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Green Maritime Methanol: Business Case Analysis

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Summary

Increasing pressure on shipping to contribute to reduce Greenhouse Gas emissions is changing the landscape for marine fuels. In this Green Maritime Methanol project, the feasibility of application of methanol for the maritime sector are being elaborated, with a focus on short sea shipping. As part of this project, this report compares the Total Costs of Ownership (TCO) of a switch to methanol as an energy carrier for shipping compared to a reference situation (diesel, MGO or HFO) for six different vessel types.

A switch to methanol as an energy carrier has effect on both the capital expenditures (CAPEX) and operational expenditures (OPEX). Capital expenditures include the costs of adjusting the powertrain of the vessel (with either newbuilt or retrofitting engines), the costs of the fuelling system and of additional safety measures. The CAPEX calculations have been taken from the six detailed ship design studies performed in WP5 of this project.

For the OPEX, the fuel cost forecasts developed in WP4 of this project have been used. The analysis shows that there is a significant uncertainty in the development of the methanol price levels for different feedstocks. Therefore, a significant bandwidth was used in this TCO.

Additionally in this analysis, scenarios were developed for different levels of policy intervention, in the form of three different CO_2 tax scenarios:

- CO_2-tax of € 0 per ton CO_2, reference situation where no CO_2 tax is imposed.
- CO_2-tax of € 30 per ton CO_2, equivalent to the 2021 levels of the Dutch tax).
- CO_2-tax of € 150 per ton CO_2, equivalent to the expected upper levels of the Dutch tax).

The calculation of the total cost of ownership shows that the uncertainties in the price levels for sustainable methanol are reflected in the total TCO results. Under the baseline scenario, in which no CO_2-taxation or application of HBE was applied, the cumulative total costs over the years for 100% sustainable methanol concept is significantly higher than in the reference, ranging from 118% to 236% higher TCO for the different use cases. This is especially the case for the short sea container vessel, which is due to high share of the operating costs in the total TCO.

However, also the capital expenses for this case are higher due to retrofit expenses. Note that the prices used in the cost calculations are based on generic market values, real world costs may vary. Results for CO_2-pricing scenarios on the TCO for this vessel type are considerate. The option for sustainable methanol becomes much more attractive with active policy support. Sustainable bio-methanol becomes the most economical option with a CO_2-tax of €150 per tonne. The TCO of 100% fossil methanol is considerably higher than the reference case, which is not significantly affected by CO_2-taxation.

Less intensive sailing profiles, with lower annual fuel consumption, find less uncertainty and smaller price differences to the reference case.

Due to the difference in sailing profile, the share of OPEX for a low energy consuming vessel is smaller than that of very high energy consuming vessel. Therefore, without CO_2-taxation, the risk a switching to sustainable methanol is smaller for a vessel type with lower annual fuel consumption, making it a good option for a pilot.

Contents

1 Introduction

1.1 The project

IMO legislation on NO_x and SO_x emissions and increasing pressure on shipping to contribute to reducing GHG emissions are changing the landscape for marine fuels. In the quest for alternative fuels, methanol is one of the fuels that has a special interest. Methanol has low NO_x, SO_x and PM emissions and methanol, is rather energy efficient in comparison to other sustainable alternatives, is liquid under atmospheric conditions, and depending on the feedstock and technology used, can also realise significant GHG reductions. Thus making methanol a fuel that could meet future sustainability requirements. In this Green Maritime Methanol project, the feasibility of application of methanol for the maritime sector are being elaborated, with a focus on short sea shipping. The project focusses both on technical development of the powertrain as well as on logistics and operational aspects. The ambition of the project is to deliver a system design of a prototype at TRL level 6 for implementation of methanol as a shipping fuel. The project will work towards an actual implementation in a pilot.

This deliverable will develop a business case for switching to methanol and will build upon work performed in previous deliverables of this project. Aim of this work package is to compare the Total Costs of Ownership (TCO) of a switch to methanol compared to the reference fuel (diesel, MGO or HFO) for different vessel types in different policy scenarios.

1.2 Methodology

The TCO calculation performed in this report uses inputs from other reports of the Green Maritime Methanol project. As a first input, results from the analysis of the operational aspects of using methanol as bunker fuel for shipping and the corresponding supply chain analysis of methanol. The report included several price scenarios for several feedstock routes for methanol.

Furthermore, results were used from WP5, in which knowledge in Green Maritime Methanol was translated into six practical ship designs. These designs were evaluated with regard to safety, technical and economic feasibility in view of future pilot projects. The designs were developed by smaller working groups within the consortium consisting of a vessel owner/ carrier, a ship design company, complemented by other members such as engine and component manufacturers and knowledge institutes. The selected real life vessels that have been included in this analysis are shown below. As part of the analysis, insight was provided on the operational profile of the vessels, including the energy consumption, and the investments needed.

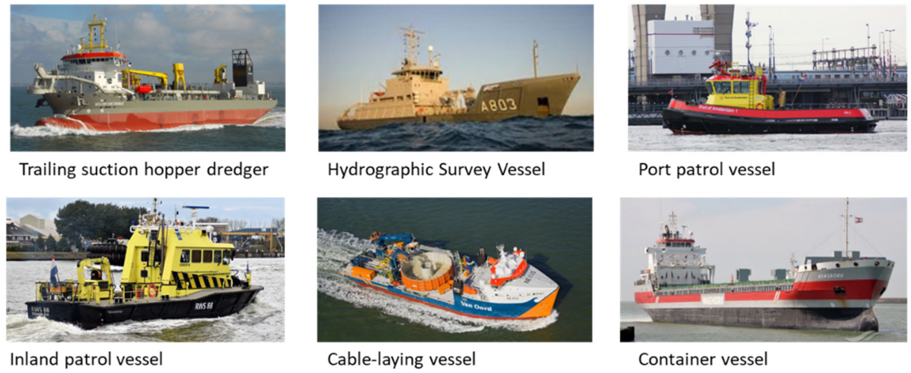

Figure 1.1: Ship types evaluated in detail for methanol solutions

With the above-mentioned inputs, total cost estimations are made over a selected operation time of 15 years. Here, some assumptions are made on financing costs, variable depreciation and residual value. With the total cost calculation accounting for fuel price changes and uncertainties, four different policy regimes are tested. By calculating the emissions associated with a specific amount of fuel consumption and pricing the amount of CO_2 emitted, the costs in different scenarios can be estimated.

1.3 Structure of this report

Chapter 2 provides a background on the policy scenarios and fuel price developments. Chapter 3 shows the results of a total cost of ownership (TCO) analysis for 2 different policy scenarios and a comparison of 2 different use cases in the same scenario. Section 3.1 analyses the TCO of a short sea vessel under three different policy scenarios (container vessel case). Section 3.2 compares the results for two different ship types, highlighting the results for a high and low fuel consumption vessel (respectively the inland patrol vessel and the trailing suction hopper dredger). The Appendix shows TCO results for all ship cases relevant to the Green Maritime Methanol project.

2 Scenario development

The following chapter analyses the most important parameters influencing cost developments of fossil and alternative fuels. The first section provides insight in relevant policies and how they translate into scenarios relevant to the TCO analysis of the previous chapter. The second section will discuss the used fuel prices and some important factors on how they might develop.

2.1 Policies make the use of alternative fuels interesting

Policies can influence energy prices significantly. In economic literature, government intervention is considered a viable option in order to internalize external costs. An external cost, or externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group [1]. There are different internalization options. One possible option would be via taxation of the harmful activity according to the external costs caused. Another solution would be to encourage or subsidize cleaner technologies thus avoiding socio-environmental costs [1]. In this analysis scenarios were developed for different levels of CO_2-prices. Input was gathered from different sources.

National CO_2-taxation
The levels of this CO_2-taxation is based on the Climate agreement of the Dutch government [1]. Starting 2021 this greenhouse gas taxation plan will impose a 30 euro per ton CO_2-equivalent GHG tax, which is expected to rise to 150 euro per ton CO_2-equivalent GHG. Shipping and aviation are exempted from this tax. However, similar strategies are expected to be implemented, therefore this scenario is used to quantify and give an estimate of the possible costs. This price level can almost be considered a Pigouvian tax: the CO_2 price needed on the negative externalities of the most polluting option, such that the total price equals the most sustainable option is calculated. This is found to be 159 euro per ton CO_2 for the proposed use cases.

EU Emission Trading Scheme for maritime transport
In September 2020 The European parliament voted in favour of the commission's proposal to include the maritime sector in the EU emissions trading system [3]. With this amendment, ships of 5,000 gross tonnage and above will be added to the ETS [4]. This market based policy instrument is the first and biggest carbon market, it operates in all EU member states, Iceland, Liechtenstein and Norway. The cap and trade system limits the amount of emissions of more than 11,000 heavy energy-using installations and airlines, emission allowances can be bought and traded within a certain emission cap. The emission cap is reduced over time. The EU ETS covers 40% of the EU GHG emissions.

RED II implementation in the Netherlands
In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy.

The Directive 2009/28/EC specifies national renewable energy targets for 2020 for each country, taking into account its starting point and overall potential for renewables. [5]

The proposal with respect to RED II implementation in the Netherlands, sets a target for 2030 of 5 PJ of renewables for inland shipping, ports and maritime shipping. The existing opt-in for maritime shipping and aviation will end by January 1st, 2025. There is a proposal for an exception in case of advanced biofuels (annex IX, A feedstock) or renewable fuels of non-biological origin (synthetic or e-fuels). Maximum amounts of conventional biofuels (PPO) and UCO biofuels (Annex IX list B) are based on the 2020 shares. The growth between 2020 and 2030 (HBE target growth from 16.4% to 27.1%) should be from the categories ANNEX IX list A and ‘Other’.

The current Dutch policy to exclude maritime shipping form the national blending mandate (with the above mentioned exception) is because the international emissions from maritime do almost not (only very limited) calculate towards the national GHG reduction targets. Inclusion of the opt-in has shown a strong decrease of use of biofuels in maritime last year (2020), lowering the use of biofuels in road transport and thus negatively affecting the Dutch national GHG targets.
A Dutch opt-in for maritime shipping has shown to be of great importance to the use of renewable fuels in shipping through the option to claim renewable fuel units (or tickets=). The price of these tickets (€11.70/ GJ for waste based biofuels in October 2020) can substantially lower the price of renewable fuels on board ships [2] [3].

With the proposal to keep the opt-in for maritime shipping in case of advanced biofuels, maritime fuels would still be able to make use of the reduced price for these fuels. Here, an international level playing field is important. This could help develop a bunkering market for maritime biofuels. Due to the international character of this sector, ship owners are likely to look at where bunkering of renewable fuels has the most profitable incentives. If for example one country in Northwest Europe is to introduce a multiplier of 1.2 for maritime, it will become more interesting to bunker biofuels in their ports.

2.2 Fuel prices are uncertain within a specific range

Current bunker fuel prices
An estimation of the current fuel prices and their dependencies is shown in Table 2-1. With these cost ranges a distinction between low, moderate and high price scenarios is defined based on lowest and highest bunkering prices in 2019. Figure 2.1 provides a graphical overview of the estimation of the average price per fuel and the bandwidth for the scenarios. Following paragraphs extend on the policy dependency, associated scenarios, market development and price outlooks as reported in WP4 of the green maritime methanol project.

Table 2-1: Analysed fuels and their respective cost ranges for 2019 and policy dependencies.

Fuel	Cost range	Cost dependency
MGO/LSMGO	€ 10-13/GJ	Policy, oil price
ULSFO	€ 10-15/GJ	Policy, oil price
VLSFO	€ 11-13/GJ	Policy, oil price
HFO (IFO350)	€ 5-10/GJ	Policy, oil price
LNG	€ 8-11/GJ	Policy
Fossil methanol	€ 14-18/GJ	Policy, Natural gas price
Bio-methanol	€ 16-32/GJ	Policy, Biomass & green gas price

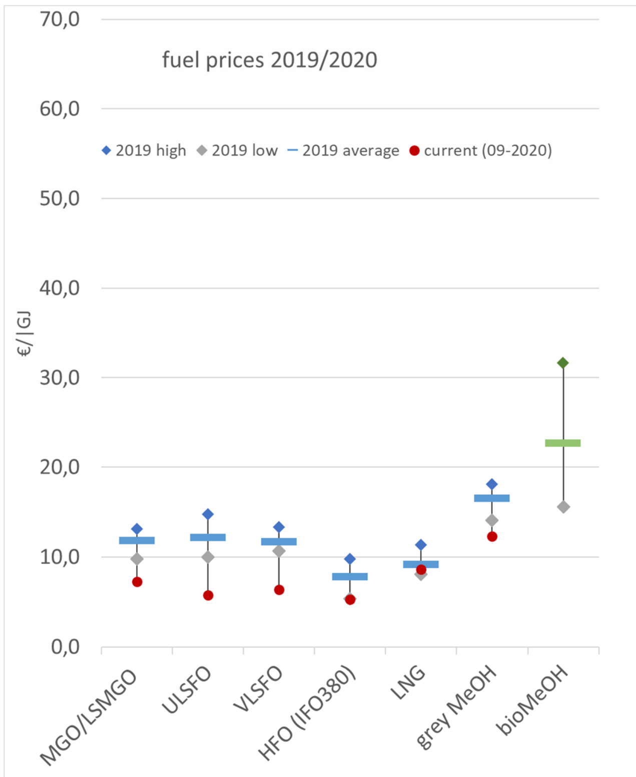

Figure 2.1: Analysed fuels with average price and low-high price scenarios.

Two aspects are crucial in the analysis of the current bunker prices: the introduction of the IMO 2020 low sulphur requirements and the COVID-19 impact on global trade, fuel prices and maritime transport. The International Maritime Organisation (IMO) has ruled that from 1 January 2020, marine sector emissions in international waters be slashed. The marine sector will have to reduce sulphur emissions by over 80% by switching to lower sulphur fuels. The current maximum fuel oil sulphur limit of 3.5 weight percent (wt%) will fall to 0.5 wt%. This does not impact the strict sulphur cap of 0.10% in so called SECA Sulphur Emission Controlled Areas.
The SECA areas include the Baltic Sea area, the North Sea area, and the North American area as well as the United States Caribbean Sea area. These new Sulphur requirements are reflected in the bunker products.

The following fuels are distinguished, that describe the sulphur content and viscosity of residual fuel:

- IFO 380; Intermediate fuel oil with a maximum viscosity of 380 centistokes (<3.5% sulphur). IFO is a blend of gasoil and heavy fuel oil, with less gasoil than marine diesel oil. This fuel is no longer compliant to the new IMO 2020 regulation, but can be blended with alternative low-sulphur products or can be used in combination with open-loop or closed-loop scrubbers in order to comply to the IMO 2020 regulation.
- IFO 180; Intermediate fuel oil with a maximum viscosity of 180 centistokes (<3.5% sulphur). This fuel is no longer compliant to the new IMO 2020 regulation, but can be blended with alternative low-sulphur products.
- MGO; Marine Gas Oil with a Max 1.50% Sulphur "Clear and Bright" Distillate (DMA, DMZ, etc). This fuel is no longer compliant to the new IMO 2020 regulation, but can be blended with alternative low-sulphur products, such as LSMGO.
- LSMGO; Low-sulphur (<0.1%) Marine Gas Oil - The fuel is to be used in EU Ports and Anchorages in accordance to the EU Sulphur directive 2005/33/EC and SECA requirements.
- VLSFO; Very-Low Sulphur Fuel Oil, containing < 0,5% sulphur. This is used to comply to the new IMO 2020 requirements. It used to fit some regional requirements, such as in China, which were less strict then most SECA requirements.
- ULSFO; Ultra-Low Sulphur Fuel Oil, containing < 0,1% sulphur, which is used to comply to the strict SECA requirements as well as the EU Sulphur directive 2005/33/EC.

Also relevant to mention is the impact of COVID-19 on bunker process. Commodity markets for energy products are closely interconnected with global trade and economic growth predictions. Obviously, COVID-19 has huge impact on the demand side and in transparent markets like the Rotterdam Bunker Index we see this directly reflected in the price development.

<u>Market demand and price development fossil fuels</u>
In the WP4 report of Green Maritime Methanol, a detailed analysis surrounding market demand and price indices volatility of bunker fuels was developed.
This analysis is used to make accurate predictions regarding bunker fuel price development. The following section highlights some of the observations made in WP4.

Bunker fuel constitutes around 50% of ships operating cost, so bunker prices have a huge impact on ship owners, operators, and charterers. High bunker prices encourage the use of alternative energy for the shipping industry such as gas, biofuels and also methanol. The fuel price for shipping (Free on Board (FOB)) does not only consist of the production costs but also distribution costs and a margin for the seller. Levies are not accounted for since bunkering of international marine fuels (e.g. HFO, MGO) is free of duty and VAT [6].

Bunker fuel is a derivative of crude oil and therefore there is some correlation between crude oil prices and bunker fuel prices. Bunker prices also depend on the availability of the product in the market.

Bunker prices also depend on the schedule of barges (logistics) of the supplier, for example if the supplier has already taken bunker supply orders for particular dates than prices are expected to be higher. There are also other factors such as speculation in the crude oil market, refining priorities and capacity constraints, inherent difficulties for vessel operators in either storing or hedging fuel – create pricing distortions that may have an impact on bunker oil prices. Bunker suppliers determine the price for their bunker fuel depending on their cost, product availability and logistics availability.

All bunker fuel prices dropped significantly since September 2019, the main cause would be price erosion due to the COVID-crisis. The low Sulphur fuels did experience a price elevation around the time the IMO 2020 Sulphur directive came into practice. These price changes have increased the bandwidth of the prices analysed in the TCO calculation.

Market demand and price development methanol
According to the IHS and MMSA, the global methanol supply in the year 2015 amounted to 76 – 79 million metric tons (MT) and has grown to nearly 100MT/ year in 2020. The total production capacity has grown from 122Mt to 152Mt in the same period, meaning that methanol plants on average operate at roughly 65% of their nameplate capacity. Roughly 40% of the global methanol supply has an energy or fuel purpose, while 60% are used as a feedstock in the chemical industry.

Focusing on the European methanol market, we note that the theoretical nameplate capacity of EU27 methanol plants in 2020 is estimated to be approx. 3.7 million tons[1], and has not significantly changed since then. Not all capacity is currently utilized. According to production statistics by the European Commission, total production in the European Union (EU27) amounted to 1.5 million metric tons of methanol in 2018. Statistics between 2010 and 2018 show that production has been stable. Production in 2019 in the Netherlands is estimated to ramp up to approx. 1.0 Mt due to increased production capacity. Currently, several companies are developing plans to build plants for production of renewable methanol.. Current these plans add up to approximately 1.4 million tons of bio- or carbon recycled methanol.

In contrast, the *demand* of methanol in Europe is much higher than the quoted production volumes. The European methanol demand has grown from 5.7MT in the year 2015 to approx. 7.5MT in 2018 [7]. A large share of this demand is imported from outside of the EU. Important import countries are Russia (1.6 Mton in 2019), Trinidad (1.4 Mton), United States (0.6 Mton), Norway (0.6 Mton) Venezuela (0.5 Mton), Equatorial Guinea (0.5 Mton) and Egypt (0.4 Mton) [6]. High imports to Europe may be attributed to higher natural gas prices in comparison with Russia, the Caribbean and the Middle East, which offer more affordable methanol prices due to abundant natural gas supply.

The Netherlands is an important trade hub for methanol in Europe. Around 35% of the extra EU imports are transferred in the Netherlands and distributed to other European countries. This role is similar for other chemical products.

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[1] Estimation of methanol producers in the consortium

Table 2-2: Production, trade and apparent consumption of methanol in EU27 in 2018 (Mton).

Country	Production	Import	Export	Apparent consumption[1]
Belgium	0.0	0.8	0.2	0.6
France	0.0	0.7	0.0	0.7
Germany	1.1	1.5	0.3	2.3
Italy	0.0	0.6	0.0	0.6
Netherlands	*0.5*[e]	2.5	2.2	*0.8*[e]
Poland	0.0	0.7	0.2	0.6
Spain	0.0	0.7	0.0	0.6
Other EU27	0.0	1.8	0.3	1.4
EU27 total	***1.5***	***9.2***	***3.2***	***7.5***

[1] *Consumption was calculated using production and trade statistics*

[e] *Production values for the Netherlands are confidential for 2018. Estimations were made based on the available production values presented between 2009 and 2017.*

Source: TNO based on Eurostat Comext and Prodcom [6] and [8]

The market price of methanol is rather volatile and closely related to crude oil and natural gas prices. Figure 2.2 below visualizes thee price development of methanol. It can be seen that, in the period from 2007-2020, the methanol price fluctuated significantly. European peak prices crossed 540€/ton in 2008 [9]. Very recently, in April 2020, the methanol price in Rotterdam was again at a four-year-low, with spot prices in the range of 150-185€/ton, partly due to the economic impact of the corona crisis [10].

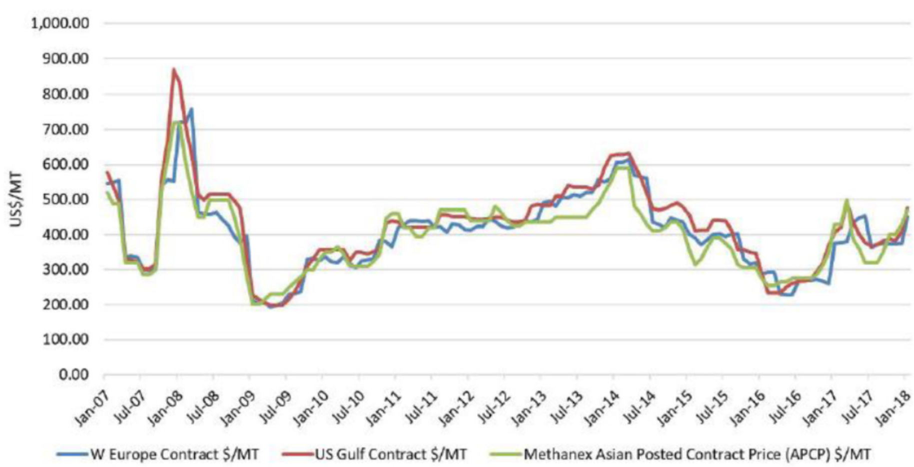

Figure 2.2: Methanol price development between January 2007 and January 2018 (USD per ton)
Source: WTC (2019) [11]

Vitiello (2020) [12] argues that in times of low methanol prices (around or below 200€/ton) in combination with high natural gas prices, the economic feasibility of methanol production becomes questionable. As a result, methanol plants may run at only 50 or 60% of their capacity or be entirely idled.

An example is the Romanian Doljchim methanol plant, which was shut down during the price drop in 2009. In the fourth quarter of 2019, when the methanol price dropped to approx. 205€/t in combination with curtailed feedstock, methanol producers in the Asia-Pacific region have started to shut down production facilities [12].

Outlook fuel prices
To calculate the TCO for the entire lifetime of the vessel, estimations of fuel price developments for different scenarios are made for the 2030 situation [13][14]. Figure 2.3 shows the used fuel prices and scenarios used in the total cost calculations. The Figure shows very slight increases for the oil-based bunker fuels, more importantly it shows significant decline in price for fossil and bio-based methanol.

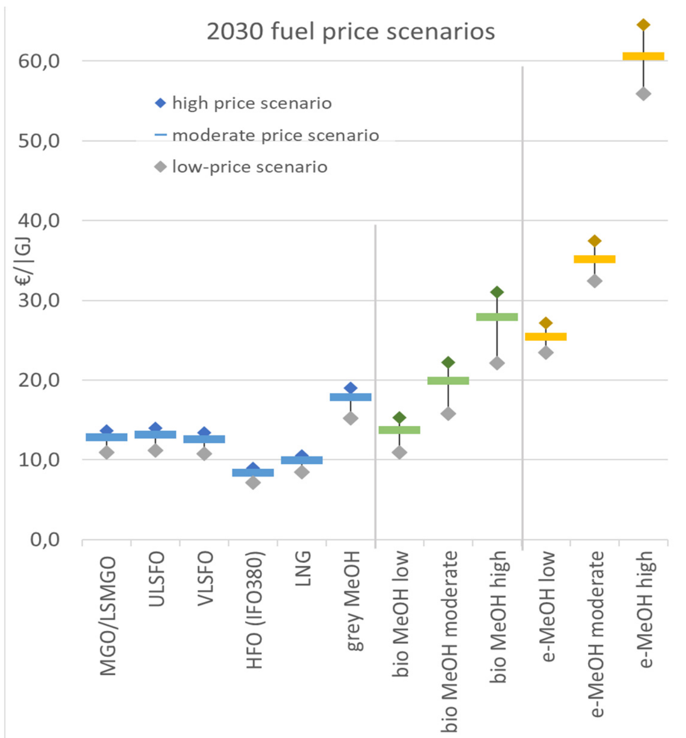

Figure 2.3: Analysed fuels with average price and low-high price scenarios for 2030.

Polaris market research estimates that the market for methanol might increase significantly in the coming years. The development and outlook of the European and global methanol demand is shown in more detail in Figure 2.4. Due to the overall low utilization of methanol production facilities, it is expected that production at existing facilities may easily be scaled up by at least 40 – 50% in order to meet the increasing demand arising from the transition to methanol as a maritime fuel.

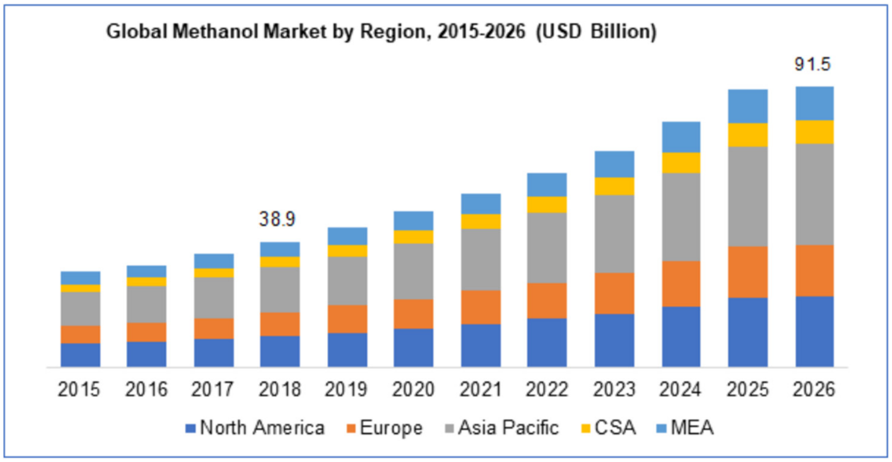

Figure 2.4: Expected development of the Global Methanol market by region between 2015 and 2026 [15].

Transparency market research estimates the global bunker demand to grow by 2.5% per year in the period 2019-2027 [15]. TNO estimates an even stronger growth of the maritime freight performance over the period 2015-2030, whereas container growth is mainly absorbed by larger vessel capacity, while liquid bulk growth is mainly due to expansion of the fleet (no larger vessels) [16]. Assuming a 2.5% yearly increase in bunker volume until 2030 would result for Rotterdam in a total volume of 11.7 million m^3 in 2030. For the ARA-region, this would sum up to 22,5 million m^3.

2.3 Conclusions

Based on the policy analysis, specific scenarios were developed in which different levels of CO_2-prices were considered:

- CO_2-tax of € 0 per ton CO_2, reference situation where no CO_2 tax is imposed.
- CO_2-tax of € 30 per ton CO_2, equivalent to the 2021 levels of the Dutch tax), and
- CO_2-tax of € 150 per ton CO_2, equivalent to the expected upper levels of the Dutch tax).

There are significant uncertainties with respect to fuel price development in the coming years, especially for bio-methanol or e-methanol. Therefore, the TCO analysis considers three price scenarios, summarized in Figure 2.1 and Figure 2.3.

3 Total cost of ownership for different shipping cases and policy scenarios

3.1 Proposed CO_2-emission cost increase will reduce the gap between fossil and methanol

The following analysis describes the use case of sailing on methanol for a short sea container vessel. For this TCO, the overall costs for 6 different fuel options are presented. Firstly, in grey and brown the reference scenarios using standard fossil fuels are shown, respectively HFO and MGO. Besides the two reference fuels, four types of methanol concepts are presented.

These concepts differ both in the amount of methanol that is being used (single fuel or dual fuel) and the feedstock for methanol that is being used (either sustainable of fossil methanol):

- In green methanol concept 1 shows the case for 100% sustainable methanol[2].
- Methanol concept 2 in dark blue shows the case for 80% sustainable and 20% fossil methanol.
- Methanol concept 3 in light blue gives the MGO (30%) sustainable Methanol (70%) dual fuel option.
- Methanol Concept 4 in yellow indicates the 100% fossil methanol case.

The following figures show the summation of the yearly cumulative costs (CAPEX, OPEX and possible emission costs) over a time interval of 15 years. This is done for the CO_2 costs scenarios of respectively 0, 30 and 150 euro per ton CO_2.
The capital expenses have been discounted over time with a variable depreciation rate. To indicate the uncertainty with respect to fuel price development, the light coloured intervals show the costs in high and low fuel price scenarios as proposed in Figure 2.3. Due to the uncertainty of methanol as a shipping fuel prices and the maturity and availability of fossil fuels, the latter has a smaller confidence interval. In the appendix an overview can be found of the assumptions used for the calculations.

[2] Feedstock is biomass, which includes agricultural and forestry products such as wood pellets, black liquor, animal waste products (manure) and organic fraction of municipal solid waste and sewage sludge.

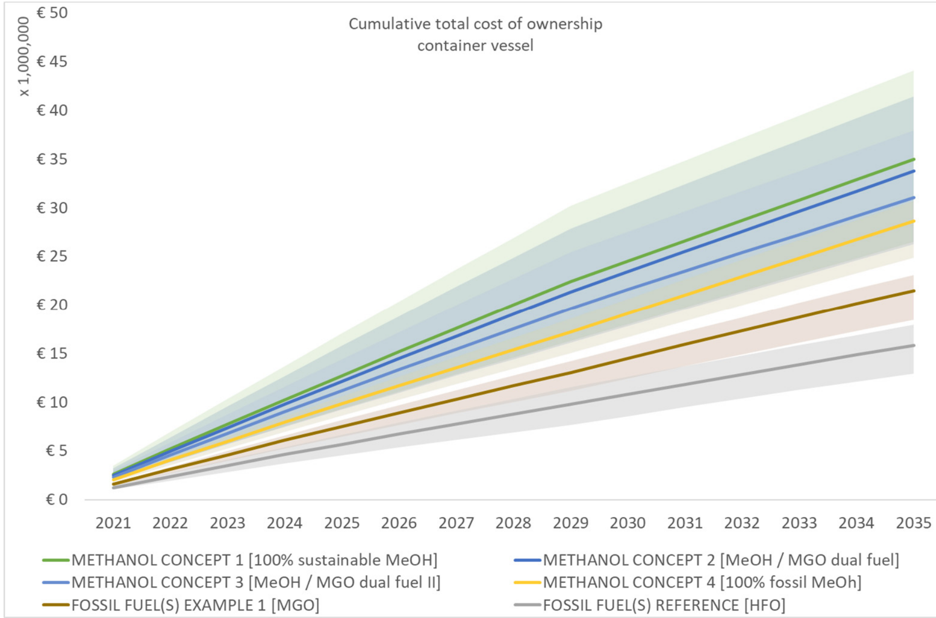

Figure 3.1: TCO results for a container vessel with €0 per ton CO_2-emission tax.

Figure 3.1 shows the TCO results for the proposed concept container vessels with no CO_2-emission taxation (current situation) and without the application of HBEs. In this scenario it is clear that the cumulative total costs over the years for 100% sustainable methanol concept is the highest and the HFO concept is the lowest. This is mainly due to higher fuel prices resulting in higher operating costs, however, the capital expenses for this case are also higher due to retro-fit expenses.

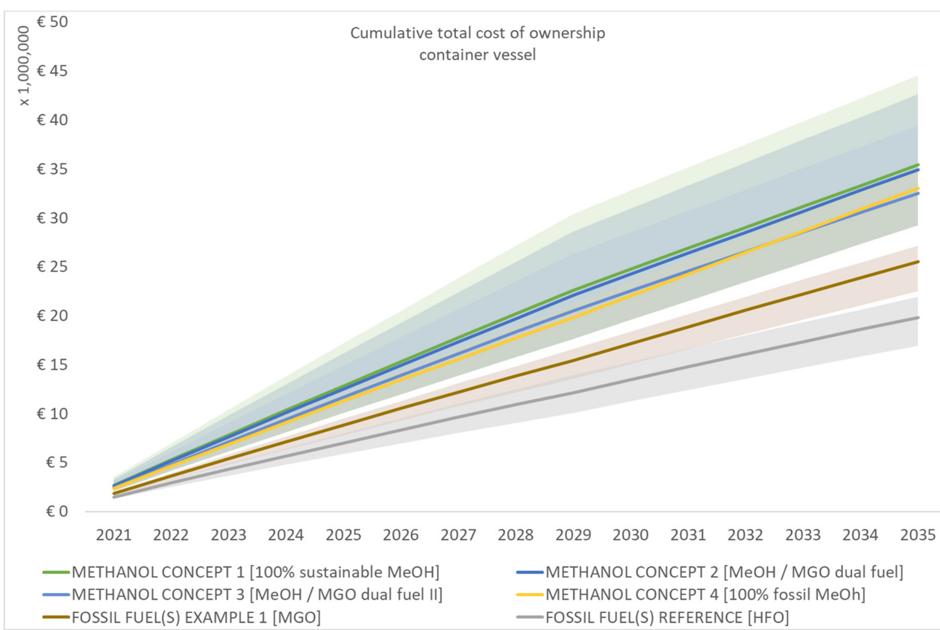

Figure 3.2: TCO results for a container vessel with €30 per ton CO2-emission tax.

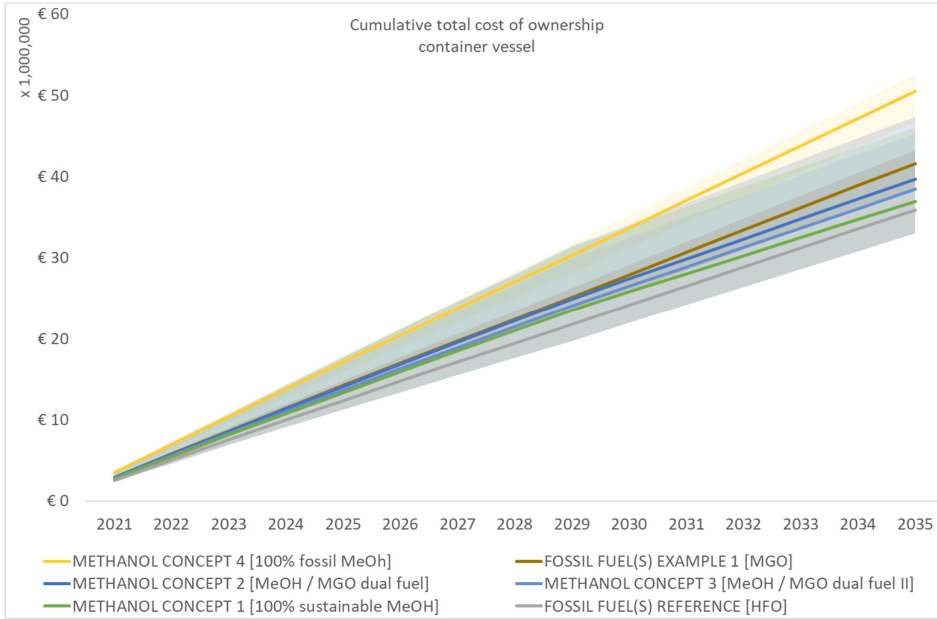

Figure 3.3: TCO results for a container vessel with €150 per ton CO2-emission tax.

Figure 3.2 and Figure 3.3 show the TCO results for the proposed concept container vessels with a €30 per ton CO_2-emission tax and a €150 per ton CO_2-emission tax respectively. This relates to the numbers proposed by the Dutch climate agreement [1], where a €30 per ton CO_2-equivalent of greenhouse gas emission is levied. This can be increased to the €150 per ton CO_2-equivalent GHG emissions. Currently, shipping and aviation are exempted. However, a similar approach is discussed which takes the complexities of global trade into account [2]. From Figure 3.2 it appears that under a 30 euro per ton CO_2 tax single and dual fuel options become comparable. Figure 3.3 shows that with a tax of 150 euro per ton CO_2, the 100% sustainable methanol concept becomes one of the cheaper options in the case of the container vessel.

Figure 3.4, Figure 3.5 and Figure 3.6 on the following pages present the share of total costs per segment. These are defined as CAPEX, capital expenses for the ship and financing costs. OPEX, fuel and maintenance costs (operational costs, such as crew salaries have been treated as equal for all concepts), and emission costs due to policies. In Figure 3.6 it shows that with a cost of €150 per ton CO_2, around 50% of the total costs for MGO will be spend on emission taxes.

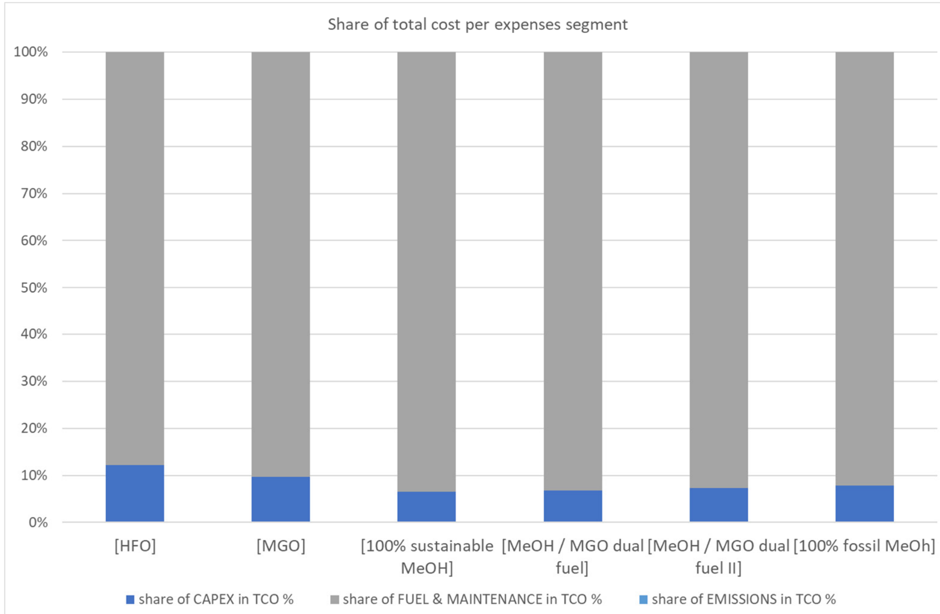

Figure 3.4: Share of total cost for a container vessel per segment of CAPEX, OPEX and emission costs for the €0 CO_2 tax scenario.

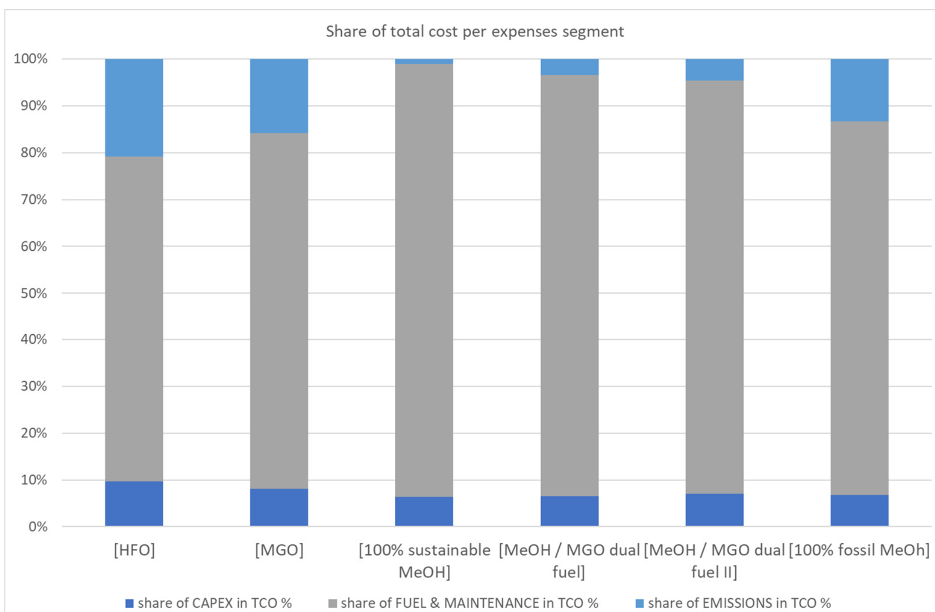

Figure 3.5: Share of total cost for a container vessel per segment of CAPEX, OPEX and emission costs for the €30 CO_2 tax scenario.

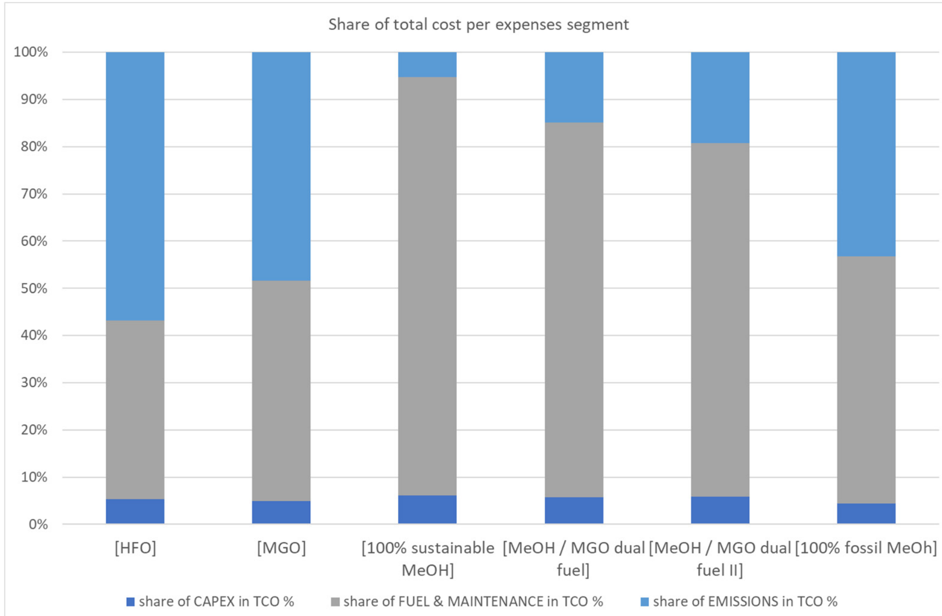

Figure 3.6: Share of total cost for a container vessel per segment of CAPEX, OPEX and emission costs for the €150 CO_2 tax scenario.

3.2 Less intensive sailing profiles find less uncertainty and smaller price differences

This section compares the two cases of an inland patrol vessel and a trailing suction hopper dredger under the same policy regime of €30 per ton CO_2.
These cases are chosen to be compared due to the large differences in size, power demand, fuel consumption and sailing profile. Where the inland patrol vessel is smaller and has a lower relative power demand and fuel consumption.
The € 30 per ton CO_2 scenario is chosen to compare the results in a probable future situation.

Figure 3.7 and Figure 3.9 show the TCO results and share of costs respectively for an inland patrol vessel. Figure 3.8 and Figure 3.10 show the TCO results and share of costs respectively for a trailer suction hopper dredger. From these results some observations can be made. Due to the difference in sailing profile, the share of OPEX for an inland patrol vessel is smaller than that of the dredger. This difference in fuel consumption directly relates to the associated CO_2-emissions and thus the costs for emission taxes. Another key observation is that the relative differences in TCO for the use of different concept vessels for the inland patrol vessel are much smaller than that of the dredger.

However, results found in the section 3.1 are representative for all use cases. When considering the upper level of CO_2-taxation, sustainable methanol is a financially attractive option.

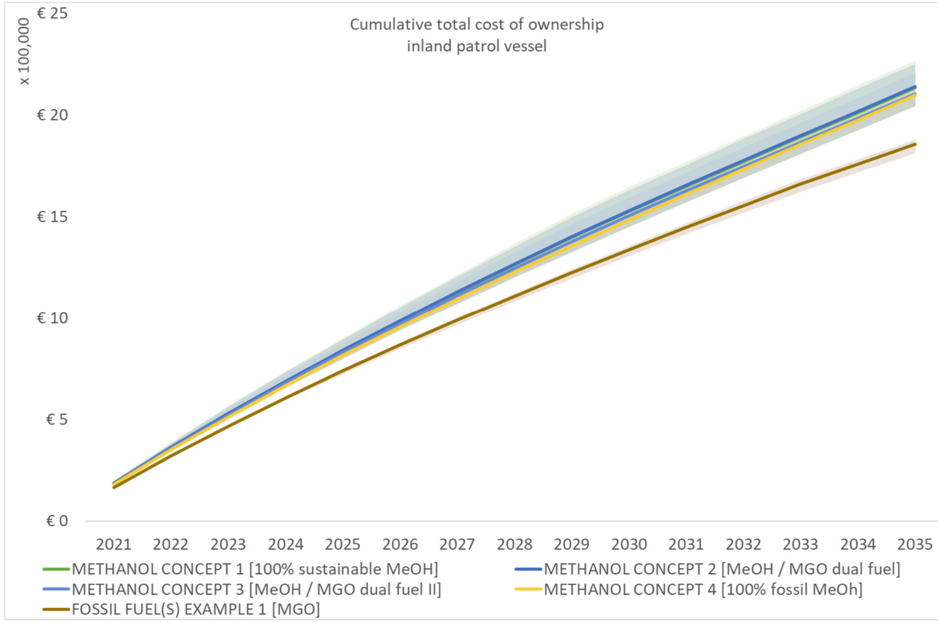

Figure 3.7: TCO results for an inland patrol vessel with €30 per ton CO_2-emission tax.

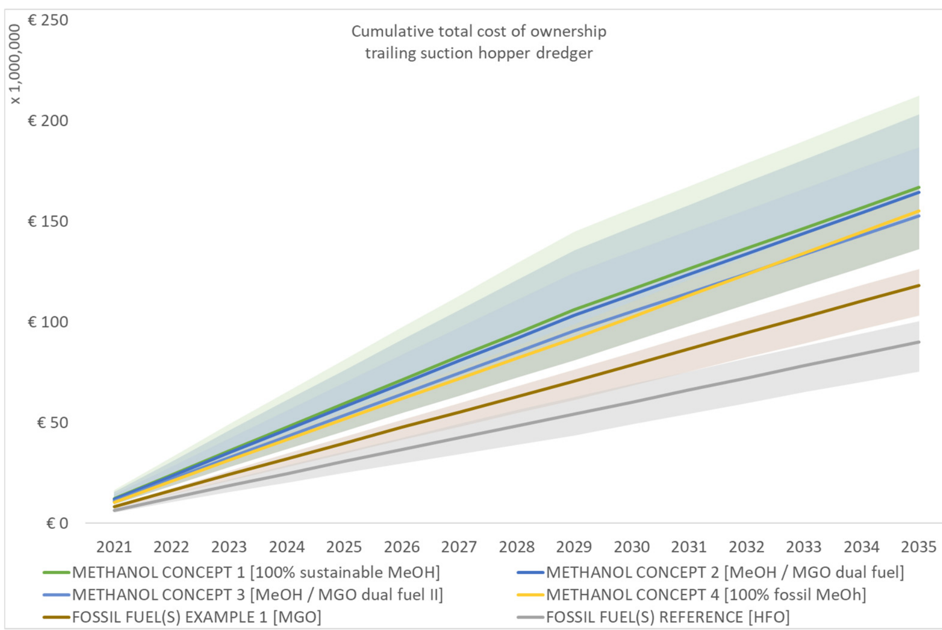

Figure 3.8: TCO results for a trailing suction hopper dredger with €30 per ton CO_2-emission tax.

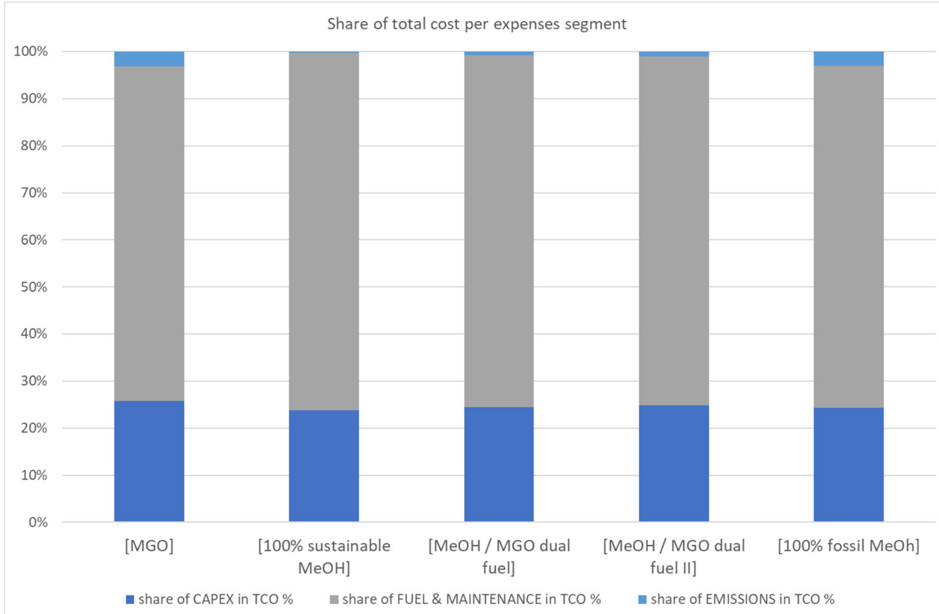

Figure 3.9: Share of total cost for an inland patrol vessel per segment of CAPEX, OPEX and emission costs for the €30 CO_2 tax scenario.

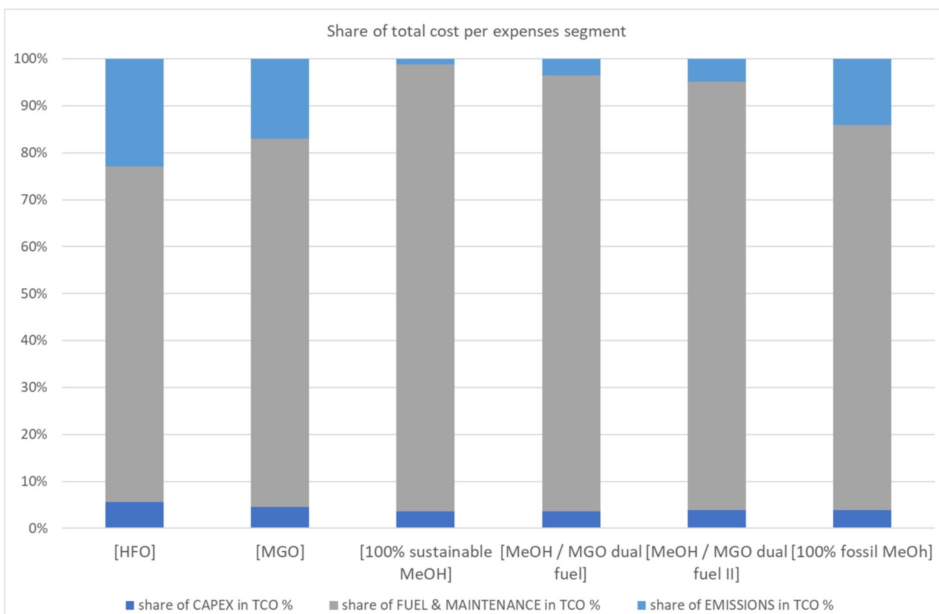

Figure 3.10: Share of total cost for a trailer suction hopper dredger per segment of CAPEX, OPEX and emission costs for the €30 CO_2 tax scenario.

3.3 Conclusions

The calculation of the total cost of ownership shows that the uncertainties in the price levels for sustainable methanol are reflected in the total TCO results. Under the baseline scenario, in which no CO_2-taxation or application of HBE was applied, the cumulative total costs over the years for 100% sustainable methanol concept is significantly higher than in the reference (HFO), ranging from 118% to 236% higher TCO for the different use cases. The option for sustainable methanol becomes substantially more attractive with active policy support. Sustainable bio-methanol becomes the most economical option with a CO_2-tax of €150 per tonne. The TCO of 100% fossil methanol is considerably higher than the reference case, which is not significantly affected by CO_2-taxation.

Less intensive sailing profiles find less uncertainty and smaller price differences to the reference case. Due to the difference in sailing profile, the share of OPEX for a low energy consuming vessel is smaller than that of very high energy consuming vessel. Therefore, without CO_2-taxation or HBE value, the risk of switching to sustainable methanol is smaller for a vessel type with lower annual fuel consumption, making it a good option for a pilot.

4 References

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5 Signature

The Hague, 22 December 2020

TNO

Paul Tilanus
Projectleader

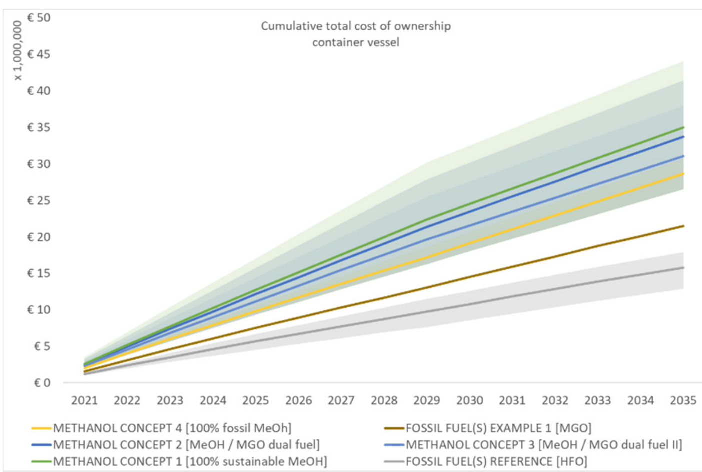
Jorrit Harmsen
Author

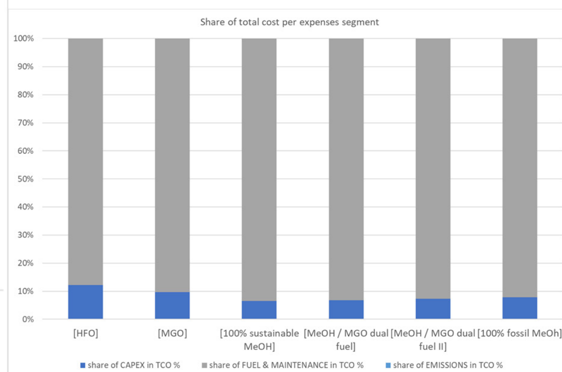
A TCO results for the different shipping types

Container vessel

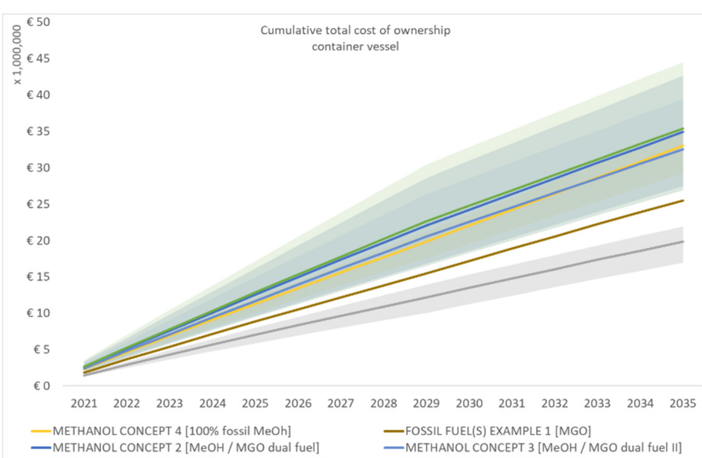
Vessel	E-Borg
Owner	Wagenborg Shipping
Built:	2009
Builder:	Koninklijke Niestern Sander
Length over all:	137.9 m
Breadth overall:	15.9 m
Draught design approx:	7.98 m
Deadweight tonnage:	11,300 ton
Total bunker capacity:	850 m^3 HFO 70 m^3 MGO
Power:	4500 kW Wärtsilä 9L32C engines
Speed:	11.2 knots

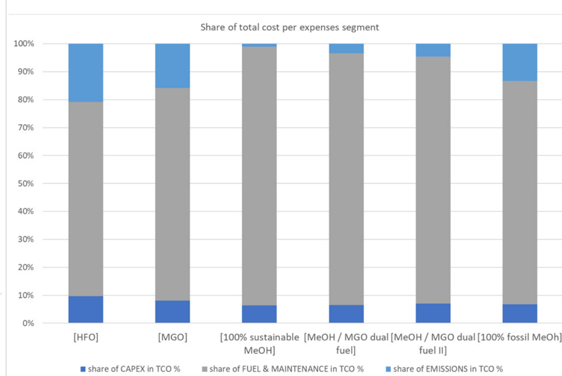
€0 CO_2 tax



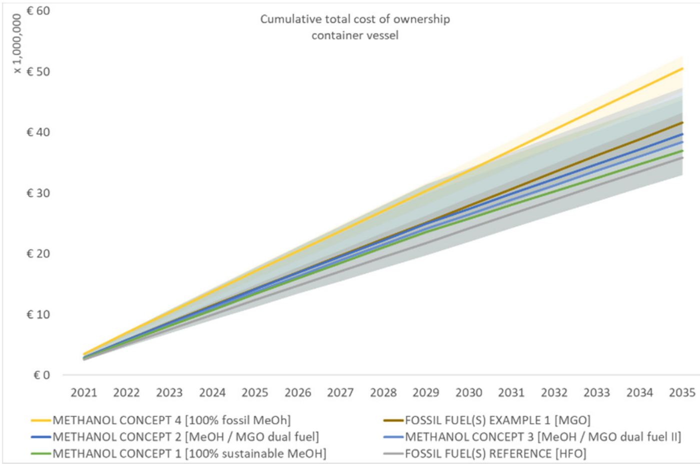


€30 CO_2 tax





€150 CO_2 tax


Cumulative total cost of ownership
container vessel
x 1,000,000
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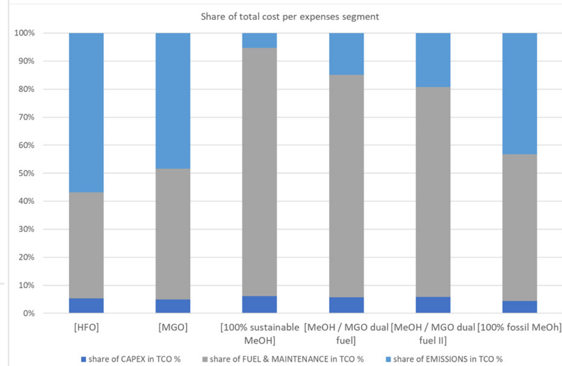
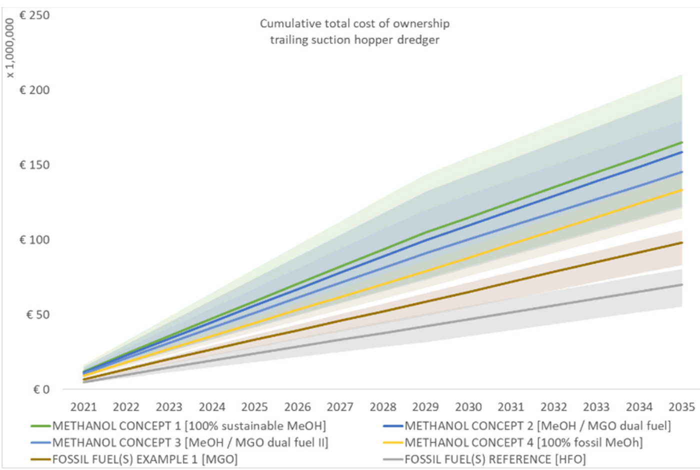
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
METHANOL CONCEPT 4 [100% fossil MeOh]
FOSSIL FUEL(S) EXAMPLE 1 [MGO]
METHANOL CONCEPT 2 [MeOH / MGO dual fuel]
METHANOL CONCEPT 3 [MeOH / MGO dual fuel II]
METHANOL CONCEPT 1 [100% sustainable MeOH]
FOSSIL FUEL(S) REFERENCE [HFO]

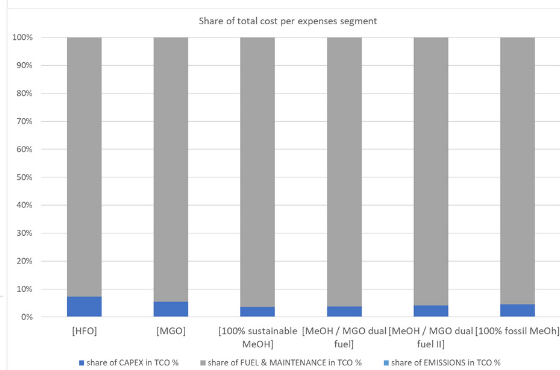

Share of total cost per expenses segment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
[HFO]
[MGO]
[100% sustainable MeOH]
[MeOH / MGO dual fuel]
[MeOH / MGO dual fuel II]
[100% fossil MeOh]
share of CAPEX in TCO %
share of FUEL & MAINTENANCE in TCO %
share of EMISSIONS in TCO %

Trailing suction hopper dredger

Vessel	Willem van Oranje
Owner	Boskalis
Built:	2010
Builder:	IHC Dredgers B.V.
Length over all:	144 m
Breadth moulded:	28 m
Depth to upper deck:	13.5 m
Max. draught dredging:	10.0 m
Displacement:	34 000 tons (approx.)
Hopper capacity	12 000 m^3
Total bunker capacity:	1,585 ton HFO/MDO (incl. service tanks)
Main Power:	12,000 KW (2x Wärtsilä 12V32)

€0 CO_2 tax





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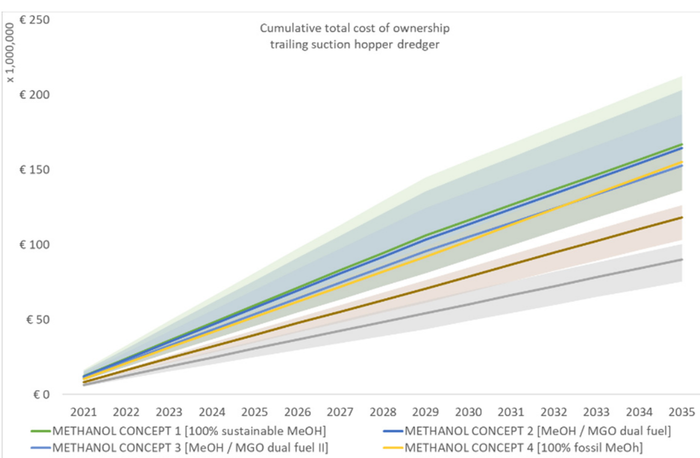

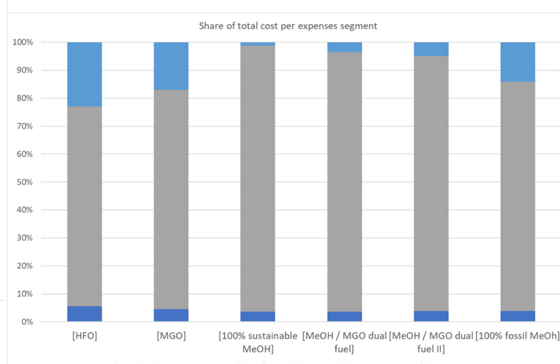

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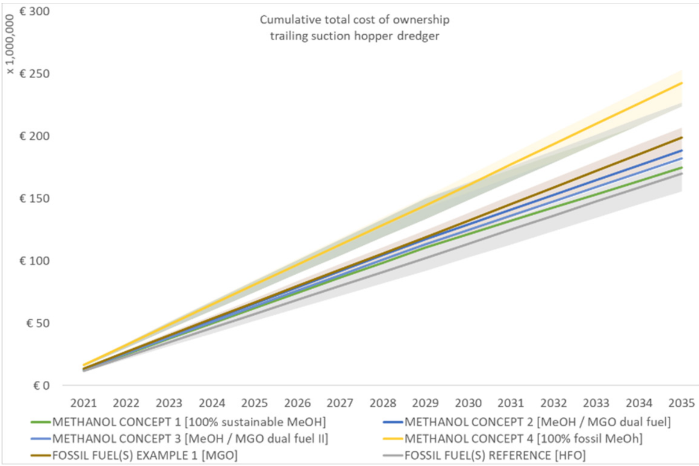
Cumulative total cost of ownership
trailing suction hopper dredger
x 1,000,000
€ 300
€ 250
€ 200
€ 150
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€ 0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
METHANOL CONCEPT 1 [100% sustainable MeOH]
METHANOL CONCEPT 2 [MeOH / MGO dual fuel]
METHANOL CONCEPT 3 [MeOH / MGO dual fuel II]
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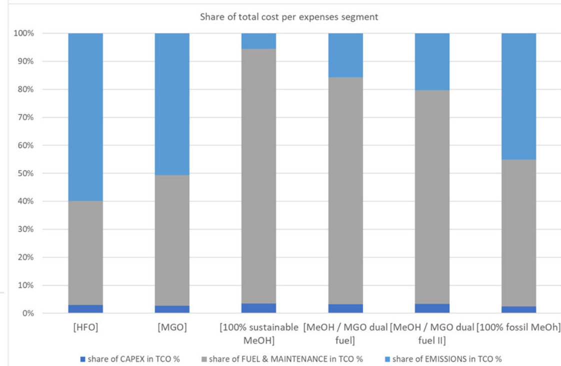
FOSSIL FUEL(S) EXAMPLE 1 [MGO]
FOSSIL FUEL(S) REFERENCE [HFO]


Share of total cost per expenses segment
100%
90%
80%
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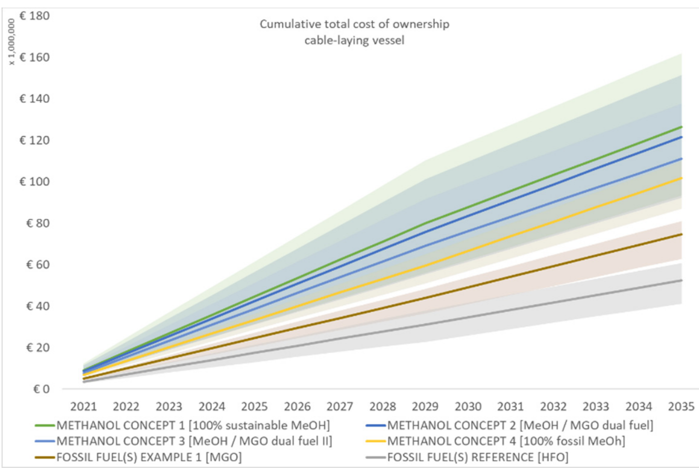
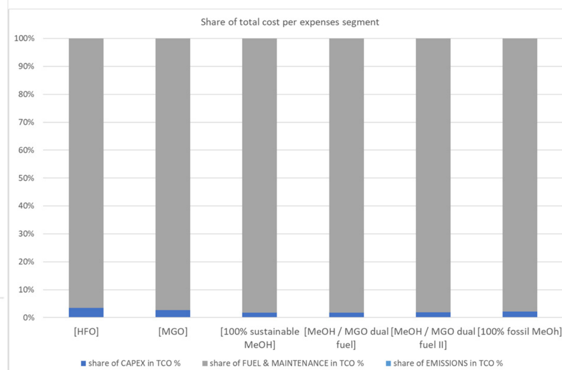
40%
30%
20%
10%
0%
[HFO]
[MGO]
[100% sustainable MeOH]
[MeOH / MGO dual fuel]
[MeOH / MGO dual fuel II]
[100% fossil MeOh]
share of CAPEX in TCO %
share of FUEL & MAINTENANCE in TCO %
share of EMISSIONS in TCO %

Cable laying vessel

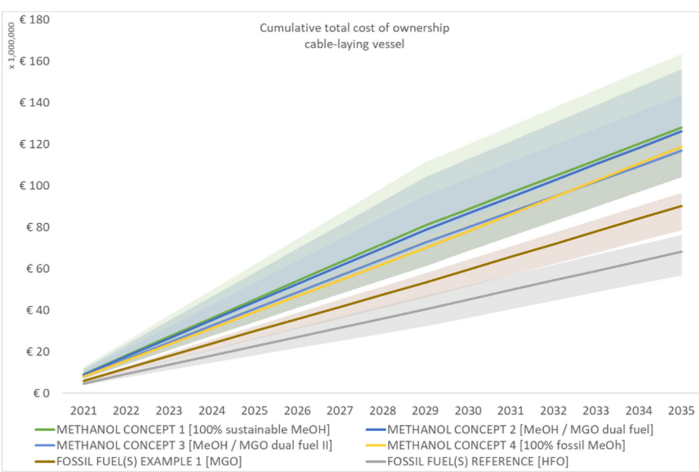
Vessel	Nexus
Owner	Van Oord
Built:	2014
Builder:	
Length over all:	122.68 m
Breadth moulded:	27.45 m
Max. draught dredging:	5.82 m
DWT:	8,398 tons
Cable carousel	5,000 tons
Total bunker capacity:	1,678 m^3 (incl. service tanks)
Main Power:	10,948 kW (Total Power installed)
Speed:	12.4 knots

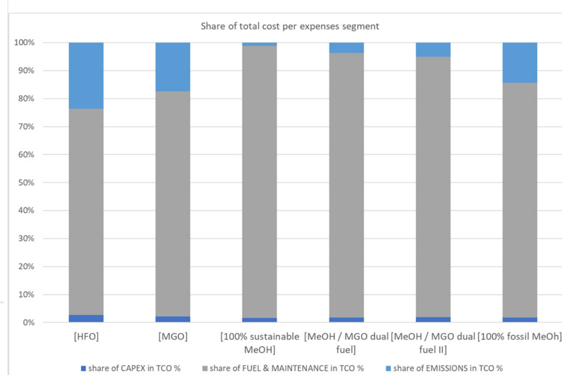
€0 CO_2 tax



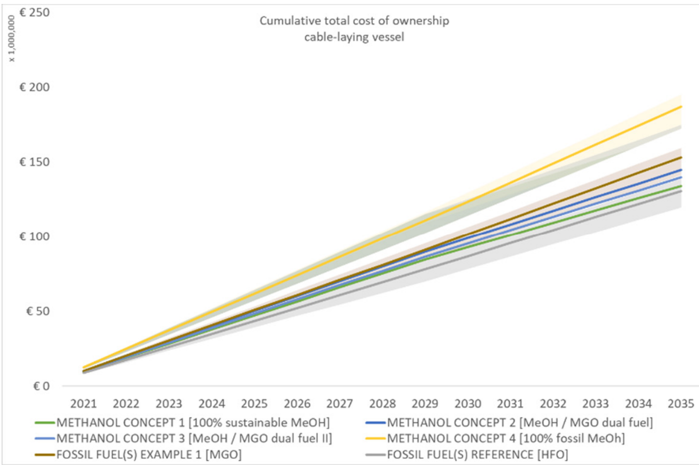


€30 CO_2 tax





€150 CO_2 tax


Cumulative total cost of ownership
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x 1,000,000
€ 250
€ 200
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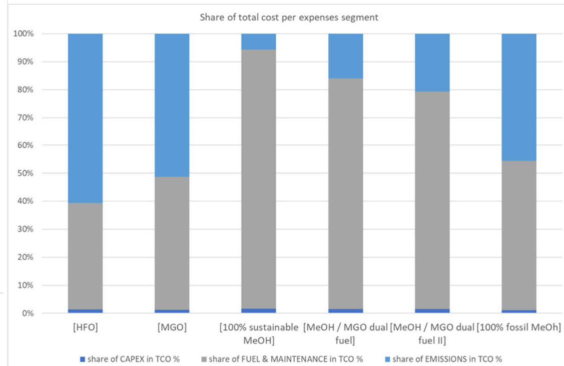
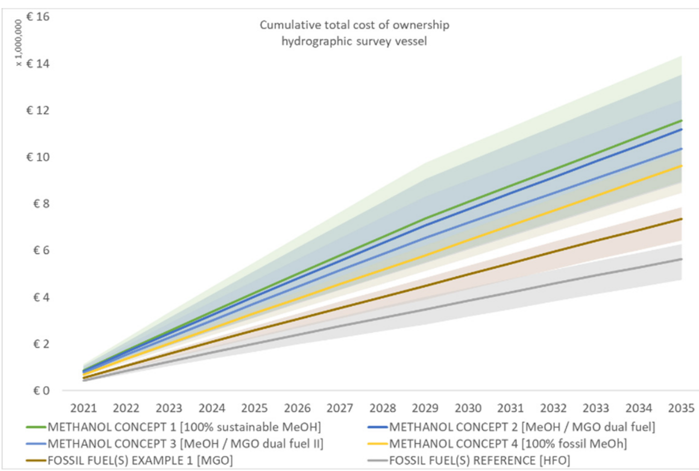
€ 100
€ 50
€ 0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
METHANOL CONCEPT 1 [100% sustainable MeOH]
METHANOL CONCEPT 2 [MeOH / MGO dual fuel]
METHANOL CONCEPT 3 [MeOH / MGO dual fuel II]
METHANOL CONCEPT 4 [100% fossil MeOh]
FOSSIL FUEL(S) EXAMPLE 1 [MGO]
FOSSIL FUEL(S) REFERENCE [HFO]

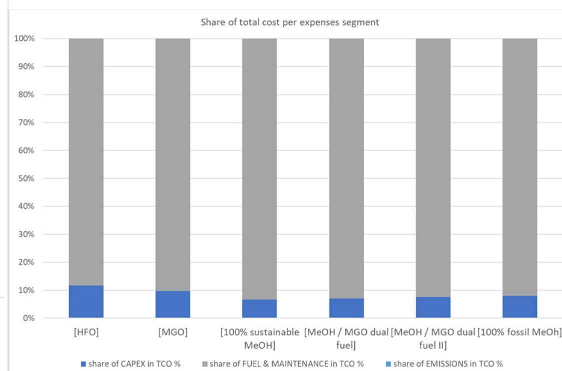

Share of total cost per expenses segment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
[HFO]
[MGO]
[100% sustainable MeOH]
[MeOH / MGO dual fuel]
[MeOH / MGO dual fuel II]
[100% fossil MeOh]
share of CAPEX in TCO %
share of FUEL & MAINTENANCE in TCO %
share of EMISSIONS in TCO %

Hydrographic survey vessel

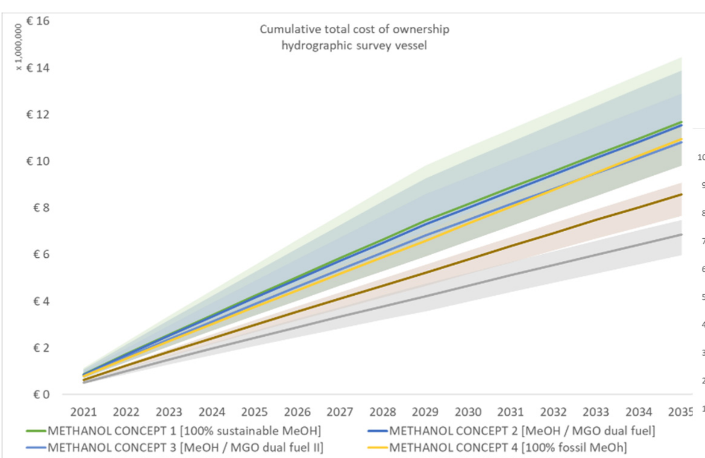
Vessel	Zr.Ms. Snellius/ Zr.Ms. Luymes
Owner	Royal Navy
Built:	2003
Builder:	-
Length over all:	75 m
Breadth moulded:	13.1 m
Draught :	4.0 m
Displacement:	1.750 tons (approx.)
Total bunker capacity:	435 m^3
Main Power:	1,500 kW (Diesel-electric drive)

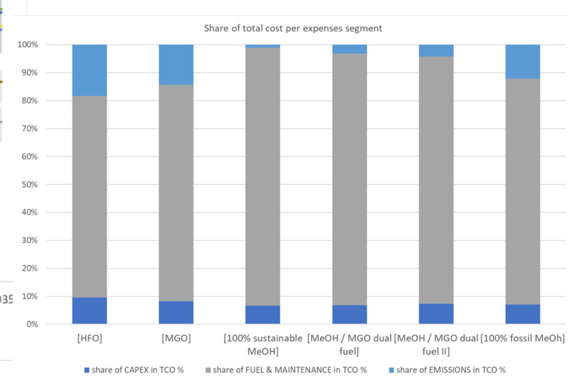
€0 CO_2 tax



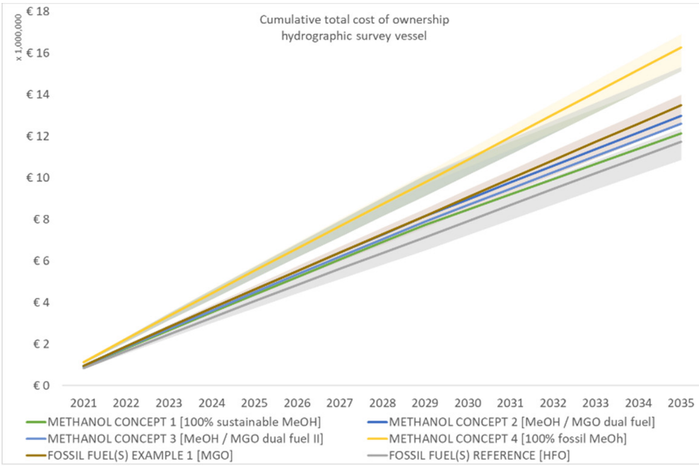


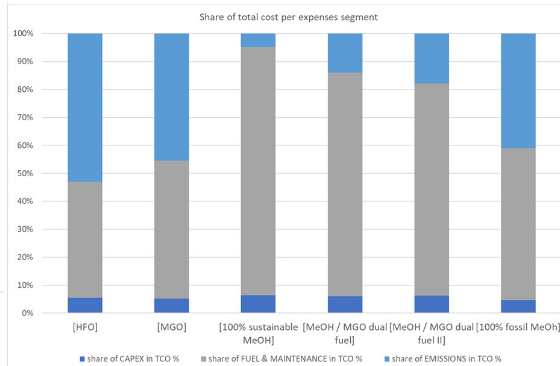
€30 CO_2 tax





€150 CO_2 tax

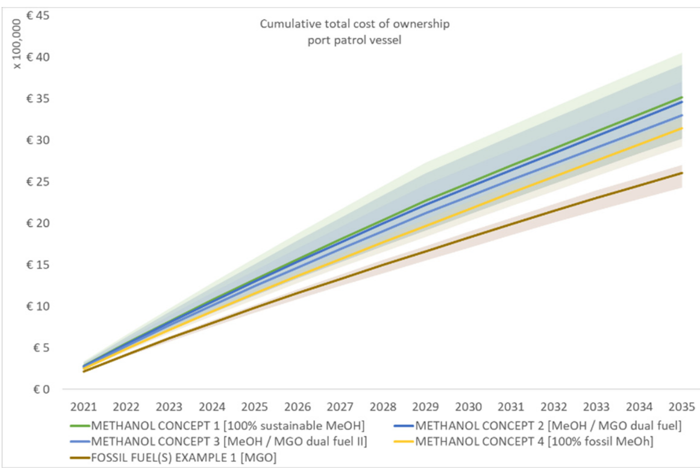

Cumulative total cost of ownership
hydrographic survey vessel
x 1,000,000
€ 18
€ 16
€ 14
€ 12
€ 10
€ 8
€ 6
€ 4
€ 2
€ 0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
METHANOL CONCEPT 1 [100% sustainable MeOH]
METHANOL CONCEPT 2 [MeOH / MGO dual fuel]
METHANOL CONCEPT 3 [MeOH / MGO dual fuel II]
METHANOL CONCEPT 4 [100% fossil MeOh]
FOSSIL FUEL(S) EXAMPLE 1 [MGO]
FOSSIL FUEL(S) REFERENCE [HFO]

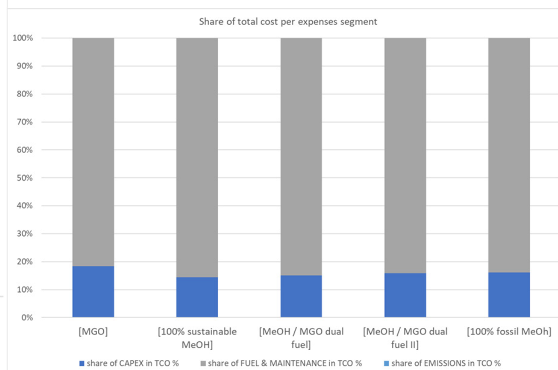

Share of total cost per expenses segment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
[HFO]
[MGO]
[100% sustainable MeOH]
[MeOH / MGO dual fuel]
[MeOH / MGO dual fuel II]
[100% fossil MeOh]
share of CAPEX in TCO %
share of FUEL & MAINTENANCE in TCO %
share of EMISSIONS in TCO %

Port patrol vessel

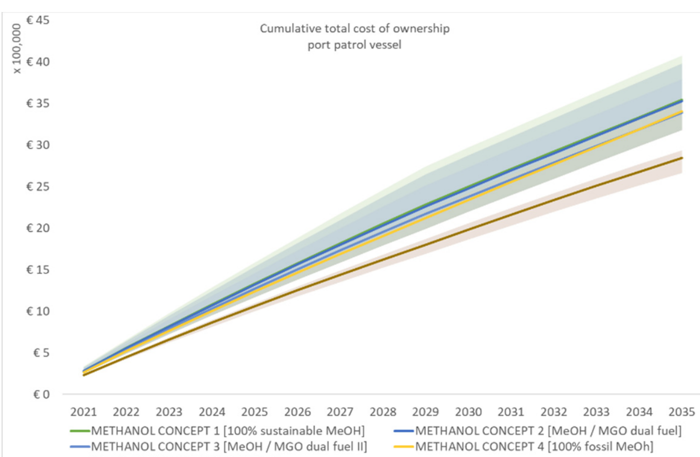
Vessel	Castor
Owner	Port of Amsterdam
Built:	2013
Builder:	Damen Shipyards
Length over all:	19,64 m
Breadth moulded:	7.94 m
Depth to upper deck:	3.39 m
Draught design approx:	2.49 m
Displacement:	176 tons
Total bunker capacity:	14 tons MGO
Power:	896 kW (2x Caterpillar C18, 425 kW, 1800 rpm)
Speed:	11.2 knots

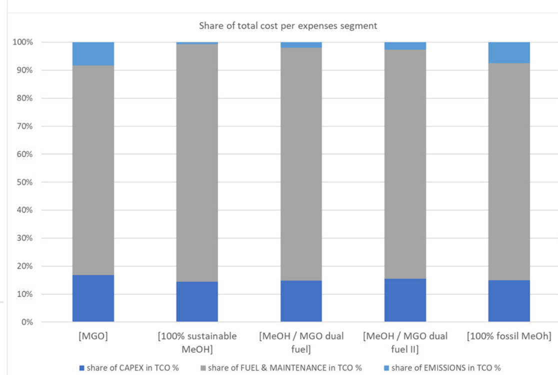
€0 CO_2 tax



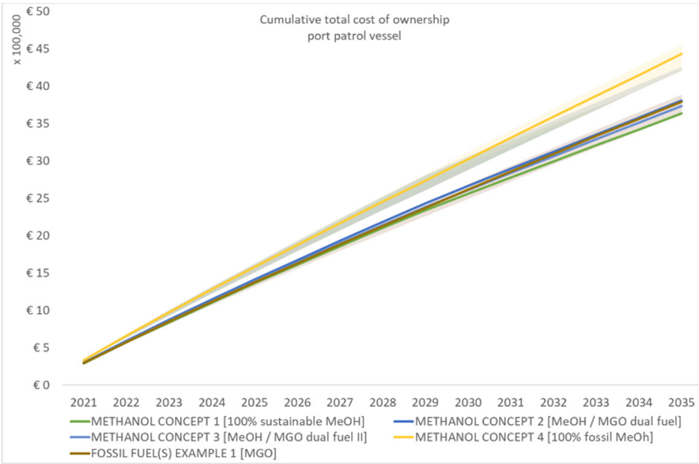


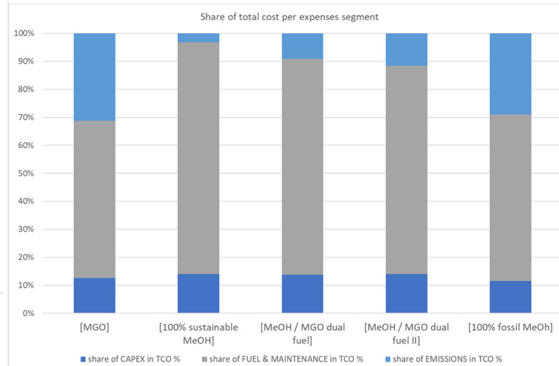
€30 CO_2 tax





€150 CO_2 tax

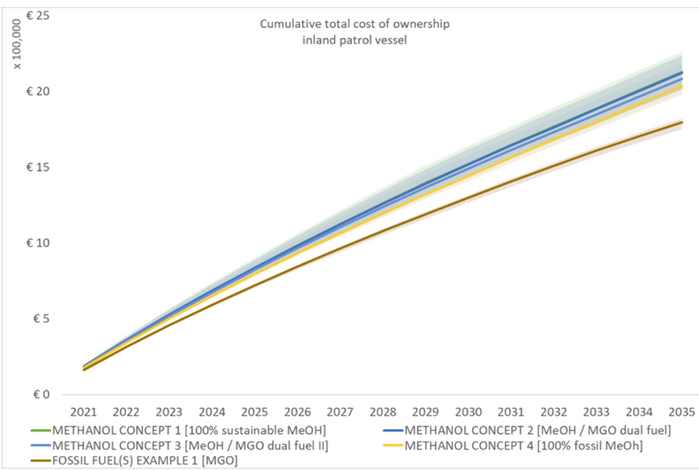

Cumulative total cost of ownership
port patrol vessel
x 100,000
€ 50
€ 45
€ 40
€ 35
€ 30
€ 25
€ 20
€ 15
€ 10
€ 5
€ 0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
METHANOL CONCEPT 1 [100% sustainable MeOH]
METHANOL CONCEPT 2 [MeOH / MGO dual fuel]
METHANOL CONCEPT 3 [MeOH / MGO dual fuel II]
METHANOL CONCEPT 4 [100% fossil MeOh]
FOSSIL FUEL(S) EXAMPLE 1 [MGO]

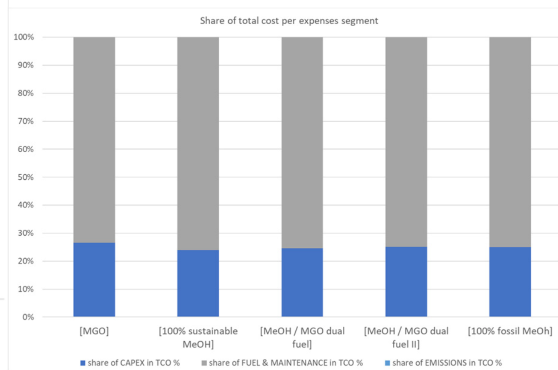

Share of total cost per expenses segment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
[MGO]
[100% sustainable MeOH]
[MeOH / MGO dual fuel]
[MeOH / MGO dual fuel II]
[100% fossil MeOh]
share of CAPEX in TCO %
share of FUEL & MAINTENANCE in TCO %
share of EMISSIONS in TCO %

Inland patrol vessel

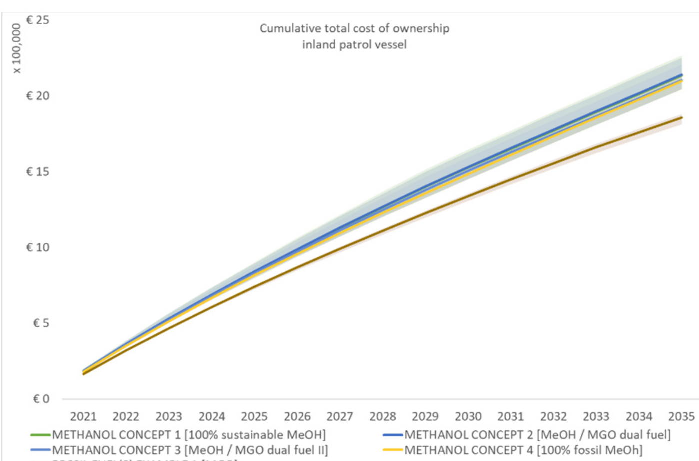
Vessel	RWS 88
Owner	Rijksrederij
Built:	1998
Builder:	Damen Shipyards
Length over all:	18.47 m
Breadth moulded:	5.00 m
Depth to upper deck:	2.49 m
Draught design approx:	1.35 m
Displacement:	66 tons
Total bunker capacity:	3 tons MGO
Power:	1040 kW (2x MAN D2840LE401, 520 kW)

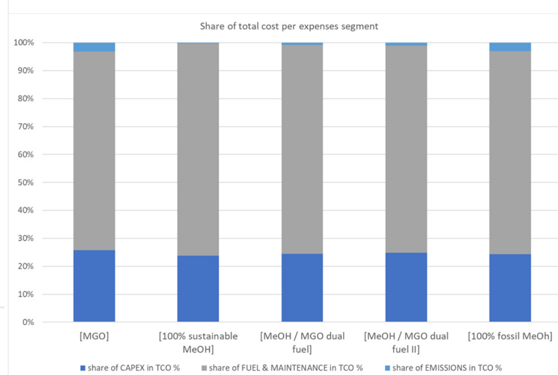
€0 CO_2 tax



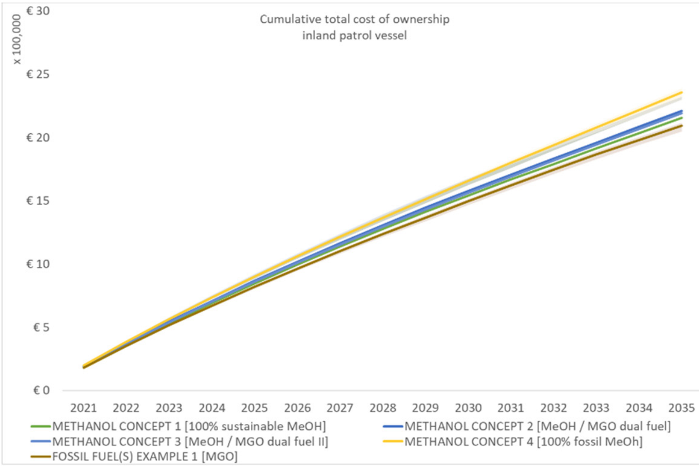


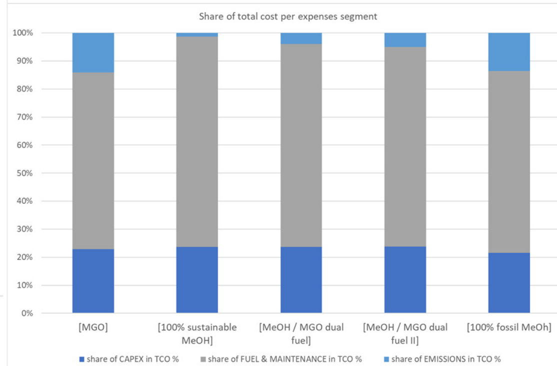
€30 CO_2 tax





€150 CO_2 tax


Cumulative total cost of ownership
inland patrol vessel
x 100,000
€ 30
€ 25
€ 20
€ 15
€ 10
€ 5
€ 0
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
METHANOL CONCEPT 1 [100% sustainable MeOH]
METHANOL CONCEPT 2 [MeOH / MGO dual fuel]
METHANOL CONCEPT 3 [MeOH / MGO dual fuel II]
METHANOL CONCEPT 4 [100% fossil MeOh]
FOSSIL FUEL(S) EXAMPLE 1 [MGO]


Share of total cost per expenses segment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
[MGO]
[100% sustainable MeOH]
[MeOH / MGO dual fuel]
[MeOH / MGO dual fuel II]
[100% fossil MeOh]
share of CAPEX in TCO %
share of FUEL & MAINTENANCE in TCO %
share of EMISSIONS in TCO %

B Assumptions TCO calculations

Category	Type	Units	HFO	MGO	Fossil MeOH	Sustainable MeOH
Energy carrier	**Energy content**	MJ/kg	40	42.7	19.9	19.9
	Energy density	Kg/m3 @ 15C	1010	860	784.5	784.5
	Emission factor	g/MJ WTP	89.7	89.5	97.7	4.4
Costs	**Tank price**	€/m3	50		70	
	Engine price	€/kW	400		420	
	Financing cost	%	4			
	Depreciation period	Years	15			
	Residual value	%	15		10	