methanol:

- The EU ETS allowances were set at 100 euro.
- The VLSFO price was set at 500 euro per ton.

REFERENCES

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