Department of Mechanical and Aerospace Engineering

Evaluation of main engine conversion of chemical tanker for mitigation of emissions with the utilization of methanol as a marine fuel

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Signed: Christos Panagiotis Tzortzinis Date: 11 August 2021

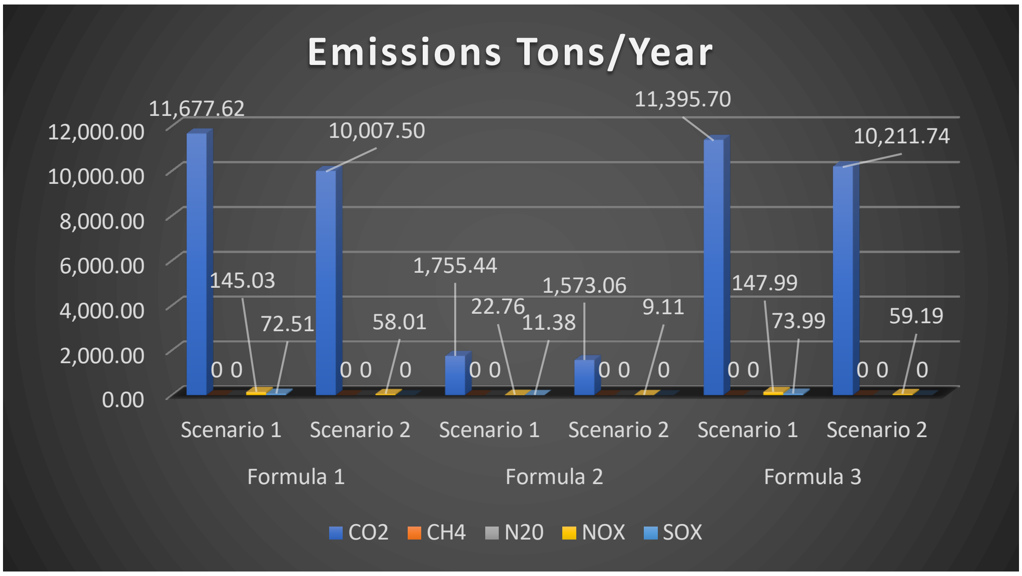
Abstract

This research aims to address the potentials of methanol as a marine fuel towards the reduction of greenhouse gas (GHG) emissions in the maritime industry. The main objective is the proposal of conversion of an existing engine on a chemical tanker; British Engineer, that utilises heavy fuel oil (HFO) to the alternation of methanol and comparison of the current emissions and the aftermath of the change. A variety of methods for the adoption of methanol were investigated along with their suitability to adapt to the current market and their financial and environmental prosperity. A literature review was conducted that established a "gap" regarding the alternation potentials of the fuel on existing operational ships.

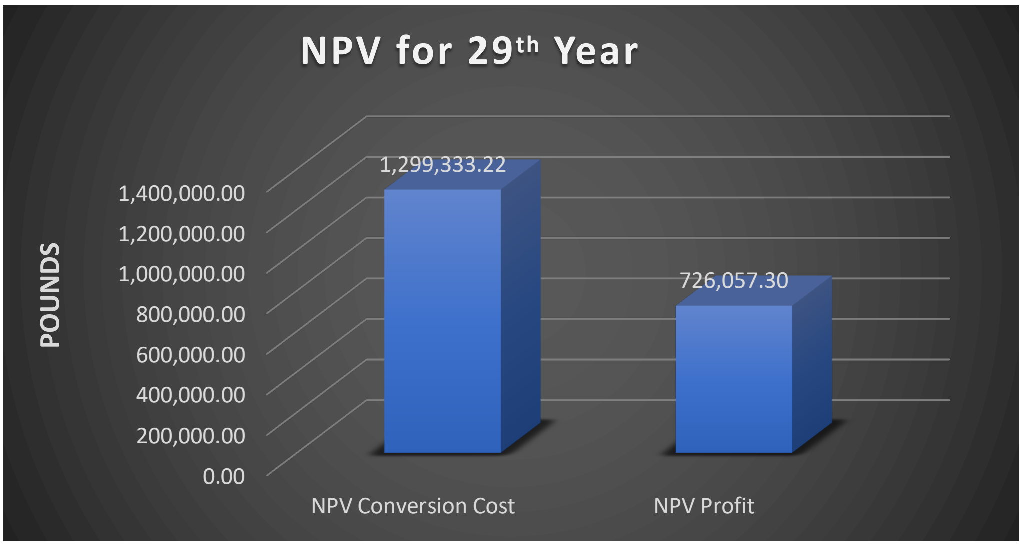
A comparison was made of the potential outcomes if the company implemented the engine conversion along with the contribution to the reduction of GHGs from the ship. The methodology outlined proposed a new way to assist the elimination of emissions. HFO and methanol as fuels were compared and the calculation process was found and described in detail. Subsequently, emission rates of the pollutants were selected, which were significant for the annual estimation of the respective emissions. The conversion of the engine was deployed following what would be possible to adapt to the engine from components currently on the market.

Consistent with the specifications of the installed main engine, the parts selected could achieve the elimination of the emitted pollutants. The limitations were discussed with the main issue being availability of the ship's data regarding the nautical miles operated from each separate engine of the ship. Consequently, an assumption was made that the ship operated only using its main engine. The results confirmed the conversion could be profitable for the upcoming years but with a low cashback. A financial plan, the comparison of the current prices of both fuels along with the conversion and operational costs, assessed the estimation of the Net Present Value (NPV) to be £1,299,333.22.

Furthermore, this study evaluated a variety of ways for the reduction of the cost for methanol production, with the optimum to be the exploitation of biomass or 'green' electricity, gaining approximately £1,259,146.06 annually. The comparison of the two fuels is of incomparable interest. There is undoubtedly a patchwork of special features which were evaluated thoroughly making methanol the optimum choice as a marine fuel for the upcoming years, as it could minimize emissions in the maritime sector and at the same time be profitable for the investors.



Graphs 1: Detailed description of emissions sets, from all calculation formulas and scenarios.



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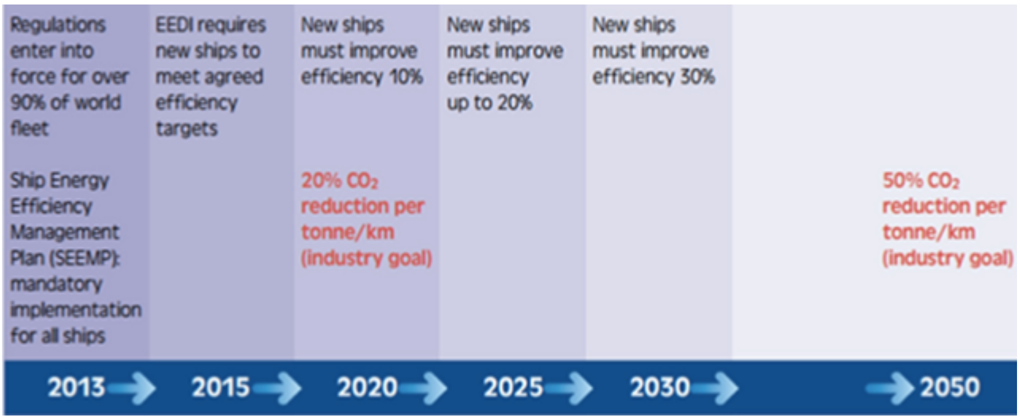

Figure 1: The International Maritime Organization (IMO) plan for minimizing pollutants until 2050 [111].

KEYWORDS: Methanol, HFO, Marine Fuel, Conversion, Emissions, Engine, IMO, Paris Agreement, Costs, NPV, Profit, Consumption

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''You cannot go back and change the beginning, but you can start where you are and change the ending'' C.S.Lewis

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Nomenclature

Symbol	Description
CCS	Carbon Capture Module
CFD	Contract for Difference
CTO	Coal to Olefins
DME	Dimethyl Ether
ECAS	Emission Control Area
EEPI	EEPI
EGR	Exhaust Gas Recirculation
HFO	Heavy Fuel Oil
ICIC	Independent Commodity Intelligence
IPCC	International Commission Climate Change
IMO	International Maritime Organisation
LHV	Lowest Calorific Value
MERC	Marine Environment Protection Committee
MGO	Marine Gas Oil
MTBE	Methyl Tertiary Butyl Ether
OPEX	Operating Expenses
SCR	Selective Catalytic Reduction
SFOC	Specific Fuel Oil Consumption

1.0 Introduction

A patchwork of legislative proposals, aimed at 55% immediate climate neutrality, was approved by the European Commission in July 2021 [111]. In more detail, the ways in which it will contribute to global environmental prosperity are reported and defined [111]. The shipping sector has a particularly negative role in global emissions because it is responsible for 3% of this total [110]. Essentially, this number is related to maritime transport and trade [110]. If the rapid growth of the world population is combined with the equally increase in commercial demand, it will result in the creation of more ships [114].

In fact, for this reason, an increase of 3% is projected and will be a very serious problem soon [114]. Of particular importance is the fact that the United Nations Agreement on Paris 2015 set a goal of minimizing greenhouse gas emissions from the shipping sector by 50% by 2050 [115]. In essence, global awareness of climate change is leading to new ideas in new energy transition needs, using fuels without the presence of carbon and sulfuric acid [112]. Undoubtedly, renewable energy sources can take both gaseous and liquid forms, and the result is that electricity can thus be stored as a chemical [112].

In this way, the specific substance can be used as energy storage but also any kind of fuel [112]. Methanol is a very important substance, which when used in pilot transport, is often referred to as a fuel that with proper management and further study will help minimize gaseous emissions [113]. This is because methanol as a fuel has not been fully studied in recent years, so it is being studied, trying to fill the ‘gap’ in the world of methanol [113]. Starting from this position, to stimulate such an innovation, the European Union (EU) in collaboration with the International Maritime Organization (IMO) has created a patchwork of regulations and guidelines for methanol as a marine fuel [26].

Meanwhile, a strong measure is the introduction of emission control regulations for air pollutants such as nitrogen oxides (NO_X) and of course sulfur oxides (SO_X) [116]. It is easy to conclude that the rapid but at the same time strict requirements of the industrial market accelerate the immediate need for innovative fuels with ideal solutions, with full respect for the environment, industry and of course the Paris 2050 targets [117]. The sustainable goal of this dissertation is to significantly reduce maritime emissions. In this dissertation, the use of methanol as the main fuel was theoretically investigated.

It is necessary to point out the multiple advantages of methanol compared to other fuel alternatives. For example, because it is a liquid fuel, it can be stored in standard fuel tanks and thus cryogenic installation is not necessary for the cooling process and of course the fuel pressure relative to hydrogen [118]. Modifications required to the fuel system in relation to the cryogenic0installation are considered "negligible" because methanol has a low flash point [119]. Just before the end, it is necessary to point out that the test carried out before combustion, is an ideal measure to further prevent the formation of NO_X.

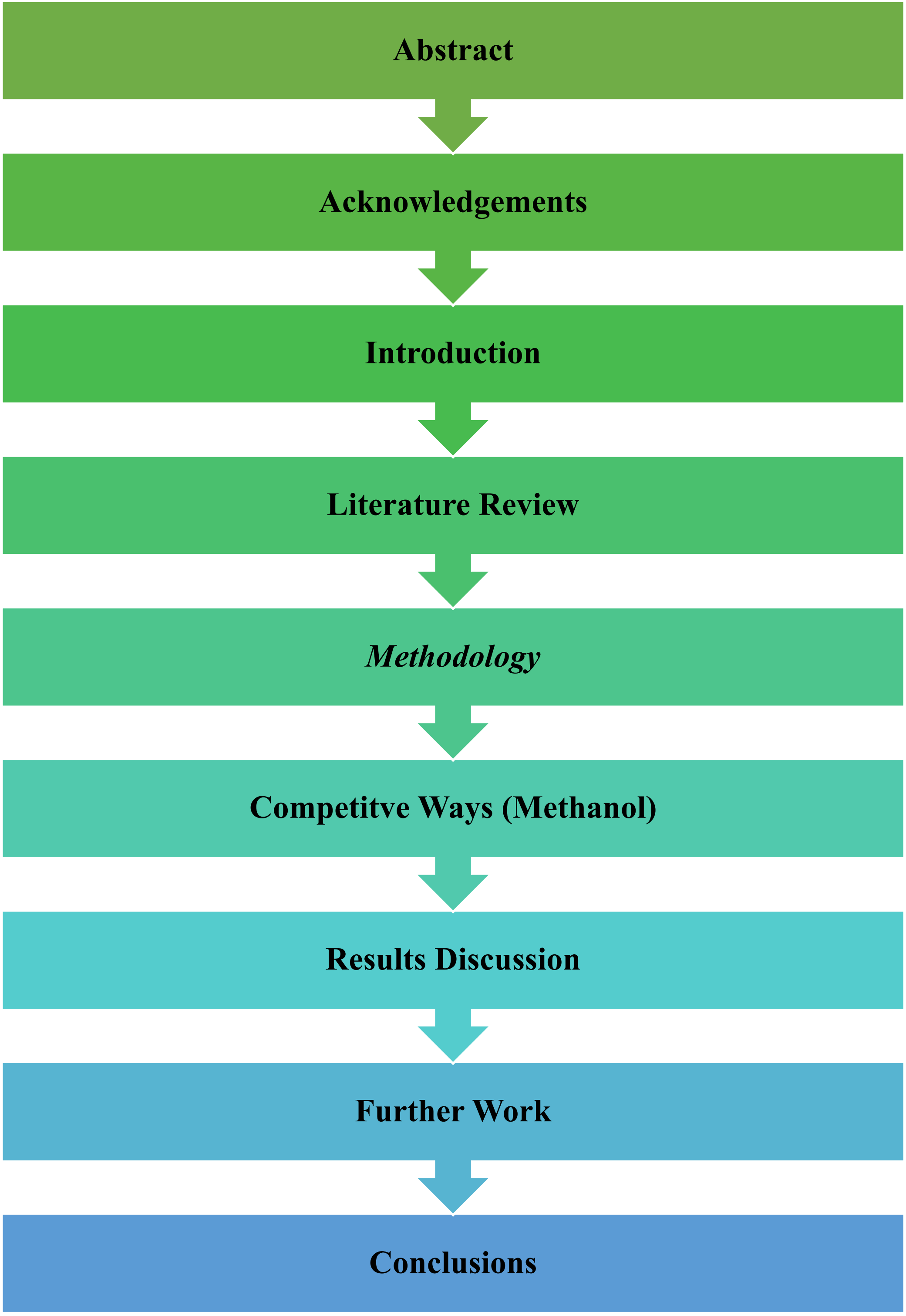
Essentially, the internal structure of diesel engines changes, moreover, when a system for the additional treatment of exhaust gases is installed, the corresponding emissions (NO_X, SO_X) will be significantly reduced to meet the Tier standards [3]. Finally, the methodology carried out summarizes the ideal choice of systems for conversion, and of course the detailed description of how the emissions is calculated and the economic analyzes. In essence, we have contributed to the goal set by the International Commission on Climate Change (IPCC) to keep global warming below 1.5 ° C by 2050 [120].

1.1 Structure of the Dissertation

The dissertation consists of a total of 9 sections. Includes Abstract, Acknowledgments, Introduction, Literature Review, Methodology, Results, Conclusions and Further Work. This structure was chosen for the complete organization of the dissertation, creating a "logical sequence of events". The environmental problems of shipping, the characteristics of methanol as well as its combination as a marine fuel and a report on the production and the demand it faces are presented in detail.

Then came the detailed report on emissions Marpol, SO_X – $N0_X$ and of course the 'literature gap of methanol' that was addressed. Just before the end, a patchwork of engine conversion methodology with emission calculation and economic analysis is presented in more detail. Finally, the results of a ‘discussion’ are obtained, combining a proposal for Further Work and of course the conclusions drawn from the research.

Table 1: Overview of Dissertation Structure



2.0 Literature Review

2.1 Environmental Impact Assessment

Heavy Fuel Oil (HFO) is a very economical solution graphs 20 combined with perfect energy efficiency, which is why most ships use this fuel [2]. A patchwork of impurities characterized by enormous sulfur content are contained in HFO, with the result that the environment and human health are adversely affected by emissions of sulfur oxide SOx and nitric oxide NOx [4]. Therefore, for the immediate prevention of pollution from the shipping industry, an International Convention was created, which is essentially the International Convention on Shipping that regulates the gaseous emissions of ships, called 'MARPOL' [3]. There are maritime areas where very strict controls have been introduced in accordance with 'MARPOL' to reduce gaseous emissions [5].

These areas are called Emission Control Areas (ECAs) and specific emission limits for SOx and NOx must be followed [1]. In addition, the global sulfur content limit should be reduced by 3% (m / m) figure 2 in 2020 and beyond, with a target of 0.5% sulfur content [2]. Ships traveling to these control areas are required to use 0.1% figure 3 sulfur fuels, effectively accepting the use of 'scrubbers' to predict HFO emissions [4]. Table 2 and figure 3, show the specifics for NO_X emissions derived from diesel engines combined with the year of construction of the ship as well as the average rotational speed that characterizes it, according to 'MARPOL' [6]. Tier III includes ships operating in the UK's emission control areas and in addition to North America. Tier II: includes ships after January 2011 and finally Tier 1 includes ships from January 2000 to January 2011 [6].

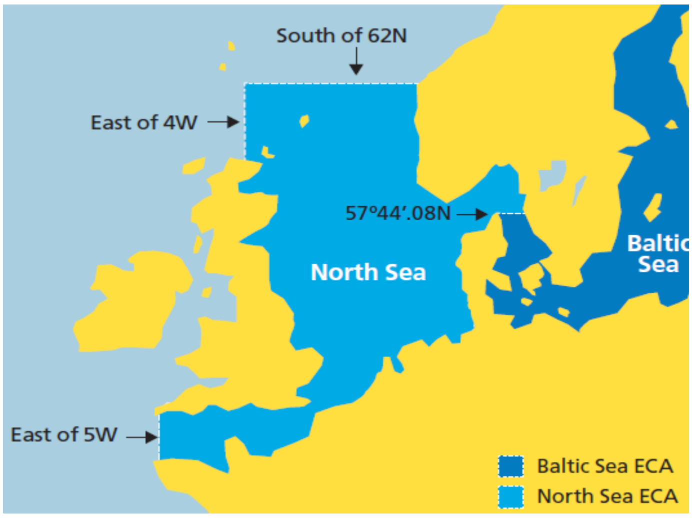


Figure 2: SECAs in Baltic and North seas [129].

Table 2: Description Tier [3].

TIER	
Tier III	Ships Built (After 1 January 2016)
Tier II	Ships Built (After 1 January 2011)
Tier I	Ships Laid (1 – 2000 / 1 – 2011)

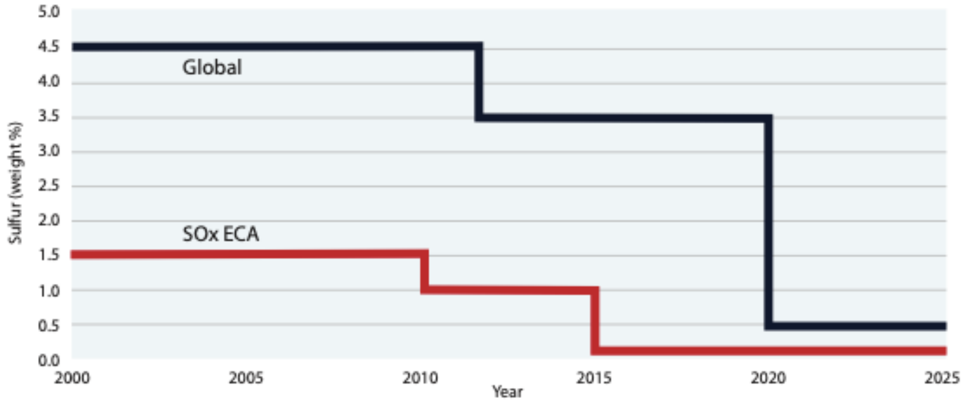


Figure 3: Limits present and future Sulphur content of marine fuels [5]

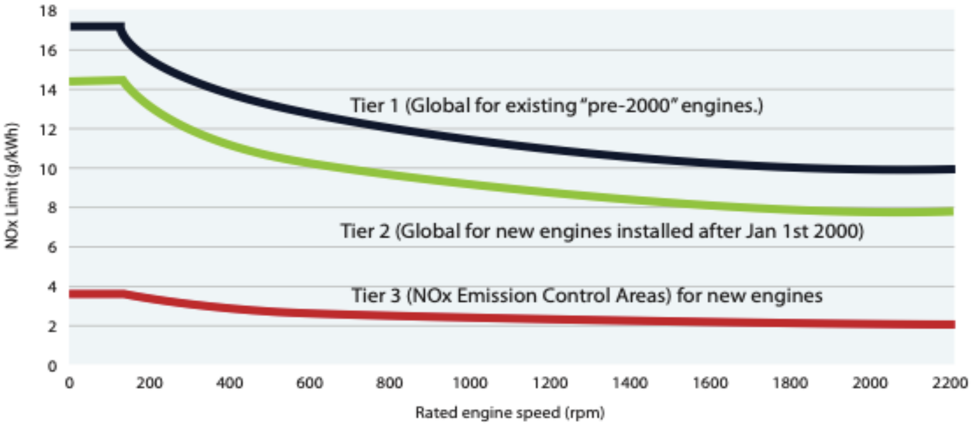


Figure 4: Depicts the appropriate NOx emissions for each tier level [6].

Inter alia, the United Nations has expressed a patchwork of major concerns about the problem of climate change assisted by the shipping sector [9]. In full cooperation with the IMO, with methodical and highly targeted moves, they created a framework capable of controlling the performance of ships, helping to reduce emissions [9]. Essentially, according to the size and design of the ships, they are evaluated to achieve clean energy efficiency for the environment, following a clean mode of operation, called the 'Energy Efficiency Planning Index' (EEPI) [8].

Figure 5: Analytical ECAs world map [130].

2.2 Emissions SOx

It is widely believed that sulfur oxides have serious and harmful effects on the environment and human health [13]. A 2016 finish study [Marine Environment Protection Committee (MERC)], showed that there may be 570,000 premature deaths from the shipping industry in Europe in 2020 - 2025 due to sulfur oxides [13]. The applicable limits are listed in the table below, which are linked to a specific type of directive from the European Union, stating that ships in European ports must use fuels with a sulfur content of up to 0.1% [13].

Table 3: Sulphur context limits for fuel [14].

EXPECT ECA	WITHIN ECA
0,5 % m/m from 1/1/2020	0,1 % m/m from 1/1/2015
3,5 % m/m from 1/1/2012	1,0 % m/m from 1/7/2010
4,5 % m/m from 1/1/2012	1,5 % m/m from 1/7/2010

Shipping companies face a patchwork of SOx-related problems and strive to respond appropriately to optimal emission reduction applications [14]. There are alternative fuels such as MGO and, in theory, hydrogen and methanol, which are 'low in sulfur' or are suitable for use with proper scrubbers [15]. According to Paulauskiene, in theory an ideal combination of 20% biodiesel and 10% methanol would be an acceptable marine fuel [17]. In addition, according to the Ammar study, combining biodiesel and methanol fuels results in a theoretical reduction of 75% of SO_X and NO_X, respectively, on cargo ships [17].

2.3 Emissions NOx

According to MARPOL and regulation 13, ships have certain amounts of nitrogen oxides that are allowed to emit, always according to the rated engine speed, because in this way they try to reduce the corresponding emissions worldwide [3]. Specifically, there are 3 existing tier levels, which must be strictly adhered to reduce pollutants [18]. Table 4 shows in detail the respective limits, there is a huge 76% difference in the levels between Tier II and Tier III [18]. The result is that the ship's speed does not have as much of an impact as the engine power if combined with the cargo [18].

Table 4: NOx emissions limits (g/kWh), n = rated engine speed (rpm) [3].

Tier	N < 130	N > = 2000	N = 130 – 1999
I	17	9.8	$45 * n^{-2}$
II	14.4	9.7	$44 * n^{-2}$
III	3.4	2	$9 * n^{-2}$

2.4 Emissions SOx – NOx

According to a survey conducted European Union on total marine emissions, the result was that 16.5% of all emissions belong to the NO$_X$ and 11% to the SO$_x$, they constitute 27.5% of the total marine emissions and have approximately 33.33% difference [19]. In addition, they are characterized as the most harmful and alongside dangerous gases by marine engines, because of which they are ranked in the top 10 most dangerous pollutants for the environment [19]. An increase of 35% is projected by the year 2030, and this is because the world population is increasing and meanwhile this will increase the demand for additional itineraries and shipbuilding [20].

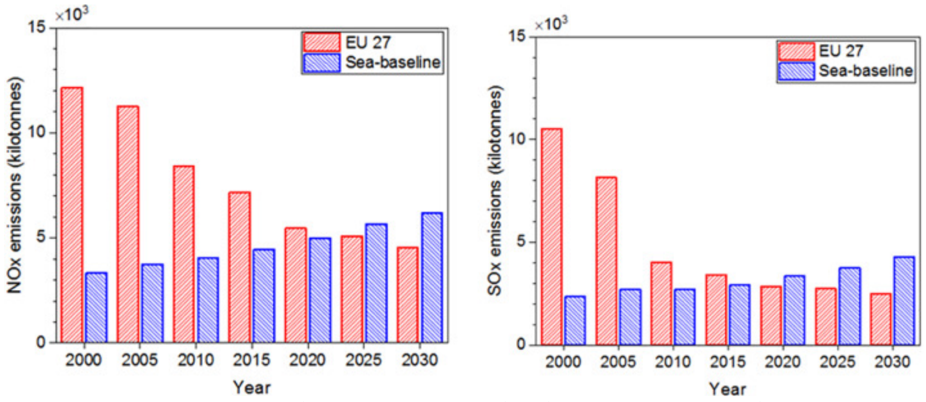


Figure 6: NOx and SOx emissions trend in the 2000 – 2030 period [19].

2.5 ‘Literature Gap of Methanol as Marine Fuel’

According to research, the need to minimize global gas emissions is immediately understood [108]. The need to minimize the climate impact of the shipping sector is imperative, as they account for 3 % of global gas emissions [108], [110]. In addition, tackling emissions requires the introduction of new alternatives and promising fuels to the maritime sector with the main ‘sustainable’ goal of eliminating carbon from traditional fuels [109]. Further analysis revealed a ‘gap’ in the study literature examining methanol as a marine fuel.

At present, this alternative energy source has not been studied in the maritime sector in the context of an existing ship engine that has run existing nautical miles, calculating the difference in emissions from the two fuels. Meanwhile, the economic barriers to methanol as a marine fuel and the ways in which "marine methanol" will become in demand in the coming years have not been studied. This dissertation, with the theoretical conversion of the main engine into a methanol engine, tried to fill this ‘gap’ by contributing a new methodology for minimizing emissions in the shipping sector.

Optimally combining the ‘green and at the same time economically viable ways’ to fill the ‘gap’ created by the study of methanol in the field of marine investment. Finally, the dissertation filled the ‘gap’ of methanol studies, proving that it could be a technically feasible solution to minimize emissions from shipping. Contribute to the emission reduction targets of the European Union [108] through a practical methodology contributing for the first time a methodology for minimizing emissions.

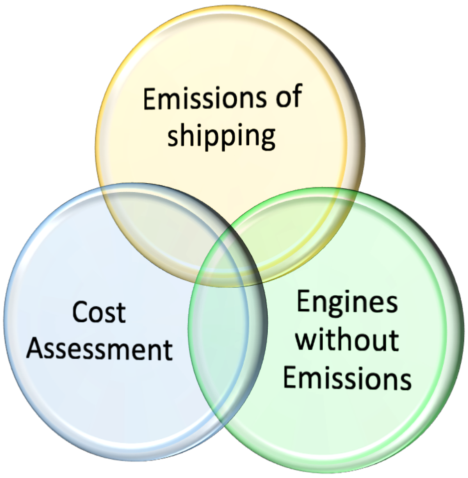


Figure 7: Overview of existing literature review.

2.6 Characteristics of Methanol

Unquestionably, the formulas ‘CH3OH’ or ‘MeOH’ express the very simple form of alcohol which is methanol [23]. Admittedly, it is a volatile and flammable substance, which has no color but also has an alcoholic odor, and in liquid form is at room temperature [24]. It is also one of the most commercial chemicals in the world, combining its application in the chemical industry and its application as fuel at an early level [23]. Specifically, in the chemical industry, it contributes the most to the production of olefins, acetic acid and of course formaldehyde (30%), with ideal applications in innovative petrochemical products [23].

Furthermore, to produce ‘Methyl Tertiary - Butyl Ether’ (MTBE) methanol is an integral component, which optimally improves the octane of gasoline from all types of vehicles, essentially contributing to the ideal reduction of emissions [24]. Methanol exhibits a patchwork of optimal specific activities, making it worthily unique in its kind, characterized by a low calorific value (LHV) of 19.9 MJ / Kg, thus helping to minimize emissions during the process. combustion [25]. It would be a serious omission not to mention the significant difference that is reflected in the capacity of the tanks, as almost twice the amount of methanol fuel is required, due to which the more frequent refueling of the ship is necessary [26].

However, due to the ratio of the lowest thermal value analyzed above, there is essentially a double difference in the consumption ratio [27]. In this context, another characteristic of methanol that must be considered because it is of particular importance is its flammability limit [27]. Initially, in the process of evaporating fuel, when the vapors reach a certain concentration with the air, then there is a chance that an explosion will result if a spark appears [27]. Meanwhile, in the case of methanol, the flammability zone is observed to be much larger than that observed in heavy fuel oil and extends substantially in the range of 6.7 - 36% by volume relative to air [26].

Inter alia, at the lower values of methanol, there is virtually no risk of explosion because the gas mixture is classified as "poor" and after that, for the highest values of maximum flammability, the mixture is classified as "rich" [26]. Therefore, the ceiling should be avoided, because an unexpected air leak can increase the air concentration, and meanwhile lead to a drop in the ratio within the limits of the specific flammable zone [28].

Alongside, the flame of methanol has a specific peculiarity, it is the blue-transparent color with the result that it is not easily distinguished [27]. Further, the use of an ‘alcohol resistant’ foam fire extinguisher is ideally recommended for extinguishing because it instantly reduces vapor formation and dilutes the methanol concentration [29]. Undoubtedly, methanol does not contain sulfur, alongside it contributes significantly to the compliance of environmental regulations to reduce emissions [19]. Also, sulfur dioxide is characterized as corrosive to engines, essentially by avoiding this option there is no occurrence of this problem [30].

However, alcohols have a corrosive effect on some materials, such as magnesium, aluminum and of course copper [30]. Thus, it is imperative to use compatible materials such as stainless steel, and meanwhile other metals to be coated with nickel or zinc [30]. In summary, the kinematic viscosity is particularly low in the case of methanol fuel, with the optimal result of minimizing the lubricating capacity of the respective infusion pumps [30], and of course, improving the fuel injection mode and at the same time perfecting the kinematic viscosity [31].

Table 5: Characteristics methanol [5], [26], [32], [33], [34].

PROPERTIES	METHANOL	REFERENCES
Chemical Formula	CH_3OH	[26]
Density (Kg/m^3) – Lower Heating Value (MJ/Kg)	790 – 19.9	[26]
Stoichiometric A.F.R (Kg/Kg)	6.5	[5]
Flammability Limits (Vol% in air)	6.7 - 36	[26]
Kinematic Viscosity at 25^0 ^0C (mPa*s)	0,59	[5]
Boiling Point ^0C	65	[5]
Flash Point ^0C	11	[26]
Auto Ignition ^0C	455	[5]
Cetane Number	5	[5]
Octane (R.O.N./M.O.N.)	109 / 89[3]	[26]
Water Solubility	Complete	[32]
Sulphur Content %	0	[32]
Net Heating Value (GJ/m^3)	16	[33]
Carbon Contents (wt. %)	37,49	[33]
Molecular Weight g/mol	32	[34]
Methanol Purity, wt - %	> 99.7	[34]
Water, < wt -%	< 0.1	[34]
Chlorides ion - Sulphur, ppm	< 0.5	[34

Freezing point, C^{O}	-97.6	[34]
Ron - neat	107 - 109	[34]
Blending Ron – Blending Mon	127 – 136 / 99 - 104	[34]
Heat Vaporization kj/kg	1160 - 1174	[34]
Heat Combustion, net, kj/kg	19,930	[34]
Critical Temperature C^{0}	239	[34]
Density (g/cm^{3})0-0Pressure (MPa)	8.084	[34]
Density0(g/cm^{3})	0.2715	[34]
Thermal Conductivity, mWm^{1}k^{-1}	200	[34]
Liquid at 25C^{0} / Vapor at 100 C^{o}	14.07	[34]
Self – Ignition Temperature C^{00}	464 - 470	[34]
Flame Spread Rate, m/s	2 - 4	[34]
Laminar Flame Speed (10Bar, 300 K), m/s	0.5	[34]

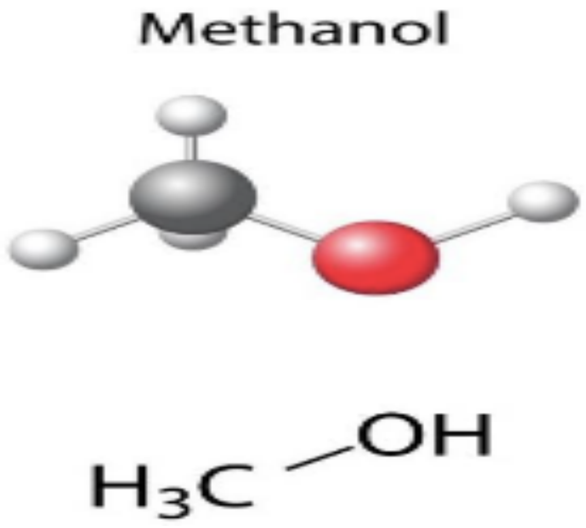


Figure 8: Symbolic representation of the methanol molecular [26].

2.7 Purchase and Demand of Methanol

For the year 2018, the global demand for methanol was estimated at 78 million tons, with the additional production capacity from the factories at 122 million tons [35]. However, the country that is characterized as a pioneer and with a leading role in the use of Methanol is China [35]. In fact, it accounts for 54% of global demand, or 41.6 million tones [35]. In this way, it acquires a chaotic difference from second western Europe with a demand of 8.1 million tons and the third North America with 7.8 million tons [35]. It should be noted that the data presented on demand do not include the Coal to Olefins (C.T.O) sector, which has the potential to be associated with huge petrochemical production [35].

In detail, Methanol can be sourced from a relatively large number of ports around the world [36]. More specifically, a survey was conducted in 151 ports of which 97 had Methanol available and within these ports 88 of the 100 best in the world [36]. To put it in perspective, about 34-35 million tons of methanol are currently traded internationally, with an increase of about 4-5% per year [36]. This represents one or two "global scales" per year, each of which produces about 5,000 tones per day, although the market could absorb two or three such plants per year without overly influencing the price [36].

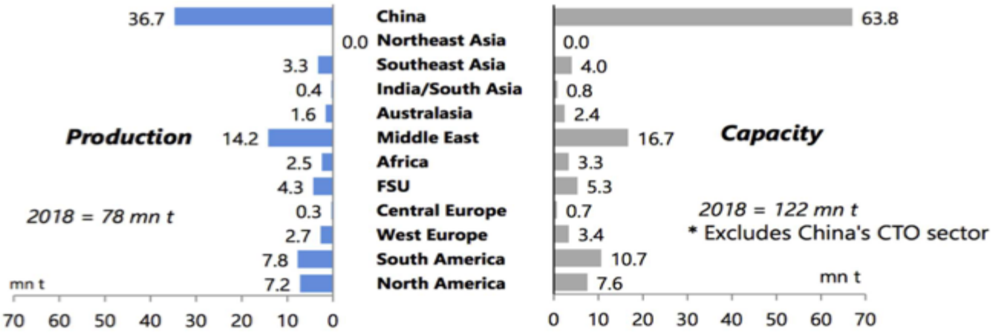


Figure 9: Global methanol production and capacity [26].

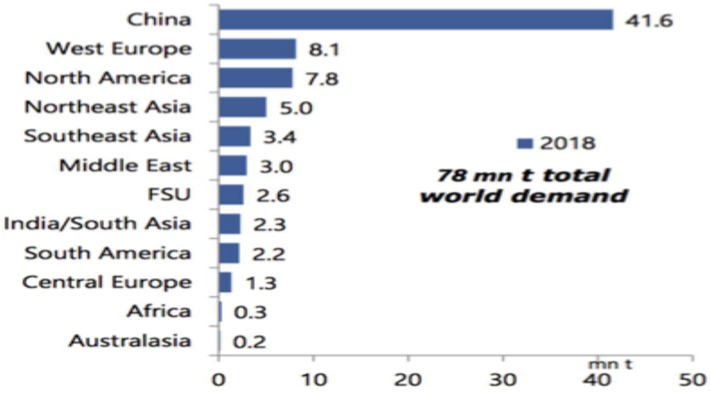


Figure 10: Global methanol demand by country and region [37].

China continues to dominate the methanol sector in terms of the relationship between demand and production [38]. It is observed that in the methanol sector there are very well compressed cash cost curves [38]. Of course, there is a lack of space to indicate the 'increase' in high production costs. [38] For the next ten years, the methanol "business" will expand at a relatively rapid rate of 4-5% each year [38].

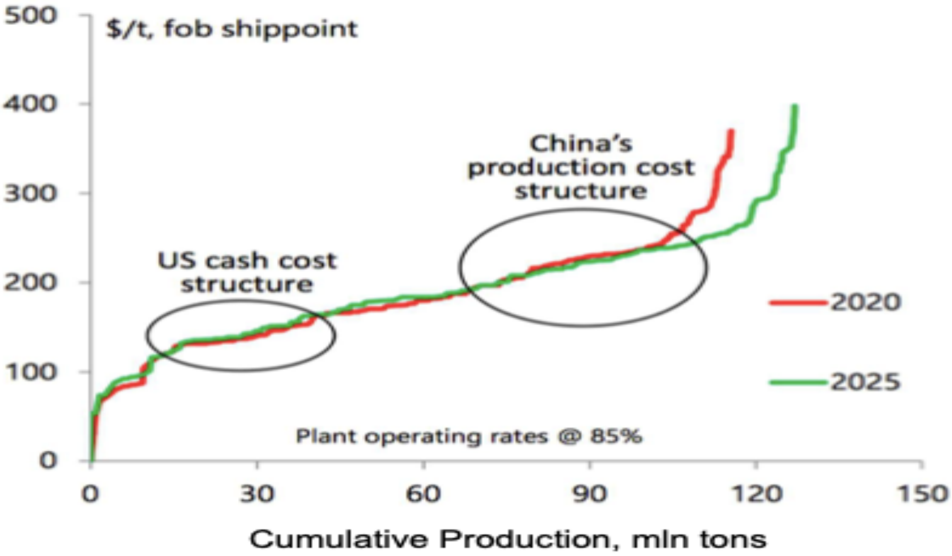


Figure 11: Methanol industry production cash cost curves [38].

According to 'IHS', 254 million liters of methanol are produced every day as a chemical raw material or transport fuel to countries around the world, namely in Africa, the Americas, the Middle East, and Europe [26]. It is theoretically enough to fully supply about 7,500 tanker trucks traveling 26 miles [26].

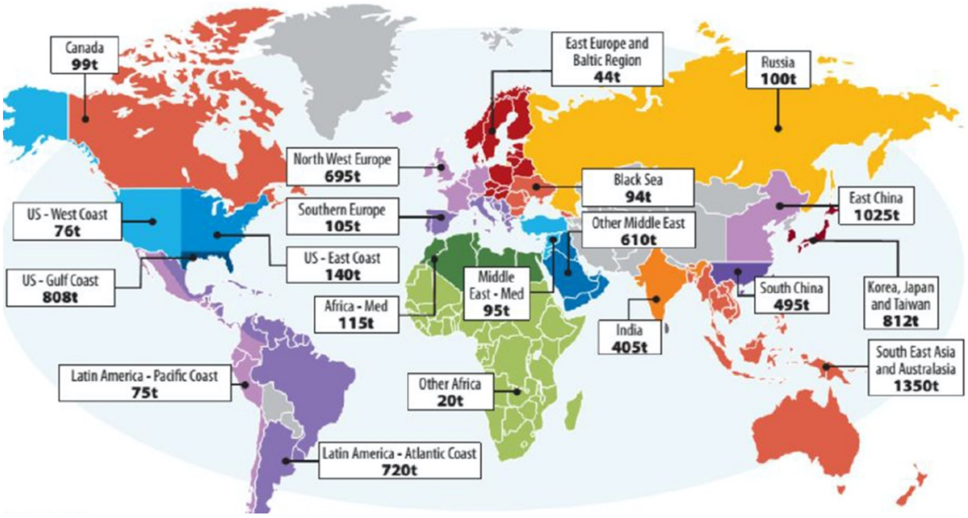


Figure 12: Methanol availability [135].

2.8 Methanol Price

However, one of the most important features that can determine the price of Methanol is undoubtedly the law of supply that is directly related to demand. In this context, we observe that the value that characterizes it, shows a large set of fluctuations, of course depending on the respective time. Figure:

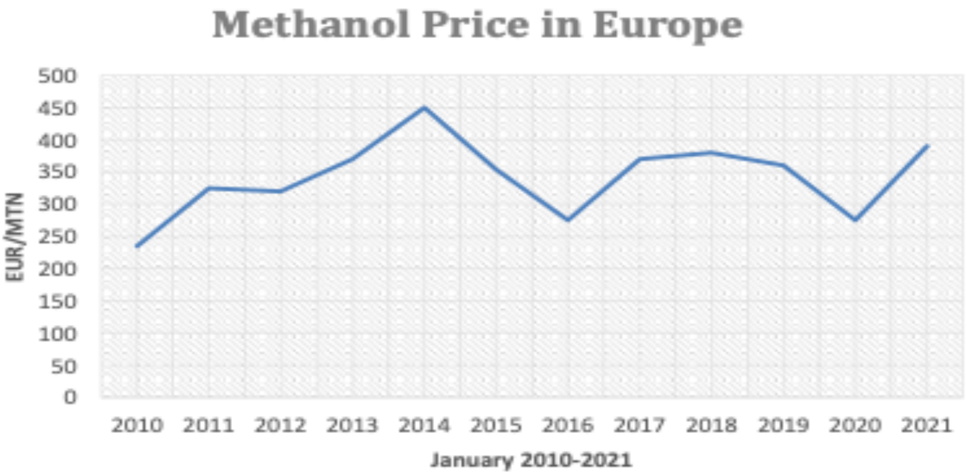


Figure 13: Price of methanol for January 2020 – 2021 [39].

After research, we observe the price of Methanol to have a significant increase, if we compare it with the last months of 2020 as shown in the chart below. In fact, in Europe it is set at 390 euros per ton, for example about 333 pounds per ton [39].

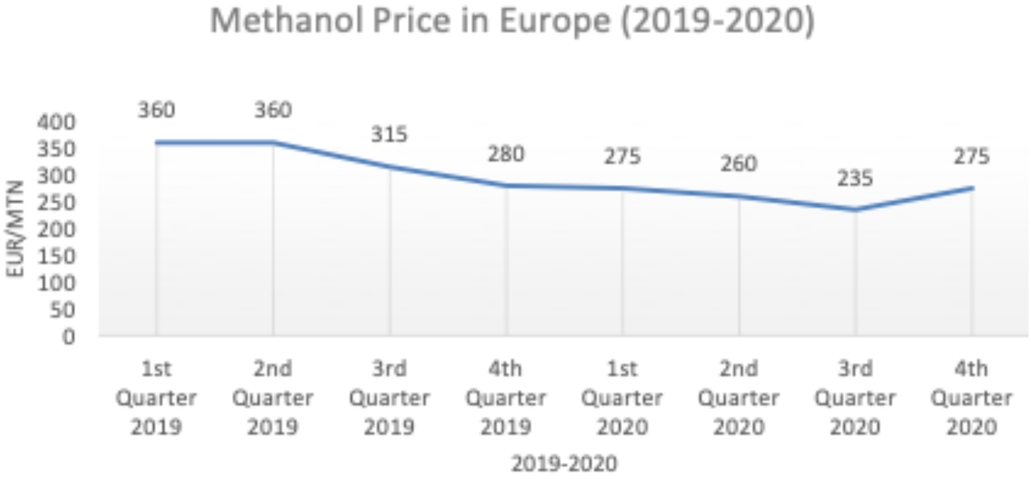


Figure 14: Price of methanol per / quarter (2019 – 2020) [39].

According to Methanex 2021 and the Independent Commodity Intelligence Service (ICIS), the price of methanol is stable every 3 months [40]. In these 3 months, it is price does not change at all [40]. Thus, on July 1, 2021, it is price was set until September 30 to be 410 euros/ton, about 350 pounds/ton [40]. Making the price increase noticeable [40].

Figure 15: Currently price of methanol 26 July 2021, time 19:17 [41].

According to trading on a contract for difference (CFD) that monitors the benchmark market for this commodity, methanol has climbed 193 CNY or 7.99% since the beginning of 2021 [43]. According to Trading Economics global macro models and analyst estimates, methanol is anticipated to trade at 2599.86 CNY by the end of this quarter [43]. On a spot and contract basis, this graphic compares worldwide methanol prices in important regional markets (United States Gulf Coast, Rotterdam, Coastal China). Shows that it will be take place from May 2018 to May 2021 [43].

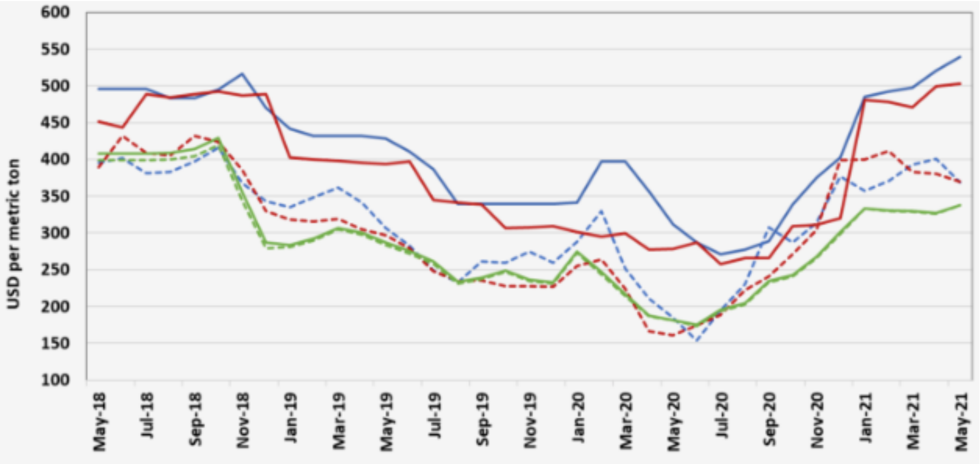


Figure 16: Methanol price – Global comparison [43].

2.9 Methanol as Marine Fuel

Undoubtedly, maritime transport has shown unprecedented interest in methanol in recent years, as an alternative fuel that has the ´possibility ´ to minimize emissions. There are more than 20 ships with methanol operation or in the order stage to be supplied with methanol [44]. The traditional fuel used by ships in international trade is HFO, shipping accounts for almost 85% of international trade, which 'translates' to 3% of all greenhouse gas emissions from sea routes [45]. In addition, the increase in specific areas of control ECA creates limits on the stricter legal framework for the use of low-sulfur fuels [46].

Due to the special way of producing methanol, when burned it does not produce gaseous pollutants because it has no carbon bonds [46]. Comparison of methanol with conventional fuels will reveal the enormous environmental benefits in terms of minimizing gaseous emissions [46]. Initially, emissions (CH_4, NO_X, N_20) are based on combustion conditions and temperature, while CO_2 - SO_X depend on the sulfur content of the fuel [47]. In the table below, you can see the forecast over a 100-year time horizon for the effect of gaseous pollutants on global warming [47].

Table 6: Global warming potential of N_20, CO_2 and CH_4 for 100-year time horizon [48].

EMISSIONS	**GLOBAL WARMING POTENTIAL (gCO_2 equivalents/g emissions)**
N_20	298
CO_2	1
CH_4	25

Actual CO_2 emissions are determined by the carbon content of the fuel, [48] so the percentage of carbon varies depending on the purity of the fuel [49]. When bio methanol is used, the CO_2 produced is substantially climate neutral and thus is not considered a gaseous pollutant [50]. When biomass-produced methanol is used, CO_2 is 'instantaneously removed' from the atmosphere, resulting in the immediate minimization of pollutants [51]. In the last 4 years, studies have been performed for the complete determination of NO_X produced by methanol [52].

The Wärtsilä-Vasa Company performed tests to compare emissions from methanol and HFO [52]. The findings revealed that there was a difference of 40% of emissions in the same engines with the same load volume [52]. Therefore, the use of methanol instead of fuel

HFO reduces NOx emissions by about 60% [53]. MAN Company conducted the same study and resulted in a reduction of NOx of about 30% compared to HFO [53]. There is no significant match between the two companies, but the results showed a promising reduction in NO_X with the use of methanol [53].

Every emission measurement is subject to uncertainty because we never know the combustion conditions and the details of the trip [53]. However, the 'Wärtsilä-Vasa Company' found that methanol fuel increases the amount of fuel and therefore the cost [53]. Shortly before the end, the results showed that the energy efficiency of marine engines with methanol remains relatively at the same optimum levels, with an insignificant factor being the extra lubricant consumption in the engine [53].

Table 7: Emissions factors for methanol combustion (Marine Engines) [54].

EMISSIONS TYPE	EMISSIONS FACTORS METHANOL (g/kWh)	EMISSIONS FACTORS HFO (g/kWh)	EMISSIONS FACTORS MGO (g/kWh)
N_20	0	0	0
CH_4	0	0	0
SO_X	0	1.8	0.144
NO_X	1.44	3.6	0.144
SO_2	248.4	272.2	270

Table 8: Total tons of emissions per year main engine [54].

EMISSIONS TYPE	METHANOL EMISSIONS FACTORS METHANOL (Tons/Year)	EMISSIONS FACTORS MGO (Tons/Year)
N_20	0	0
CH_4	0	0
SO_X	0	131.07
NO_X	104.85	262.14
SO_2	18,087.97	19,660,94

The figure shows the extraction from raw materials, the way fuel is produced, and of course the process of transport and storage, further analyzing the life cycle of fuels [55]. Of course, in the future, there is a possibility that coal levies will appear, and this will result in the fuels losing their attractiveness [55].

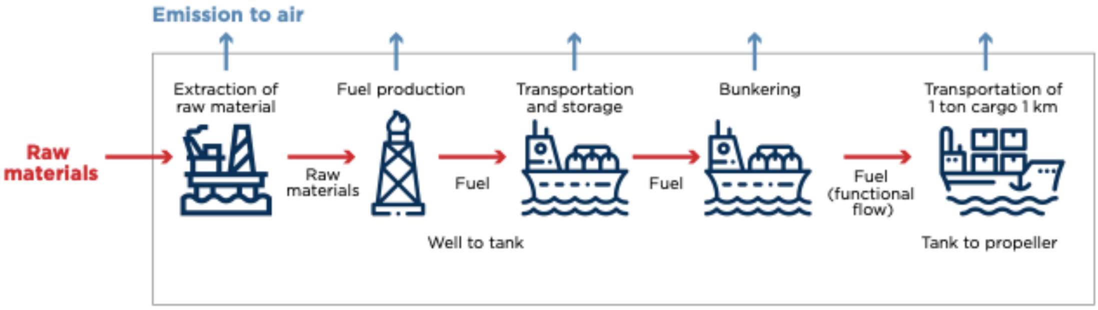


Figure 17: Life cycle analysis of marine fuel [55].

Furthermore, sulfur and carbon bonds are not contained in the molecular formula of methanol, this results in the absence of particles from combustion and thus reduces SOx [55]. However, methanol, because it has a low adiabatic flame, significantly reduces the temperature of the cylinder and this results in an additional reduction of NOx in the combustion process [55]. When the engine changes normally there will be changes, such as an increase in typical LCV 42.7 compared to methanol [56].

Table 9: Lower calorific values of fuel and specific fuel oil consumption conversion factor [56].

FUEL TYPE	LCV, kj/kg
Methanol	19,9
Diesel	42,7

3.0 Methodology

3.1 Analytical Methodology Conversion Main Engine

Initially, the theoretical conversion of the main engine will take place in the chemical tanker called ‘British Engineer’, Class max, IMO number 9724702 of the company ‘Bp Shipping Limited’ [60]. The ship was built by ‘Hyundai Mipo Dockyard’ in South Korea and was delivered to the shipping company in 2016 [59]. The reasons for choosing this ship are because in the last 12 months, it travelled a huge number of nautical miles which was 40,721 NM figure 31, this implies a huge volume of emissions and fuel consumption, which was studied in detail in the dissertation [60].

It was chosen because it travelled around the world, crossing protected environmental areas, increasing environmental pollution [61]. More specifically, this choice of ship was combined with the type of main diesel engine it uses, namely the construction company ‘MAN’ [59]. Finally, the additional reason for choosing this ship was that, according to the owner company, it uses 98% cargo capacity, which implies an additional increase in consumption and gaseous pollutants [59]. All the above are a perfect patchwork of study aimed at complete environmental protection.

Figure 18: British Engineer Vessel [58].

Table 10: Analytical description of vessel specifications.

SPECIFICATIONS OF VESSEL	
Former Names [59]	British Engineer
Vessel Type [60]	Chemical / Oil Products Tanker
Hull [60], Class [61]	Double Hull, Mariner Class
Cargo Type [59]	Oil and Products
IMO [60]	9724702
Operator [60]	Bp Shipping LTD
Classification Society [59]	Lloyds Register
Builder [60]	Hyundai Mipo Dockyard Co. (Korea)
Port of Registry [59], Flag [60]	Douglas Isle of Man, British
Operates [61]	Worldwide

Table 11: Details of tonnage vessels.

TONNAGE	
Length (OA) [61] – Length (BP) [61]	183.06 metres – 174.04 metres
Summer Draft [61]	12.2 metres
Depth [59] – Beam [60]	19.1 metres – 32.2 metres
Height [59]	48.95 metres
Dead weight [59]	45,999 tons (at summer draft)
Gross Tonnage, mt [61]	30,948 tons
Net Tonnage [60]	11,988 tons
Light Displacement [60]	11,319 tons
Top Speed [59]	15 Knots at 75% MCR
Capacity [59]	(98% Full) 52,692.22 cubic

Table 12: Details of cargo (Chemical tanker)

CARGO	
Liquid [61]	50,500
Segregated Ballast [61]	YES
IGS (Inert Gas System) [61]	YES
Cow (Crude Oil Washing) [61]	YES
Pump Description [61]	U – 12 – 600
Pump Rating [61]	600
Tanks [61], Grades [61]	14 - 6

Table 13: Description of room engine Chemical Tanker.

ENGINE	
Main Engine [60]	Man 6G50ME – B9.3(Tier II)/MCR 9,160kw
Auxiliary Engine [61]	Man 6L23 – 30H – 910 KW – STX
Engine Type [59], Engine Builder [61]	Diesel – MAN B&W
Cylinder Stroke [61], Cylinder Bore [61]	2,500 - 500
Total Power KW [61]	9,160
Total Power HP [61]	12,454

The scenario for the needs of the calculations, it was considered that the ship will complete the same number of nautical miles within a year, and of course it will cross SECA areas and future ECA areas. Furthermore, the scenario was adopted that the ship uses only the main engine, to completely minimize gas emissions and use only methanol fuel. To achieve this goal, some serious modifications must be made to the engine room. The suggested solutions that will be followed are summarized in table 15 and described in the following sections.

Table 14: Systems Installation

CONVERSION SYSTEMS INSTALLATION	
ECO – EGR →	6G 50ME – B 9.3 Main Engine [63]
SCR →	6L 23 / 30H – 910 Kw MAN [62]
6G 50ME – B 9.3 →	6G 50ME – LGI 9.5 Methanol [64]

According to the specific options, the methodology for selecting the ideal equipment installations will be studied in detail, as well as a detailed explanation of the system and its characteristics will be presented. So that this conversion methodology can minimize British Engineer emissions.

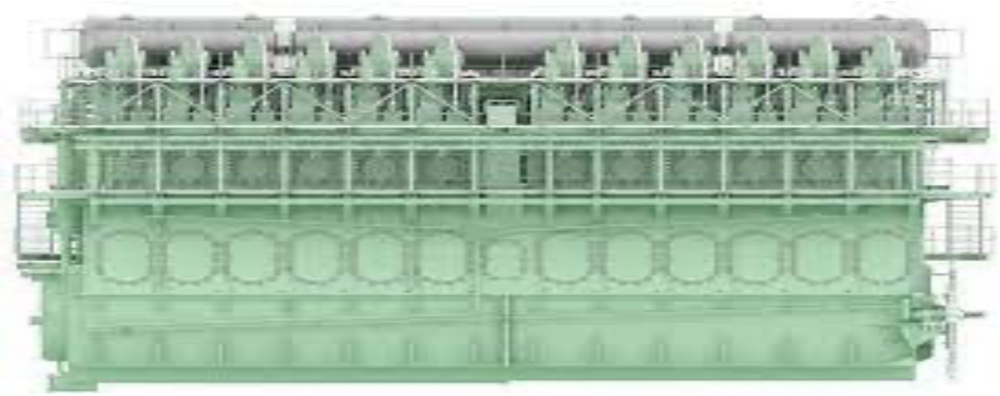


Figure 19: Methanol as marine fuel, Man engine [65]

SCR Installation (Diesel Generators)

According to the regulations (IMO Tier III) for NO_X, 'Man Energy Solution Company' provides advanced technological systems of installations, which can minimize gas emissions, meanwhile contributing to further cost improvement, such as the Selective Catalytic Reduction system. (SCR) [66]. This system is chosen because it is combined with the relatively low-cost table 26 and NO_X control in a closed loop [66]. In examples with "closed loop" applications on previous ships, the manufacturer always guarantees a stable NO_X conversion rate of approximately 30% [131]. This effectively ensures a longer catalytic life by avoiding ammonia emissions, contributing to reduced urea consumption [131]. Therefore, the exact amount of urea injected into the exhaust is ensured by the closed loop [66]. There is constant monitoring, and so it is characterized as a reliable system and shows zero slip of NH_3 and of course very little use of urea [66].

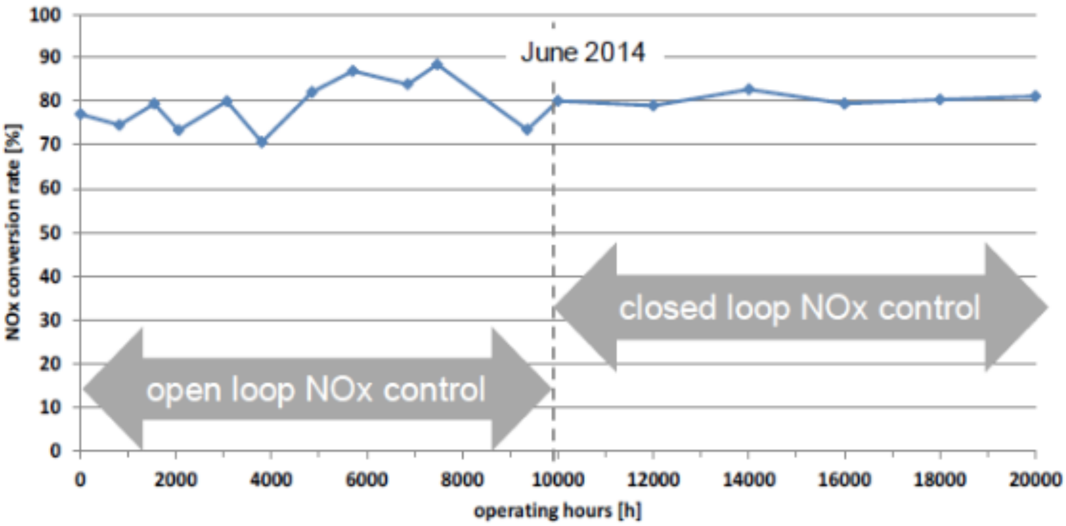


Figure 20: Closed versus open loop NOx conversion [67].

SCR System Description

A patchwork of components composes the SCR system ideal for installation, and at the same time optimal because it combines simultaneous monitoring [68]. It is structurally necessary that at the height of the hopper, the catalytic converter units present from the SCR reactor should be placed with utmost care [68]. Essentially, for water to be removed from the urea and homogenized with the flue gas to occur, the specific hydrolysis mixing unit must be methodically installed marginally before the reactor [68].

It is necessary to carry out a continuous check on the catalytic converter before and of course after, in this way there will be a thorough investigation of the exhaust gas temperature [68]. Therefore, in the above way there is a detailed and complete ‘picture’ of the parts at the corresponding output of the NO_X engine, and of course a complete picture of the engine load [68]. Finally, it creates a patchwork of urea intensity by collecting and analyzing important data including fuel consumption, necessary for future analysis [68].

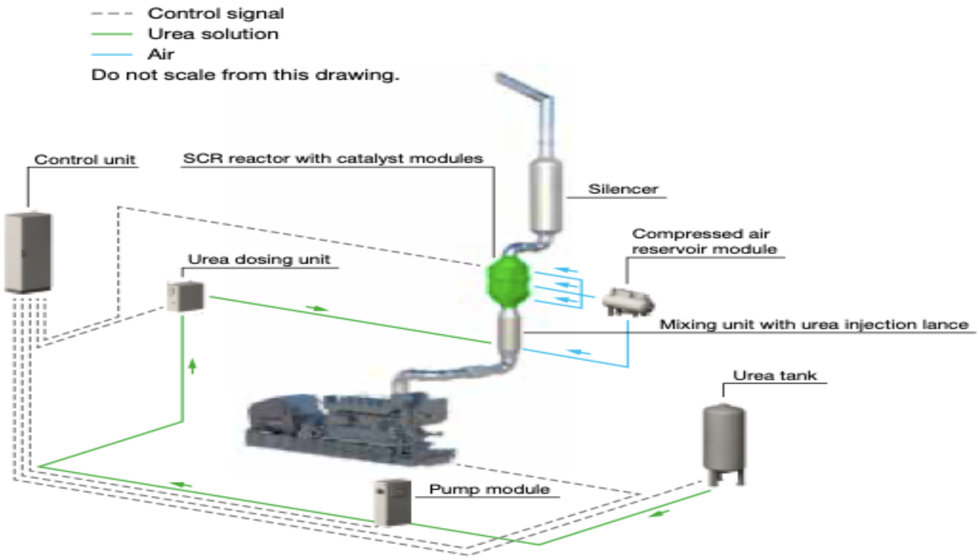


Figure 21: Man Gen – Set plant with full SCR system [68].

EGR Installation

In this conversion methodology, the ECO - SCR can always be installed according to the 'MAN Marine Engine 2nd Edition' [67]. In addition, the SFOC referring to the main engine, in stage III, uses SCR and specifically with a load requirement of 100% MCR, thus exceeding the company load requirement which is 98% table 59 and the size is smaller compared to the remaining [68]. In addition, the maintenance cost is 1,000,500 pounds for the EGR, while for the SCR = 7,450,700 pounds [70].

More specifically, the EGR is a system that offers solutions and combines the easy installation process because it is a less complex system, in full combination with very large motors, which also require less installation space [70]. In addition, the advantage is the particularly significantly lower OPEX, in full comparison with the SCR [70]. Due to methanol in our case, there is no additional effect that sulfur levels affect EGR OPEX [70].

ECO – EGR System Description

More specifically, the ECO -EGR can be characterized as a highly efficient exhaust gas recycling system with an ideal efficiency of 35% - 45% in the respective scan air receiver, and, in a category III operating number [70]. Therefore, for the air purifier to ideally acquire the optimal and alongside high thermal capacity, this specific process must be adopted methodically. Because in this optimal way, it displays an ideal low O_2 scan content.

Because there is an immediate replacement with CO_2 [70]. The EGR system has the optimal advantage, that it can cool and at the same time clean the recycled gases [70]. That is, with this process, the maximum combustion temperature is minimized, and this has as an ideal result the additional minimization of NOx, by measuring the exact O_2 content in the scan air, providing only accurate results [70].

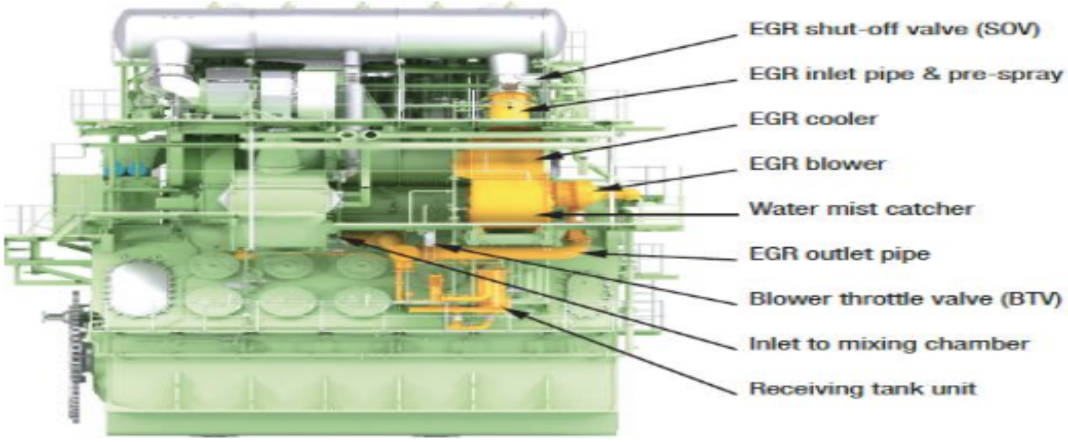


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Figure 22: Eco EGR system components / Man 2018 [71].

In our scenario, the ECO – EGR system will take the role of the air cooler. The system's configuration is shown, and it includes [71]:

Table 15: Description of system configuration [71].

SYSTEM CONFIGURATION	
'EGR Shut – Off Valve'	'Receiving Tank Unit'
'EGR Inlet Pipe and Pre – Spray'	'Blower Throttle Valve'
'EGR Cooler – Blower'	'Inlet to Mixing Chamber'
'Water Mist Catcher'	'Outlet Pipe'

It should be noted that this current system consists of a total of two strings according to the 'MAN B&W Emissions Project Guide' [68]. Initially, the EGR string with the main string, shows the optimal ability, when used, to be able to ideally direct the air purification process to the purification index [71]. The main chord then 'shows' a combination, which directs the cleaning air from the cleaning cooler to the supercharger, although in this way the exhaust and cylinder bypass resulting from the main chord is observed [68]. Finally, approximately 40% of the exhaust is safely directed to the EGR unit via the string capacity, before naturally entering the EGR fan inlet area [130].

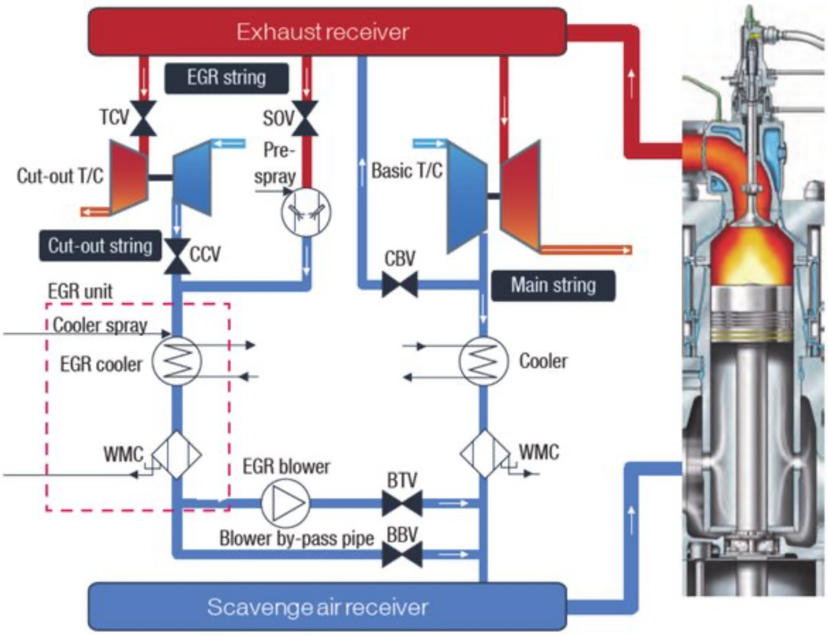


Figure 23: EGR process diagram (turbocharger cut – out matching) [72].

The EGR shut-off valve and the shift valve then activate the EGR string in parallel. Thus, for the complete absorption of the particles, the presence of water is necessary, so through the EGR chord and of course the EGR cooler the exhaust gases can pass to the purifier and thus the result is the optimal absorption of pollutants such as SO_X [72]. At the same time, for optimal system operation, the temperature of the gases is required to assist in the production of ammonium sulfate, which is an essential integral part of the SCR components [72].

Figure 25 shows the required minimum temperature, while in no case should the exhaust gases be ‘characterized’ by high temperature [72]. At 500 ^{0}C it shows approximately the maximum value it can show, the higher the greater the oxidation of ammonia is achieved resulting in the need to increase the dosage of urea in that section [77]. Finally, the catalytic fluid begins to melt in the temperature range of 500 – 550 ^{0}C, so for complete safety and protection of the installation on board, the exhaust gas temperatures must range from 300 - 500 ^{0}C [77].

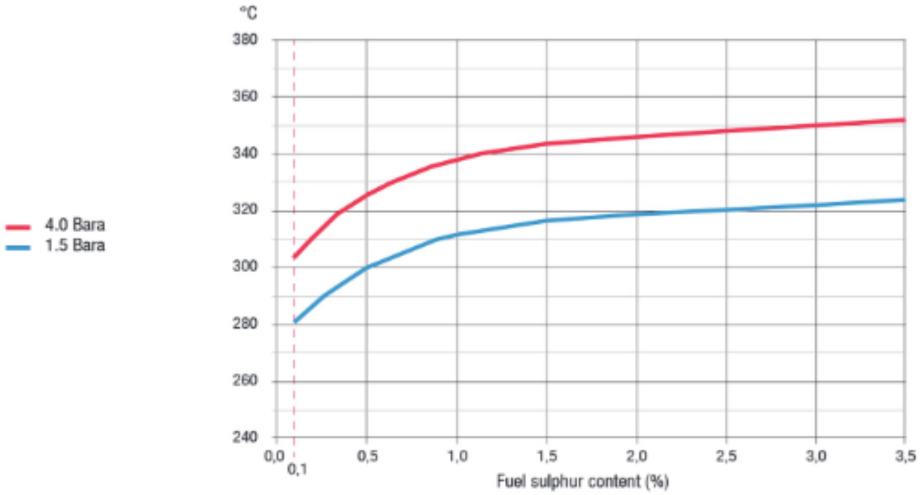


Figure 24: Temperatures required for SCR (sulphur concentration and exhaust gas pressure) [72].

In addition, to minimize the SFOC, it is necessary to bypass the roller that is effectively activated, to optimally increase the pressure of the cleaning air [73]. After that, the EGR unit should be placed on the side of the refrigerator, as shown in figure 73.

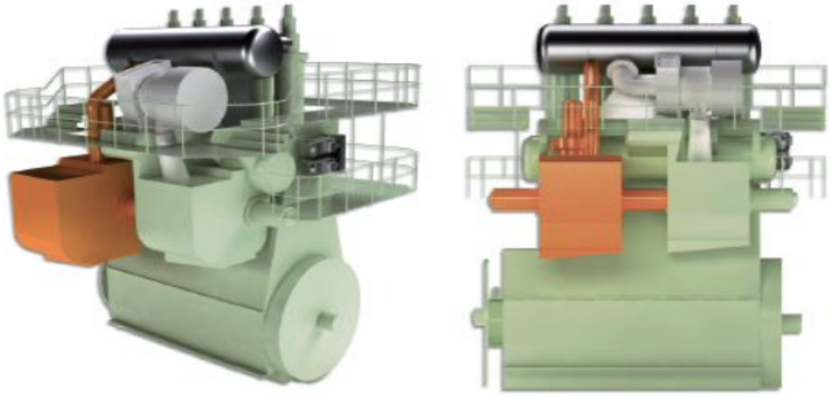


Figure 25: The turbocharger is positioned, while the EGR unit is mounted on the side [73].

Inter alia, for the optimal operation of the system, a patchwork of equipment as well as tanks is required, which must be efficiently placed in the main engine. In this case, the ECO-EGR can guarantee that the accumulated particles will be completely removed as well as the effective destruction of sulfuric acid will occur [73]. Essentially, it will be carried out by a special water treatment system that has the ideal combination of flow rate and pressure [73].

As part of the research, ‘Alfa Laval’ provides a promising system that meets 100% of Class III requirements [77]. Given the above, this is because it has a required special collection tank unit, which to carry out the optimal and at the same time proper drainage of the specific system, must be located under the EGR unit and there will be a substantial recirculation of wastewater [77].

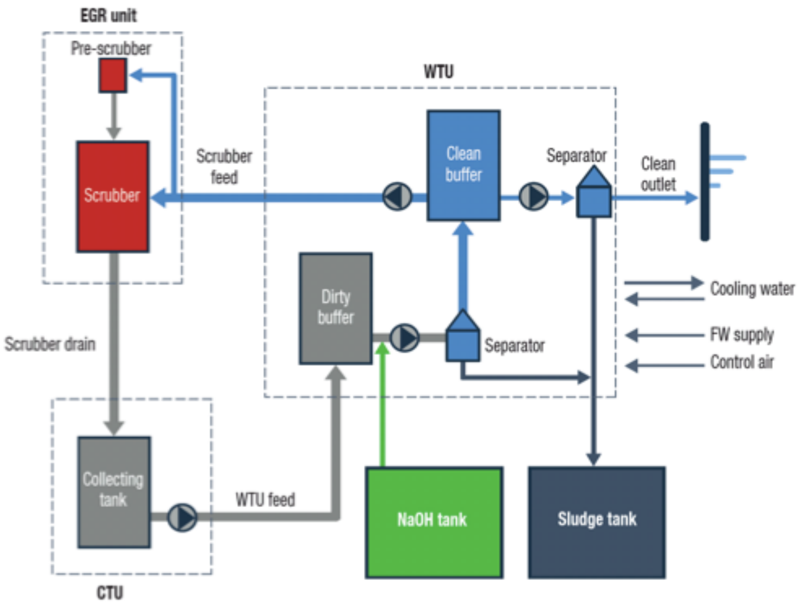


Figure 26: The WTS configuration for EGR engines is depicted schematically [74].

In addition, the 'different' provisions of the EGR are directly linked to the need to implement an independent WTS concept [74]. This phenomenon requires the presence of a special tank, which at the same time will have the ability to be used for the storage process [74]. In addition, it is vital to take place in the presence of a feed pump, which will be installed in the EGR system for proper cleaner drainage methodology, providing the required flexibility in the perfect configuration of the WTU [74].

Machinery and equipment analysis of ECO – EGR

Inter alia, in the part of the engine room and more specifically in the EGR system, special collection tanks will be placed where the dirty water coming from the treatment unit will be collected [75]. Therefore, if the feed pump is used, the effluent with a specific procedure will be discharged into the "Dirty Buffer Tank" system [75]. In this case, due to the theoretical conversion of the ship into methanol fuel, the components will have to be removed from the HFO treatment systems and, consequently, separators will be installed for the further special treatment of the dirty water from pure buffers [75].

After all, the additional role of the WTU is to be able to remove the excess EGR water that always arises in accordance with IMO rules. Consisting essentially of a quality "test" installation, pump, and special separation system [76]. In summary, it is necessary to maintain the temperature of about 45 ^{0}C in the stainless-steel tank, so as not to cause any harmful effects from the solution. Due to the use of methanol, there is no sulfur in the fuel, so optimally NaOH will be reduced [76].

Main Engine Conversion – Explanation

Undoubtedly, the methodology that took place in detail above was selected with investment criteria. Essentially, for the optimal combination of reducing gaseous pollutants with the necessary reduction of conversion costs, with the additional goal of future investment, table 26. According to the current component market, specific innovative components must be selected for further installation in the main engine, composing an ideal set that will make perfect use of the methanol fuel [66]. Initially, an ideal new cylinder head must be fitted to each of the cylinders [72].

Further, there are special methanol injectors, according to which these innovative components will be placed on all cylinder covers. It is necessary to spray the liquefied gas on the cylinder cover, through the installation process of the respective spray block [71]. Essentially, there is a set of components that contain a special control valve, in which the fuel injection (methanol) takes place [65]. Meanwhile, with the presence of additional valves at the outlet and the inlet of fuel with the combination of pipes that have a double wall, due to the high pressures they receive [68].

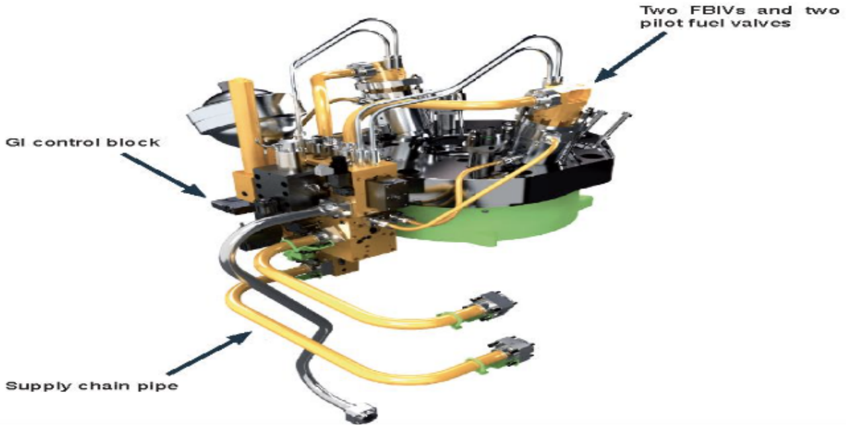


Figure 27: Fuel injectors and control block are installed in the cylinder lid Man 2019 [68].

Furthermore, the ideal injection pressure will be achieved if the corresponding pressure is increased in the fuel, and this can be achieved by combining a fuel booster valve with a power of approximately 300 bar [76]. However, the forthcoming increase in methanol caused by the synchronized infusion pressure will be around 550 bar [76]. For a patchwork of simultaneous and meanwhile sufficient cooling, combined with the optimal methodology of lubrication of the respective surfaces, the presence of a special sealing system is of utmost importance [67]. In conclusion, for operational needs it is necessary to have pressure to inside of the valve 'body', while maintaining the temperature at acceptable levels [68].

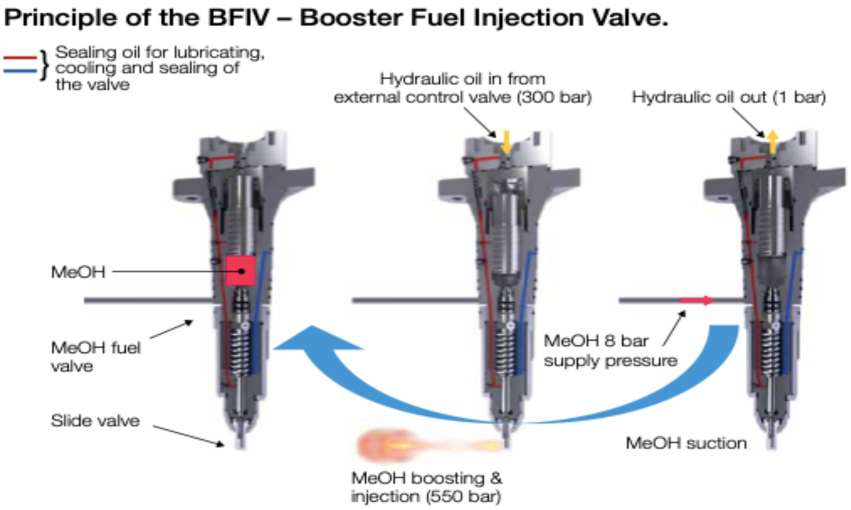


Figure 28: The working concept of the methanol booster fuel injector valve [76].

Further, methanol is characterized by a flash point of 11 ^{0}C, which is a particular problem with the marine safety field [76]. Meanwhile, double-walled walls have been selected for safety purposes, thus controlling potential leaks, facing serious future problems [65]. If a relatively high concentration of vapor occurs in the double-walled area, then the sensors that monitor the operation of the methanol will stop it "instantly" [67]. Thus, the conversion engine will be rapidly cleaned of methanol, and backup fuel will be used for complete safety [76].

Main Engine Supply System

Man Energy, in partnership with Alfa Laval´, developed a methanol-powered engine system [77].

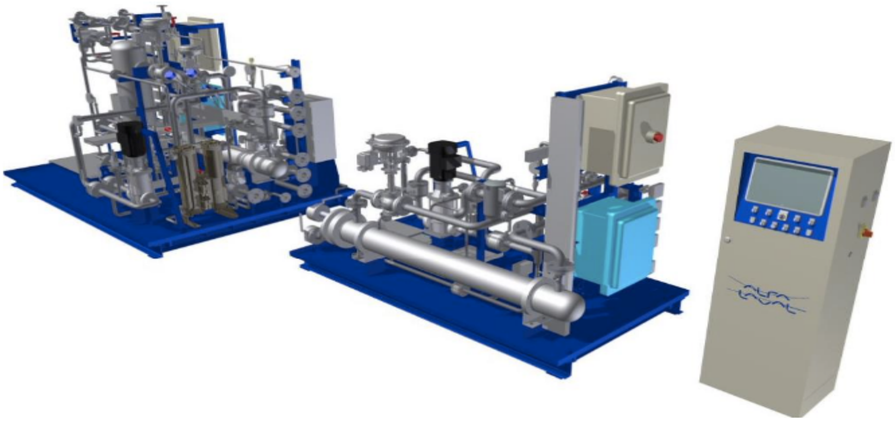


Figure 29: System by 'Alfa Laval' for methanol [77].

This system satisfies factors such as temperature increase, flow increase and of course pressure [77]. At 8 bar the pressure is expected to be, during the supply process, coming from the specially constructed alternative fuel storage tank, in addition to the corresponding circulating pump the pressure is expected to increase to 10 bar [77]. Therefore, the above process aims to liquefy the methanol so that the engine can handle a set of pressures that may reach 50 bar [77].

In the cooling system that is necessary for the ideal low temperature of the engine room, methanol is obtained at the optimum temperature, through an innovative cooling-heat system installed in the circulation circuit [78]. At the same time, the main fuel valve is connected to the engine and to the valve line, which is connected to the supply of nitrogen used for cleaning [79]. Due to the theoretical transformation, the whole system must be installed in the engine room, with double-walled pipes [79].

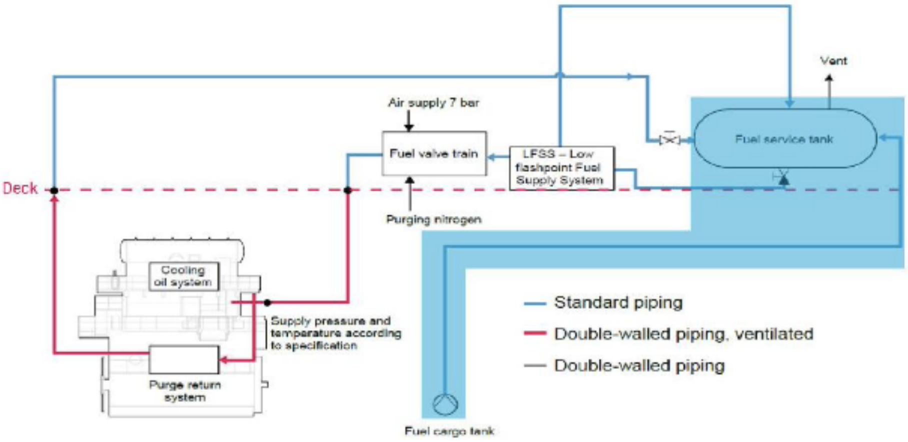


Figure 30: Transfer system of methanol [68].

In conclusion, the drainage of the respective fuel pipes is an integral process, in fact the ‘pure’ methanol from the inner pipes in the engine room is designed to return to the tank (methanol) in liquid form [68]. When there is a momentary shut down for a relatively long time, then a phase change in the standby state of the methanol takes place immediately, which is necessary for the optimal operation of the ship's engine [68].

3.2 Analytical Methodology Calculations Emissions

3.2.1 Methodology Calculations Emissions Formula 1

Undoubtedly, this formula for calculating emissions has chaotic differences compared to the other 2 formulas. Initially, a patchwork of data was needed, combining the total of the cruising hours, the average power of the ship during the naval miles, the cargo of the ship and finally the specific year of construction of the ship [132]. However, other data such as fuel consumption, engine type and emissions factors were extremely important data, required with full accuracy, to determine in detail the total emissions generated by the ship's engine for existing data [132]. The basic equation used for estimating emissions from British Engineer chemical tanker is [132]:

‘E0y, t, om, e = Σ (Pop t * EF e, om, f *Hrs om, t*VP om, t * %Load om, t)’Equation 1 [132]

Where:

- ‘E = Pollutant Specific Emissions (Tons/Year NOx, SOx, etc.).’
- ‘Pop = Pollutant of Ocean – Going Vessel (Ship Type).’
- ‘EF = Emission Factor (Engine Type and Fuel - Units glkw – hr).’
- ‘Hrs = Average Annual use in hours (Operating Mode and Vessel Type).’
- ‘VP = Average Power (Operating Mode and Vessel Type).’
- ‘Load % = Average Engine Load (Operating Mode and Vessel Type).’
- ‘Y = Inventory Year.’
- ‘Om = Operating Mode.’
- ‘T = Vessel Type (Chemical Tanker, Bulk Cargo, etc.).’
- ‘F = Fuel (Methanol, Heavy Fuel Oil, etc.).’

Each of these elements, and how they were incorporated into ship emission estimates in the ocean, are discussed below. The emissions that will be calculated will investigated two case scenarios. The first will estimate the ships emissions when it uses HFO as a fuel and the second scenario will estimate the emissions when the ship is fueled only with methanol.

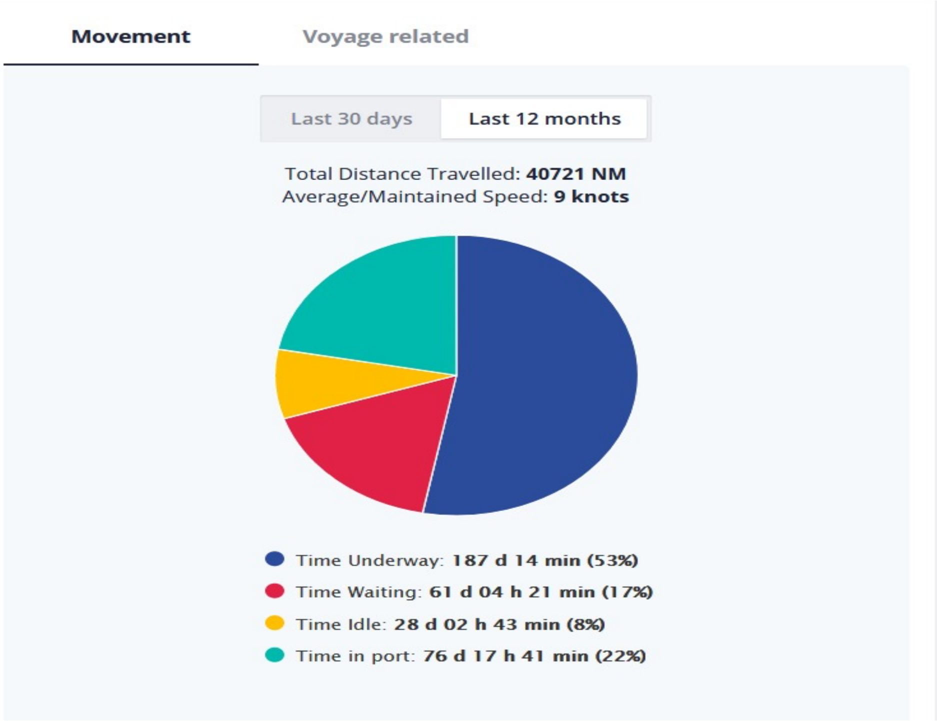
Pop = 1 Vessel, as we only estimate the emissions of the British Engineer.

EF = Emission factors. Must know the speed that the ship is moving. During the evaluation of the data, it was found that the maximum velocity of the ship is 15 knots [59] and the average speed 9 knots [60]. However, because of that, assumed that 15 knots are the high speed and 9 knots it is the medium speed of the ship. Additionally, created a range of the speed based on this assumption, as it is presented below:

Table 16: Detailed gradation of speed limits.

LIMITS SPEED - KNOTS		
For Slow	5 knots	(0 – 5 knots)
For Medium	9 knots	(5 – 10 knots)
For High	15 knots	(10 – 15 knots)

Hrs: Essentially, for the previous year, the ship operated for 187 days and 14 minutes. As Hrs represents the average annual use in hours when the ship is operating, we assume that the 14 minutes are a negligible number for the calculations. So, Hrs = 187 days = 4488 hours in operation mode.



Total Distance Travelled: **40721 NM**
Average/Maintained Speed: **9 knots**

- ● Time Underway: **187 d 14 min (53%)**
- ● Time Waiting: **61 d 04 h 21 min (17%)**
- ● Time Idle: **28 d 02 h 43 min (8%)**
- ● Time in port: **76 d 17 h 41 min (22%)**

Figure 31: British Engineer movement last 12 months [60].

VP: The average power of the ship is 9,160 kw [59].

Load %: The load is 98% [59].

Year: 2017 [61].

T: Chemical / Oil Tanker [59].

Scenario 1: Heavy Fuel Oil (Formula 1)

(CO_2)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = CO_2 = 277.2 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t) = (1 * 277.2 g/kWh *4,488 Hours * 9,160 kW * 98%) = (1 * 277.2 g * 4,488 * 9,160 * 0.98) =1.116779989 * 10^{10} g

  E y, t, om, e (CO_2) = 11,677.62 tons / year

(CH_4)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = CH_4 = 0 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t) = (1 * 0 g/kWh *4,488 Hours * 9,160 kW * 98%) = 0 g

  E y, t, om, e (CH_4) = 0 tons / year

(N_2O)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = N_2O = 0 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t) = (1 * 0 g/kWh *4,488 Hours * 9,160 kW * 98%) = 0 g

  E y, t, om, e (N_2O) = 0 tons / year

(NO_X)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = NO_X = 3.6 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t)= (1 * 3.6 g/kWh *4,488 Hours * 9,160 kW * 98%) = (1 * 3.6 g * 4,488 * 9,160 * 0.98)= 145,036,362.2 g

  E y, t, om, e (NO_X) = 145.03 tons / year

(SO_X)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = SO_X = 1.8 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t)= (1 * 1.8 g/kWh *4,488 Hours * 9,160 kW * 98%) = (1 * 1.8 g * 4,488 * 9,160 * 0.98)= 72,518,181.12 g

  E y, t, om, e (NO_X) = 72.51 tons / year

Scenario 2: Methanol (Formula 1)

(CO_2)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = CO_2 = 248.4 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t)= (1 * 248.4 g/kWh *4,488 Hours * 9,160 kW * 98%) = (1 * 248.4 g * 4,488 * 9,160 * 0.98) = $1.000750899 * 10^{10}$ g

  E y, t, om, e (CO_2) = 10,007.5 tons / year

(CH_4)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = CH_4 = 0 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t) = (1 * 0 g/kWh *4,488 Hours * 9,160 kW * 98%) = 0 g

  E y, t, om, e (CH_4) = 0 tons / year

(N_2O)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = N_2O = 0 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t) = (1 * 0 g/kWh *4,488 Hours * 9,160 kW * 98%) = 0 g

  E y, t, om, e (N_2O) = 0 tons / year

(NO_X)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = NO_X = 1.44 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t) = (1 * 1.44 g/kWh *4,488 Hours * 9,160 kW * 98%) = (1 * 1.44 g * 4,488 * 9,160 * 0.98) = 58,014,544.9 g

  E y, t, om, e (NO_X) = 58.01 tons / year

(SO_X)

- $P_{opt} = 1$, $EF_{e,om,f}$ = emission factor = SO_X = 0 g/kWh
- Hours = 4,488 hours
- $VP_{om,t}$ = 9,160 kW, Load = 98%

  Equation 1:E y, t, om, e = Σ (Pop t * EF e, om, f * Hrs om, t * VP om, t * %Load om, t)= (1 * 0 g/kWh *4,488 Hours * 9,160 kW * 98%) = 0 g

  E y, t, om, e (SO_X) = 0 tons / year

3.2.2 Methodology Calculations Emissions Formula 2

The following equation was used to calculate the annual emissions of gaseous pollutants. Fuel consumption data is obtained in real time [133]. For this reason, this method can be characterized as the most reliable and alongside more detailed way of calculating gaseous emissions [133]. The following equation shows [133]:

‘E Trip,I,j,m = Σ (FC j,m,p * EF I,j,m,p)’[133], Equation 2

Where:

- ‘E_{Trip} = Emission Complete trip (tons)’
- ‘FC = Fuel Consumption (tons)’
- ‘EF = Emission Factor (kg/tons)’
- ‘Í = Pollutant’
- ‘j = Engine Type (slow – medium - high speed)’
- ‘m = Fuel Type (HFO, methanol, etc.)’
- ‘p = Phase of Trip’

As we can see in equation 2, this method requires the fuel consumption data and the corresponding emission factors. In addition, for the needs of a detailed result from the total emissions, it is necessary to consider the fuel consumption data from the modes of travel or otherwise an average price [133].

Scenario 1: Heavy Fuel Oil (Formula 2)

(CO_2)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = CO_2 = 277.2 g/kWh
- Unit Conversion from g/kWh to (kg/tons) So, 1kWh = 0.00086 tons. 1gr = 0.001 kg. CO_2 : 277.2 g/kWh =277.2 * 0.001 kg/kWh = 0.2772 kg / kWh = 0.2772kg/0.00086tonnes, CO_2 = 322.3255 kg /tons

  Equation 2: $E_{Trip,I,j,m} = \Sigma (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 322.3255 kg/tons = 1,755,455.9 kg = 1755.4459 tons

  $E_{Trip,I,j,m}$ (CO_2) = 1,755.4459 tons

(CH_4)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = CH_4 = 0 g/kWh

  Equation 2: $E_{Trip,I,j,m} = \Sigma\ (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 0 tons = 0 tons

  $E_{Trip,I,j,m}$ (CH_4) = 0 tons

(N_20)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = N_20 = 0 g/kWh

  Equation 2: $E_{Trip,I,j,m} = \Sigma\ (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 0 tons = 0 tons

  $E_{Trip,I,j,m}$ (N_20) = 0 tons

(NO_X)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = NO_X = 3.6 g/kWh
- Unit Conversion from g/kWh to (kg/tons) So, 1kWh = 0.00086 tons. 1gr = 0.001 kg.

  CO_2 : 3.6 g/kWh =3.6 * 0.001 kg/kWh = 0.0036 kg / kWh = 0.0036kg/0.00086tonnes

  CO_2 = 4.18 kg /tons

  Equation 2: $E_{Trip,I,j,m} = \Sigma\ (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 4.18 kg/tons = 22,765.07 kg = 22.76507 tons

  $E_{Trip,I,j,m}$ (CO_2) = 22.76507 tons

(SO_X)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = SO_X = 1.8 g/kWh
- Unit Conversion from g/kWh to (kg/tons) So, 1kWh = 0.00086 tons. 1gr = 0.001 kg.

  CO_2 : 1.8 g/kWh =1.8 * 0.0018 kg/kWh = 0.0018 kg / kWh = 0.0018kg/0.00086tons

  CO_2 = 2.09 kg /tons

  Equation 2: $E_{Trip,I,j,m} = \Sigma\ (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 2.09 kg/tons = 11,382.53 kg = 11.38253 tons

  $E_{Trip,I,j,m}$ (CO_2) = 11.38253 tons

Scenario 2: Methanol (Formula 2)

(CO_2)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = CO_2 = 248.4 g/kWh
- Unit Conversion from g/kWh to (kg/tons) So, 1kWh = 0.00086 tons. 1gr = 0.001 kg.

  CO_2 : 248.4 g/kWh =248.4 * 0.001 kg/kWh = 0.2844 kg / kWh = 0.2484kg/0.00086tons

  CO_2 = 288.83720 kg /tons

  Equation 2: $E_{Trip,I,j,m} = \Sigma (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 288.83720 kg/tons = 1,573,062.27kg = 1,573.06227 tons

  $E_{Trip,I,j,m}$ (CO_2) = 1,573.06227 tons

(CH_4)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = CH_4 = 0 g/kWh

  Equation 2: $E_{Trip,I,j,m} = \Sigma (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 0 tons = 0 tons

  $E_{Trip,I,j,m}$ (CH_4) = 0 tons

(N_20)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = N_2O = 0 g/kWh

  Equation 2 : $E_{Trip,I,j,m} = \Sigma (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 0 tons = 0 tons

  $E_{Trip,I,j,m}$ (N_2O) = 0 tons

(NO_X)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = NO_X = 1.44 g/kWh
- Unit Conversion from g/kWh to (kg/tons) So, 1kWh = 0.00086 tons. 1gr = 0.001 kg.

  NO_2 : 1.44 g/kWh =1.44 * 0.001 kg/kWh = 0.`00144 kg / kWh = 0.00144kg/0.00086tons

  NO_2 = 1.6744 kg /tons

  Equation 2 : $E_{Trip,I,j,m} = \Sigma (FC_{j,m,p} * EF_{I,j,m,p})$ = 5,446.19 tons * 1.6744 kg/tons = kg = 9,119.1kg = tons

  $E_{Trip,I,j,m}$ (NO_2) = 9.1191 tons

(SO_X)

- FC = fuel consumption = 5,446.19 tons
- EF = emission factor = SO_X = 0 g/kWh

  Equation 2 : $E_{Trip,I,j,m} = \Sigma (FC_{j,m,p} * EF_{I,j,m,p}) = 5{,}446.19$ tons * 0 tons = 0 tons

  $E_{Trip,I,j,m}$ (SO_X) = 0 tons

3.2.3 Methodology Calculations Emissions Formula 3

Undoubtedly, there are differences between the calculation formulas, for this reason, 3 completely different formulas were chosen so that there is a wider range of comparison of results. Essentially, Formula 3 applies if we use detailed power data from the ship's engine [134]. In addition, for the purposes of the calculations it is necessary to have the data of the cruising time from the ship, for a period of study and finally the power of the main engine [134].

E Trip,I,j,m = Σ (Tp Σ(Pe * LF e * EF I,e,j,m,p))' [134] , Equation 3

Where:

- 'E_{Trip} = Emission Complete Trip (tons)'
- 'EF = Emission Factor (kg/kWh)'
- 'LF = Engine Load Power (%)'
- 'P = Engine Nominal Power (kW)'
- 'T = Time (hours)'
- 'e = Engine Category'
- 'i = Pollutant'
- 'j = Engine Type (Slow – Medium - High Speed)'
- 'm = fuel type (HFO, Methanol, etc.)'
- 'P = Phase of Trip'

Scenario 1: Heavy Fuel Oil (Formula 3)

(CO_2)

- EF = emission factor = CO_2 = 277.2 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$ = 4,488 hours (9,160 (kw) * 100% * 277.2 g/kWh) = 11,395,714,176 g = 11,395.7 tons

$E_{Trip,I,j,m}$ (CO_2) = 11,395.7 tons

(CH_4)

- EF = emission factor = CH_4 = 0 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$=4,488 hours(9,160(kw)*100%*0 g/kWh)=0 tons

$E_{Trip,I,j,m}$ (CH_4) = 0 tons

(N_2O)

- EF = emission factor = N_20 = 0 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$=4,488 hours(9,160(kw)*100%*0 g/kWh)=0 tons

$E_{Trip,I,j,m}$ (N_20) = 0 tons

(NO_X)

- EF = emission factor = NO_X = 3.6 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma$ (Tp Σ(Pe * LF_e * $EF_{I,e,j,m,p}$)) = 4,488 hours (9,160 (kw) * 100% * 3.6 g/kWh) = 147,996,288 g = 147.99628 tons

$E_{Trip,I,j,m}$ (CO_2) = 147.99628 tons

(SO_X)

- EF = emission factor = SO_X = 1.8 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24 hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma$ (Tp Σ(Pe * LF_e * $EF_{I,e,j,m,p}$)) = 4,488 hours (9,160 (kw) * 100% * 1.8 g/kWh) = 73,998,144 g = 73. 99814 tons

$E_{Trip,I,j,m}$ (CO_2) = 73.99814 tons

Scenario 2: Methanol (Formula 3)

(CO_2)

- EF = emission factor = CO_2 = 248.4 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma$ (Tp Σ(Pe * LF_e * $EF_{I,e,j,m,p}$)) = 4,488 hours (9,160 (kw) * 100% * 248.4 g/kWh) = 10,211,743,872 g = 10,211.74387 tons

$E_{Trip,I,j,m}$ (CO_2) = 10,211.743887 tons

(CH_4)

- EF = emission factor = CH_4 = 0 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$=4,488 hours(9,160(kw)*100%*0 g/kWh)=0 tons

$E_{Trip,I,j,m}$ (CH_4) = 0 tons

(N_2O)

- EF = emission factor = N_20 = 0 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$=4,488 hours(9,160(kw)*100%*0 g/kWh)=0 tons

$E_{Trip,I,j,m}$ (N_20) = 0 tons

(NO_X)

- EF = emission factor = NO_X = 1.44 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$ = 4,488 hours (9,160 (kw) * 100% * 1.44 g/kWh) = 59,198,515.2 g = 59.19851 tons

$E_{Trip,I,j,m}$ (CO_2) = 59.19851 tons

(SO_X)

- EF = emission factor = SO_X = 0 g/kWh
- LF = 100%
- P = engine nominal power = 9,160 (kW)
- T = 187 days = 187 * 24 hours = 4,488 hours

$E_{Trip,I,j,m} = \Sigma (Tp\ \Sigma(Pe * LF_e * EF_{I,e,j,m,p}))$ = 4,488 hours(9,160(kw)*100%*0g/kWh)= 0 tons

$E_{Trip,I,j,m}$ (CO_2) = 0 tons

3.3 Conversion Cost

It is widely believed that each construction project consists of a patchwork of different aspects which in many cases are the technical point of view, the legislation, the environmental and of course the financing with the construction cost. Regarding the financial cost of the project for the modification of the main engine, we should refer to some categories of costs. According to the costs from the current industrial market as well as the economic study of the specific case studied.

The following cost categories were studied: the conversion cost in combination with the operating cost, the cost as fuel for the use of Methanol and a detailed plan was taken regarding factors such as Investment Cost Today = 2,307,414 pounds table 26, Profit Per Year = 1,289,365 pounds table 28, Breakeven of Investment = 1,6 year (1,6 year continues trip or 24 months normal trip) a Business Plan for the Next 29 Years table 28. In addition, the explanation of conversion costs will be presented because they are data that are necessary for the provision and analysis of capital values.

Table 17: Analytical methodology for calculations conversion cost

CALCULATIONS (CONVERSION COST)
1) We must recognize that engine conversion is a demanding task and assume that a team of 10 engineers is needed and estimate a time of 30 days. According to Boat Safe, it takes about 8,000 hours of very hard personal work for an engine conversion and review [122]. Thus, 8,000 hours / 24 hours = 333.33 days, therefore with 10 engineers we need about 33 days, for the needs of the calculations 30 days were assumed. According to PayScale, the average mechanical engineer salary in the United Kingdom is 31,984 pounds per year [80]. According to the above 10 * 31,984 = 319,840 pounds per year, so 319,840 / 12 = 26,653 pounds per month. Design / Survey / Engineering Study = 26,653 pounds.
2) In any case, it is necessary to have a system for its approval and meanwhile its supervision [123]. The choice in this project is the classification society especially (DNV) –GL. the coordinator and supervisor of the project has a salary of 200,000 / year [81]. If we assumed that the project would last 1 month, then we assume that it will be valid 200,000 / 12 = 16,666 pounds per month. So, Classification Society Approval = 16,666 pounds.

3) We assume that a subcontractor company is needed that will be responsible for modifying the project. According to (CMU Company) the cost for a temporary job (30 days) is about 16,389 pounds [82]. Labor Subcontractor Firm = 16,389 pounds.
4) According to the research, a patchwork of statistics was found which states that Chemical Tankers have a daily gain of about 6,895 pounds. Furthermore, it is necessary to calculate the net income that the charter company does not hypothetically receive. So, 6,895 * 30 = 206,85pounds [83].
5) The expected engine repair and required work costs = 257,542 pounds [26].
6) The capital required for the fuel supply system is a huge expense, it involves costly labor and therefore costs 429,241 pounds [26].
7) The EGR system that we installed has a price that reaches the amount = 708,731 pounds [85].
8) The SCR installation system costs 345,471 pounds [84].
9) The process of requirements provided by shipyards is about 430 pounds per day, so 430 * 30 = 12,900 pounds is the required capital [83].
10) In addition, the new installation of double wall piping costs about 230,000 pounds [26].
11) A necessary expense is the provision of safe solutions which in the case of Chemical Tankers is charged with 1,186 pounds per day, so 30 * 1,186 = 35,580 pounds [86].
12) The price for performing the work of the fuel tank substrates is equal to 11 pounds per m^2. According to the characteristics of the ship of our choice the surface is equal to = 1460, so 1460 * 11 = 16,060 pounds [87].

Then, the operating cost after the conversion of the main engine, translates as operating cost based on the operation of the methanol fuel [60]. We must consider the use of fuel for its mode of operation and based on the annual nautical miles performed by the ship of our choice, as well as the specific set of days that has been operating for the last 12 months [60].

In addition, we can calculate the fuel consumption and at the same time the methanol consumption needed for the respective nautical miles figure 32. Therefore, we have the way to calculate the operating cost after the conversion of the main engine and of course the cost of Methanol with the current financial data and standards set by the end of September 2021 [40].

More specifically, following the study of Ellis and Svanberg 2018 [88], to meet the energy needs required by a ship in case it uses methanol fuel is almost twice the amount of any type of heavy fuel oil, because of this for the needs of the calculations we will assume exactly twice the amount of methanol fuel [88]. The calculation methodology for the total fuel consumption used by the ship of our choice is presented in table 19 and according to [88].

Table 18: Analytical methodology for calculations fuel consumptions.

CALCULATIONS (FUEL CONSUMPTION)

1) Total Distance Travelled Last 3 Months: 3,021 NM = 5,594.89 km

Average / Maintained Speed: 10.3 knots

2) Total Distance Travelled Last 12 Months: 40,721 NM

Average / Maintained Speed: 9 knots = 75,415.29 km

Distances and speeds are obtained from [60].

3) British Engineer Consumption per kilometre [89], [90]

$$\text{HFOC} = \frac{SR*\%mrc*P}{p*S} \text{, Equation 4}$$

Where:

- P: Installed Engine Power
- SR: Standard rate of fuel consumption: 0.2 Kgh / km
- S ferry Speed: 9 knots = 16.67 km / hour
- p_{HFO} = Density of HFO: 1010 kg/m^3
- % mcr = maximum output that can be produced under normal conditions

For 1 year:

HFOc = 0.2kg/hour * 75% * 9,160kw / 1010kg/m^3 * 16.67 km/hour = 0.08160 m^3 / km = 81,6 L/km

So,

For 1 Km we need 81.6 L

FOR (40,721 NM) 75415.29 km = x?

X = 81.6 L * 75415.29 km = 6,153,887.82 L

Essentially, the above calculations showed that the ship for the last 12 months had an energy fuel need of 6,153,887.82 L of heavy fuel oil. According to the data collected from the survey, the nautical miles were traveled at an average speed of 9 knots = 16.67 km / hour, in addition the ship of our choice had time in port = 76 days 17 hours 41 minutes (22%), time idle = 28 days 2 hours 43 minutes (8%), time waiting = 61 days 4 hours 21 minute (17%) and time underway 187 days 14 min so the nautical miles were calculated for the 'underway days'. Therefore, the energy needs of methanol are 2 * 6,153,887.82 L = 12,307,775.65 L.

Table 19: Analytical methodology for calculations (Conversion unit)

CALCULATIONS (CONVERSION UNIT FROM LITRES TO TONS)
1) Density of Methanol = 790 kg/m^3 [Table 5], so 12,307,775.65 L of methanol = 9,723.14 tons.
2) Tons of methanol required = 9,723.1427 tons.
3) Methanol Price (currently) = 350 pounds/ton [40].
4) Cost of methanol per year = 350 per/tons * 9,723.14 tons = 3,403,099.94pounds/year.
5) According to the research, the current price of heavy fuel oil = 230,832 pounds / ton [91], so 6,153,887.82 L heavy fuel oil conversion to ton = 5,446.19 tons (Density 885 kg/m^3), so cost of heavy fuel oil = 230.832 pounds/tonne * 5,446.19 tons = 1,257,154.93 pounds/year.
6) Annual different cost between heavy fuel oil and methanol = 3,403,099.94 pounds/year – 1,257,154.93 pounds/year = 2,145,945.01 pounds/year, are presented in graphs 17.

3.4 Scenario 1: Production of Methanol from Biomass

According to Report Buyer Methanol, during the Covid-19 crisis, the global methanol market is estimated at 103.6 million tons in the year 2020-2021 and has the potential to reach 136.2 million tons by 2027 [97]. In addition, according to Statista, the global production capacity of Methanol by 2030 is expected to be around 311 million tons [98]. In fact, these 'numbers' reflect the obvious global interest in Methanol production in the coming years.

To attract new investors in the methanol sector as a marine fuel, propose in scenario 1 its production from biomass products. More specifically, according to Statista in 2020 in the United Kingdom alone there were about 2.246 trillion units of energy derived from biomass and in the United States of America about 4.532 trillion units of energy respectively [99]. Due to the large volume of waste, propose the production of Methanol to come from any kind of biomass production [100].

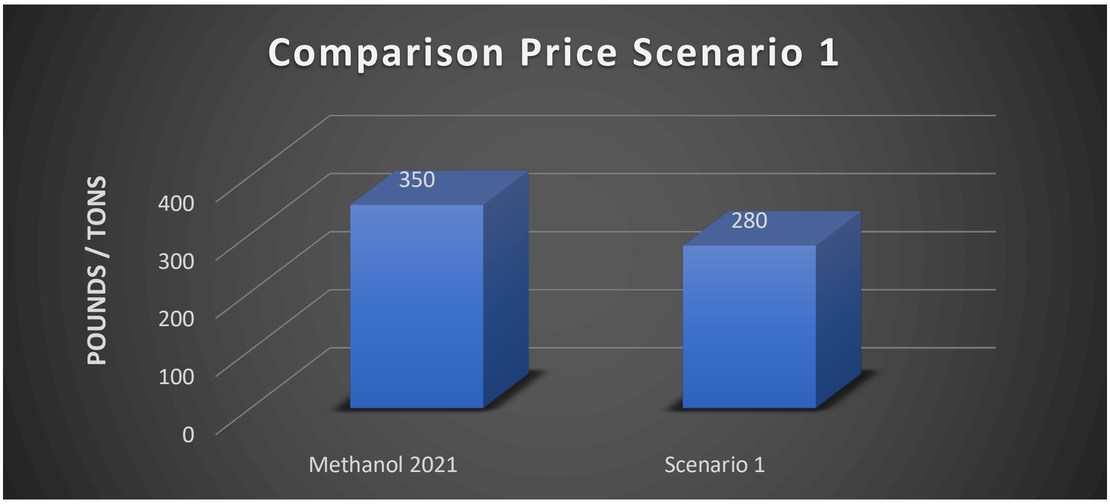
Given the above, recognize major stakeholders in the field of methanol production such as: Chemrec AB, BioMCNOBV Netherlands, BIOMASS Technology Group BV, ZSW and Choren Industries of Biomass Technology have the necessary dynamics to process the abundance of available waste from any material (wood and forest residues, livestock waste, food industry waste etc. [100] which can be processed to produce Methanol [100]. In addition, within the limits of healthy competition, propose funding from global and European green economic programs related to bioenergy, advanced biofuels, and renewable fuels [100].

Starting with this position, with funding based on a financial strategy for the exploitation of methanol for the next 5 years to support research and at the same time the development of technology for the development of methanol projects [100]. In such a case, a huge amount of biomass will be utilized as an energy source combining the various thermochemistry and biochemical processes for optimal energy use and minimization of production costs [101].

However, a wide variety of biomass can be grown and obtained in any geographical location depending on the environmental conditions prevailing there, would not pose a significant economic problem for storage and transport in terms of profit [101]. In addition, biofuels are economically viable, renewable, have minimal emissions and in many cases are not dependent on foreign resources making it a more economical solution [101].

Closing Scenario 1 [103], according to ETIP Bioenergy there is specific funding for methanol production such as The Innovation Fund [102], The innovfin Energy Demo Projects (EDP) Facility, Mission Innovation [102], The EU Horizon research and Innovation

Framework Program 2020 and The Investment Plan for Europe and the European Structural and Investment [102]. Funds, which are a first-class energy opportunity on a European and global scale and are essentially a way of attracting new investors in the 'Methanol world' to develop innovative technologies and minimize Capex and Opex, -20% cost [103].



Graphs 3: Initial cost of methanol compared to scenario 1.

3.5 Scenario 2: Production of Methanol from Renewable Hydrogen by the Electrolysis Process

To be able to fight for the energy goals of 2030, must consider that the energy impact of renewable energy sources is particularly important. Essentially, to be able to make full use of methanol, in scenario 2 we propose the possibility of using electricity to produce methanol. Undoubtedly, in this way aim at the development but also the design of Methanol production in a very innovative way, with a low carbon footprint [104].

According to Venture Radar, the largest Methanol production companies in the world are some of the followings: Siqens, Oberon Fuels, Methanex Corporation, Protabit, Innovative, Neo - H_2 etc. [105], the idea of scenario 2 is based on being able to isolate CO_2 and use it for complete mixing with the H_2 that is essentially produced by the process of electrolysis of water to produce Methanol (CH_3OH). Propose a patchwork of the largest Methanol companies in full cooperation with stakeholders and university research teams to create an innovation, facilitating the Methanol value chain while minimizing production costs.

In scenario 2, we can set up a power-fuel feasibility plant for methanol synthesis [106]. According to the study methanol synthesis as a method for CO_2 reduction and energy storage, assume an average cost of electricity for factors such as selling prices of methanol, cost of electricity and in addition the sale of hydrogen [106]. Using the Web - EcoMP (Web - Based Economic Cogenerative Modular Program) tool, can improve the thermal - economic installation [106].

Specifically, the ideal plant installation will consist of the innovative water electrolysis unit where essentially H_2 and O_2 will be generated using electricity, then it will consist of the carbon capture unit (CCS) [106]: which will be optimally connected with a power plant and can bind carbon dioxide, which is essential for methanol production [106]. Finally, there will be a methanol reactor, where with the correct compression process of the H_2 and O_2 reagents the innovative CH_3OH synthesis will take place [106].

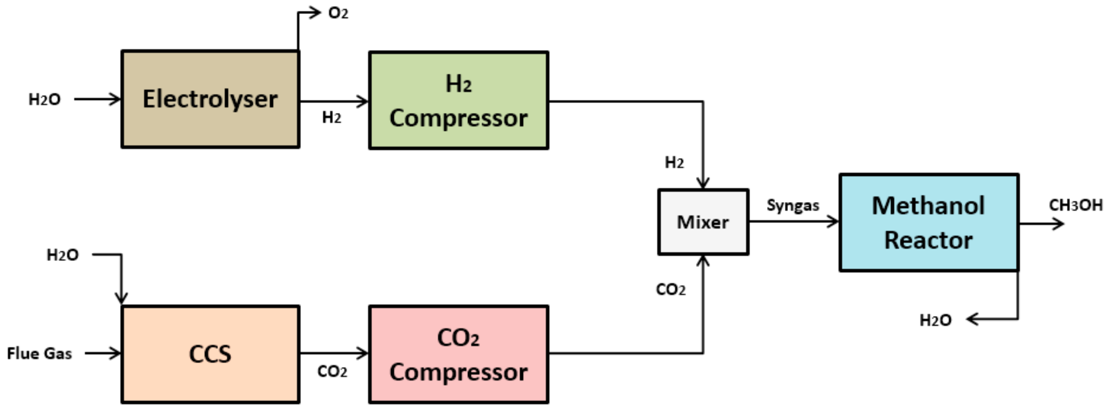


Figure 32: Simplified installation device [106].

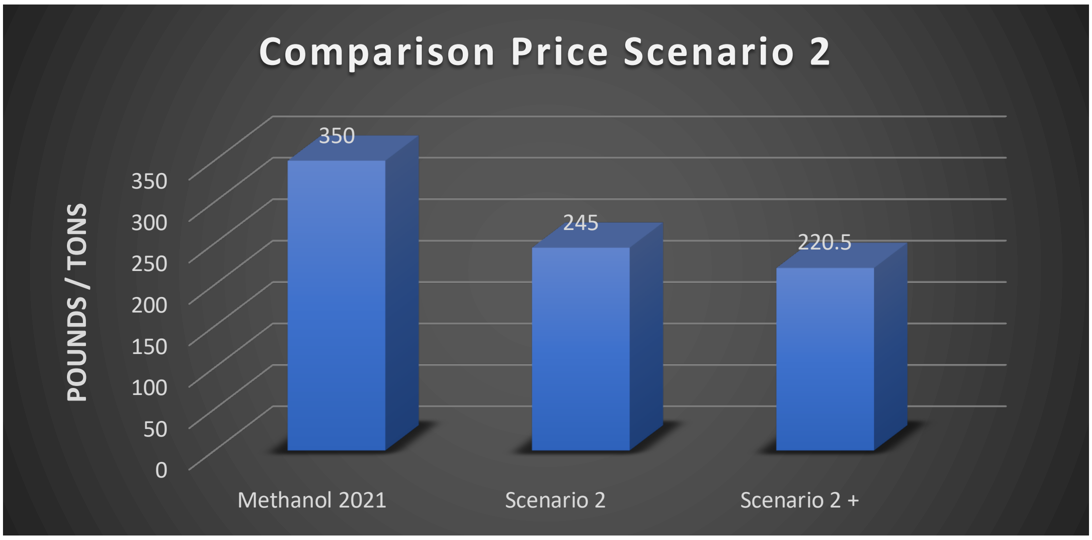
Table 20: Thermodynamic analysis main assumptions [106].

ELECTROLYSIS	METHANOL REACTOR
Electrical Consumption 5,2 kWh/Nm^3	Conversion Efficiency 96%
Outlet Pressure - 30 Bar	Recirculation Factor 85%
CCS SECTIONS	**COMPRESSION SECTIONS**
Outlet Pressure 2 Bar - (CO_2)	Isentropic Efficiency 86%
Capture Rate 90% - (CO_2)	Mechanical Efficiency 99%

It is necessary to assume a production system of approximately 50,000 tons per/year of methanol that will operate continuously every day of the year [106]. Next, we must consider the stoichiometric reaction of methanol [106]. This requires approximately 9,835 tons per year of H_2 and an additional 72,125 tons/year of CO_2 [106]. The CCS system, meanwhile, must be sized to be able to capture the required amount of CO_2 [106]. Also, electrolytes (PEMs) are also required to be installed at approximately 63 MW and a total of 78,700 tons per year for O_2 production [106].

Assuming that, have a lifespan of the investment of 20 years, always according to the lifespan of the electrolytes [106]. Next, assuming that the selling price of methanol is about 360 pounds and of hydrogen 150 pounds per tonne respectively [106]. Investment reliability of 95%, and the cost of electricity depends on market value, will assume 33 pounds / MWH [106].

The conclusions are that increasing growth will lead to lower capital costs [106]. Estimate a minimum cost reduction of approximately 30% and depending on the future price of the above factors an additional 10% minimization [106]. Then, the income from the effective sale of hydrogen, have the optimal capacity to be able to represent about 40% of the total income of the above company [106]. A possible increase of 30% in the selling price of hydrogen will bring us an additional profit of 20% in the repayment period [106].



Graphs 4: Initial cost of methanol compared to scenario 2.

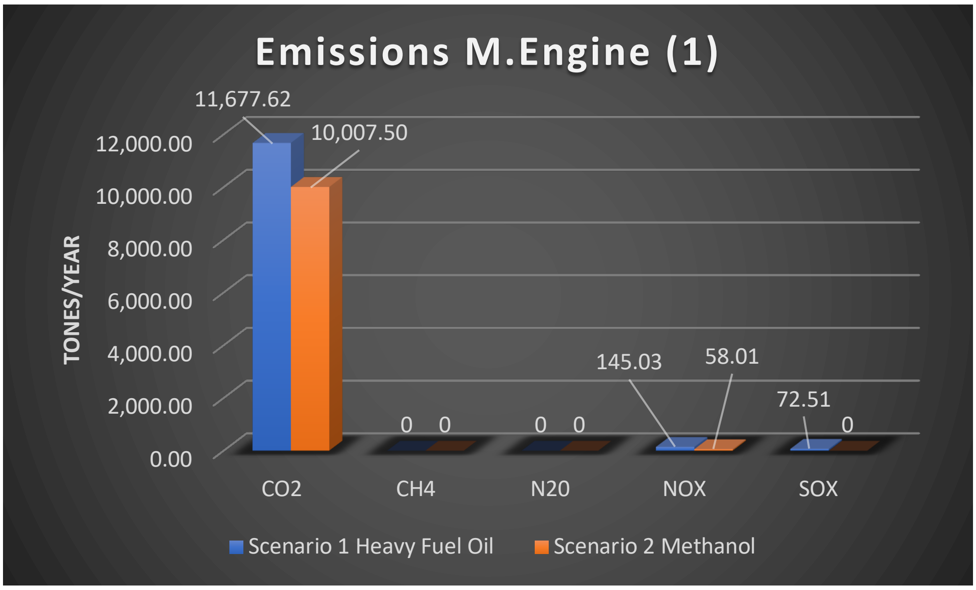
4.0 Results - Discussion

4.1 Emissions Formula (1)

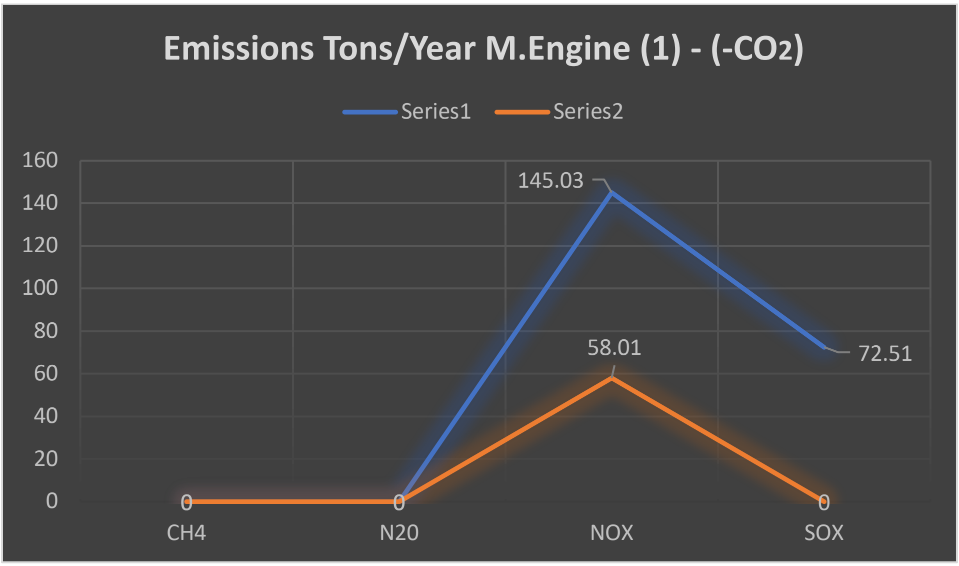
Table 21: Results calculations Tons/ Year. Formula 1.

Compound	Scenario 1 Tons/Year	Scenario 2 Tons/Year	Difference % Scenario 1
CO_2	11,677.62	10,007.5	14.3
CH_4	0	0	0
N_20	0	0	0
NO_X	145.03	58.01	60
SO_X	72.51	0	100

The first formula for calculating emissions for CH_4 and N_20 did not show any difference, because the emission factors of these components are 0, table 7. The future use of methanol fuel will result in a minimization of 14.3% / year for CO_2, 60% / year for NO_X and 100% / year for SO_X. Graphs 5 and 6, describe in detail the exact emission numbers (Tons / Year) emitted by the specific study ship, according to the first calculation formula.



Graphs 5: Total emissions tons/year scenario 1.



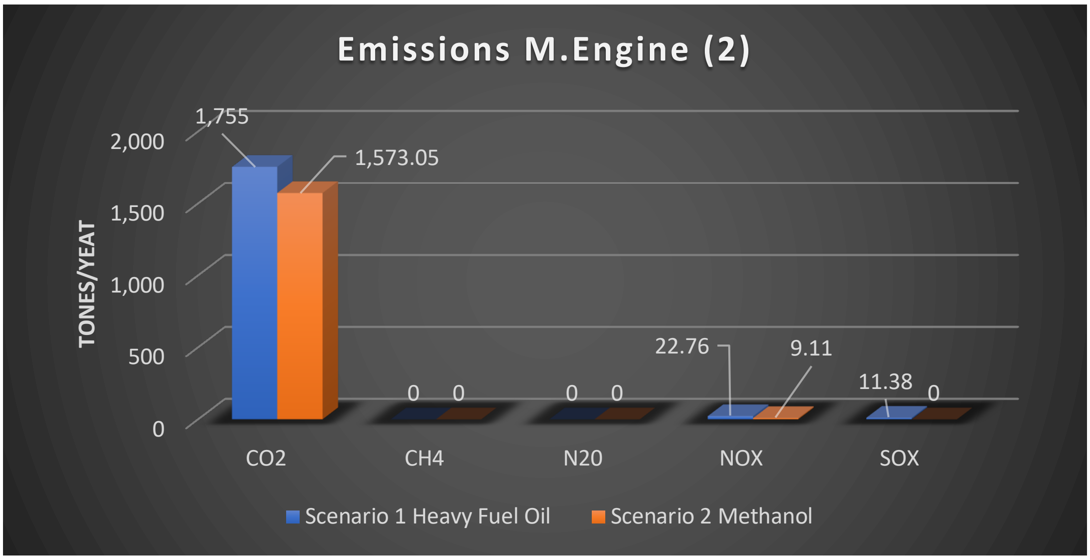
Graphs 6: Total emissions tons/year scenario 1 without CO_2.

4.2 Emissions Formula (2)

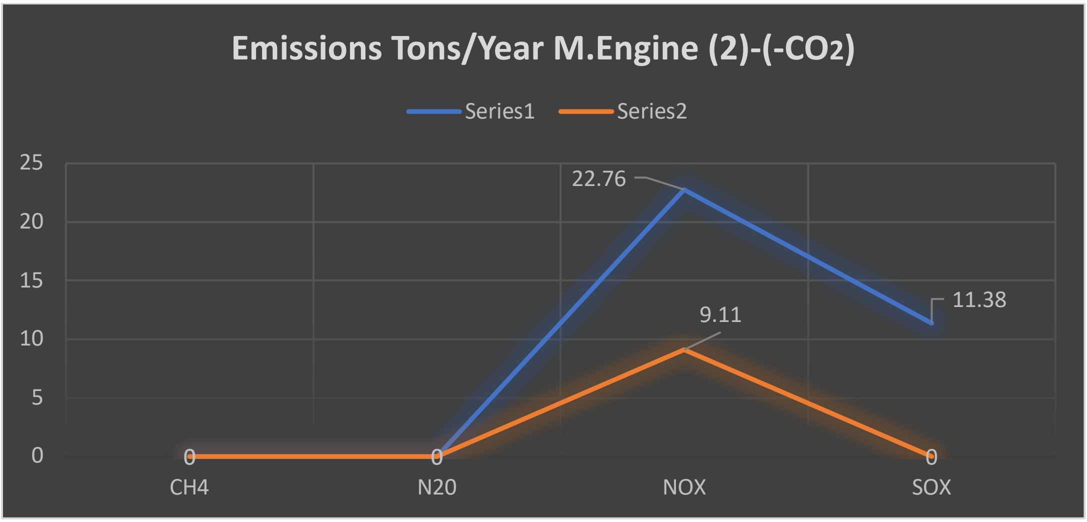
Table 22: Results calculations Tons/ Year. Formula 2.

Compound	**Scenario 1 Tons/Year**	**Scenario 2 Tons/Year**	**Difference % Scenario 2**
CO_2	1,755.44	1,573.06	10
CH_4	0	0	0
N_20	0	0	0
NO_X	22.76	9.11	59.9
SO_X	11.38	0	100

The second formula for calculating emissions for CH_4 and N_20 did not show any difference, because the emission factors of these components are 0, Table 7. The future use of methanol fuel will result in a minimization of 10 % / year for CO_2, 59.5 % / year for NO_X and 100% / year for SO_X. Graphs 7 and 8, describe in detail the exact emission numbers (Tons/Year) emitted by the specific study ship, according to the second calculation formula.



Graphs 7: Total emissions tons/year scenario 2.



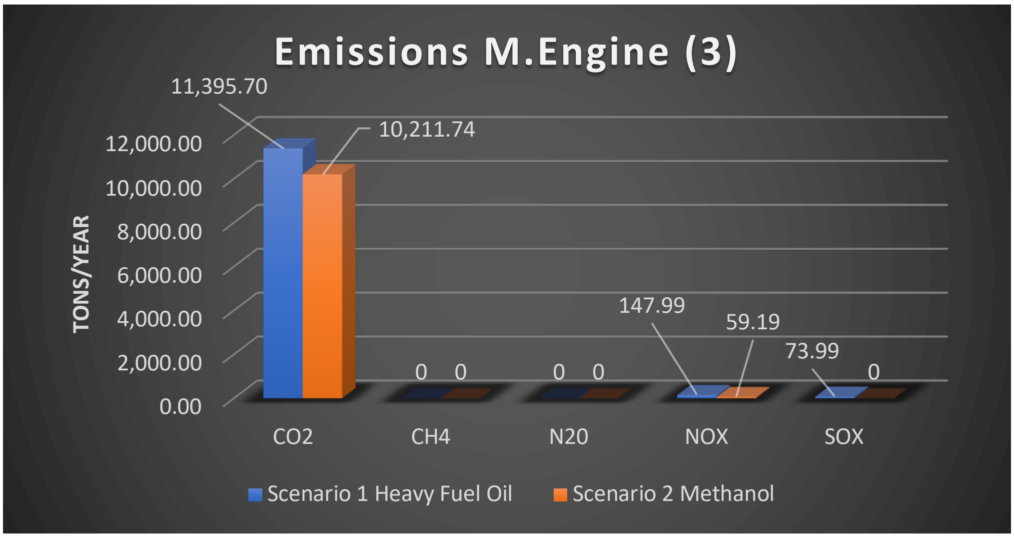
Graphs 8: Total emissions tons/year scenario 2 without CO_2.

4.3Emissions Formula (3)

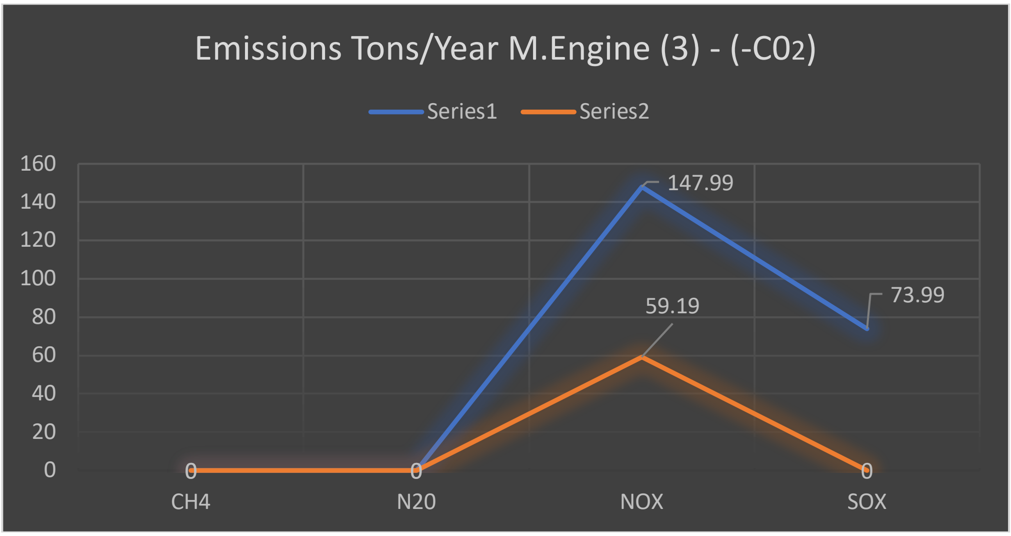
Table 23:Results calculations Tons/ Year. Formula 3.

Compound	Scenario 1 Tons/Year	Scenario 2 Tons/Year	Difference % Scenario 3
CO_2	11,395.7	10,211.74	10.3
CH_4	0	0	0
N_20	0	0	0
NO_X	147.99	59.19	49.3
SO_X	73.99	0	100

The third formula for calculating emissions for CH_4 and N_20 did not show any difference, because the emission factors of these components are 0, table 7. The future use of methanol fuel will result in a minimization of 10.3% / year for CO_2, 49.3% / year for NO_X and 100% / year for SO_X. Graphs 9 and 10, describe in detail the exact emission numbers (Tons/Year) emitted by the specific study ship, according to the third calculation formula.



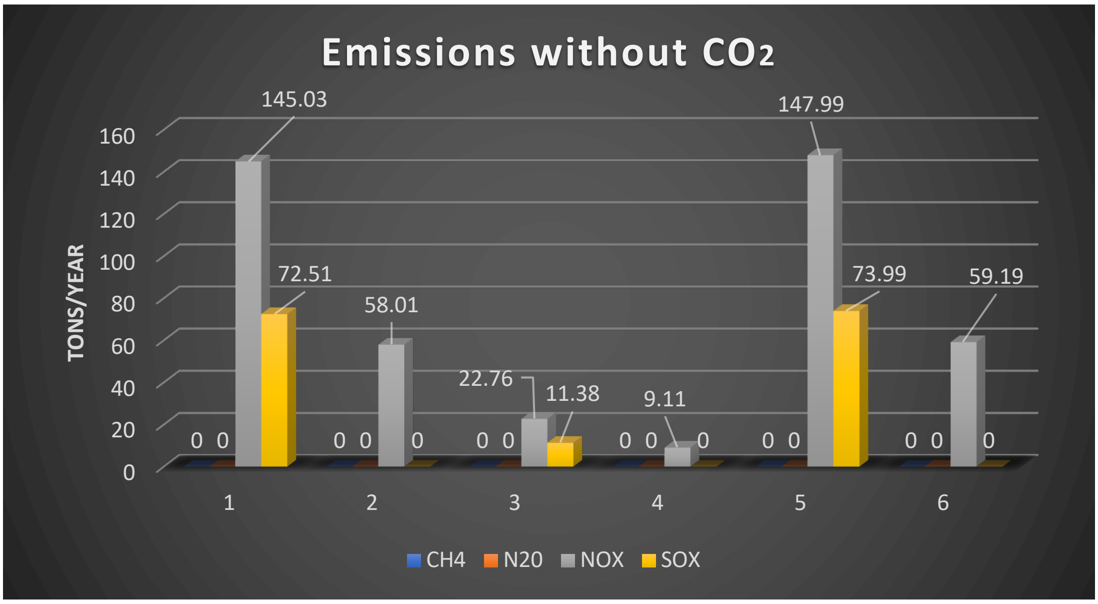
Graphs 9: Total emissions tons/year scenario 3.



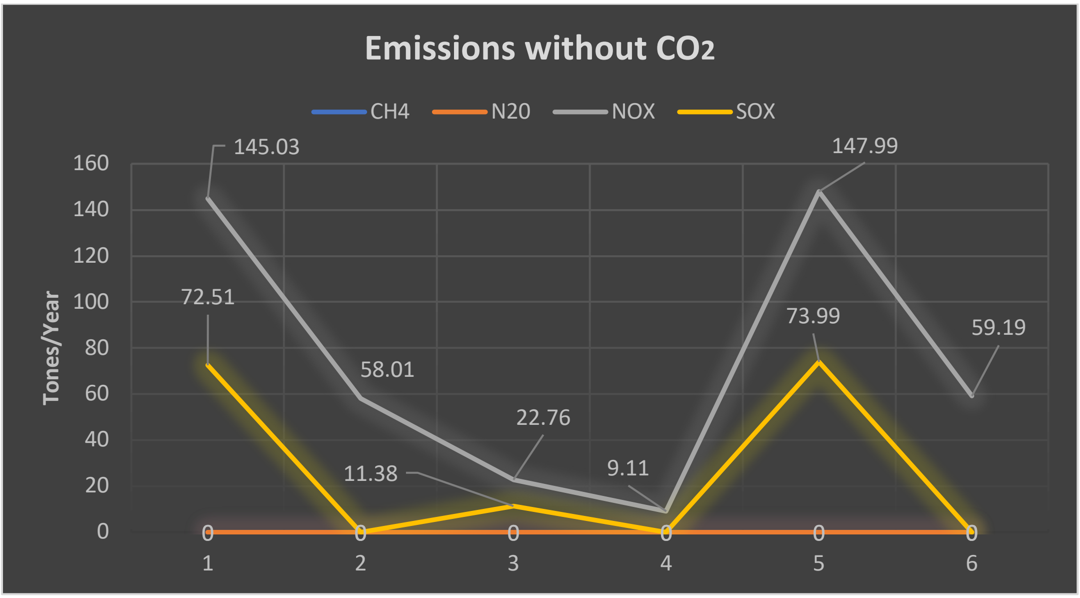
Graphs 10: Total emissions tons/year scenario 3 without CO_2.

4.4 Total Emissions 3 Formulas (Without CO_2)

For further understanding of the results, graphs 11 and 12 describe in detail the total emissions (Tons/Year) without CO_2 (large value range for this graph) for all the calculation formulas used. Notice strongly that formula 1 and formula 3 are 2% different. This indicates a particularly significant percentage of identification and alongside success between the 2 methodologies that took place.



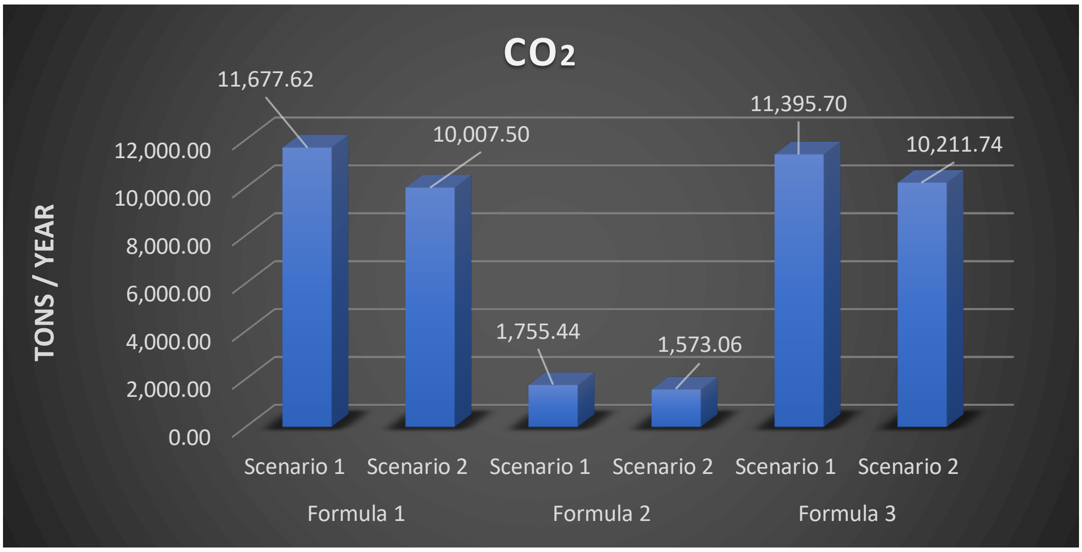
Graphs 11: Total emissions tons/year scenario 1 – 2 – 3 without CO_2.



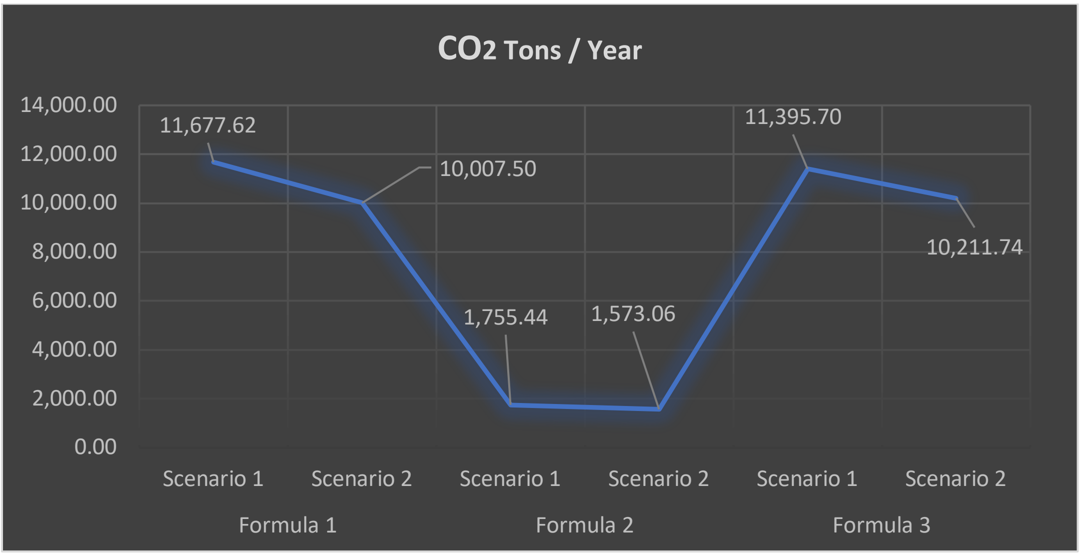
Graphs 12: Total emissions tons/year scenario 1 – 2 – 3 without CO2.

4.5 3 Formulas (Only CO_2)

For further understanding of the results, graphs 13 and 14 describe in detail the total emissions (Tons/Year) for CO_2 only (wide range of values and individual result annotation selected), for all the calculation formulas used. Notice strongly that formula 1 and formula 3 have a difference of 1.4%. This indicates a particularly significant percentage of identification and meanwhile success between the 2 methodologies that took place.

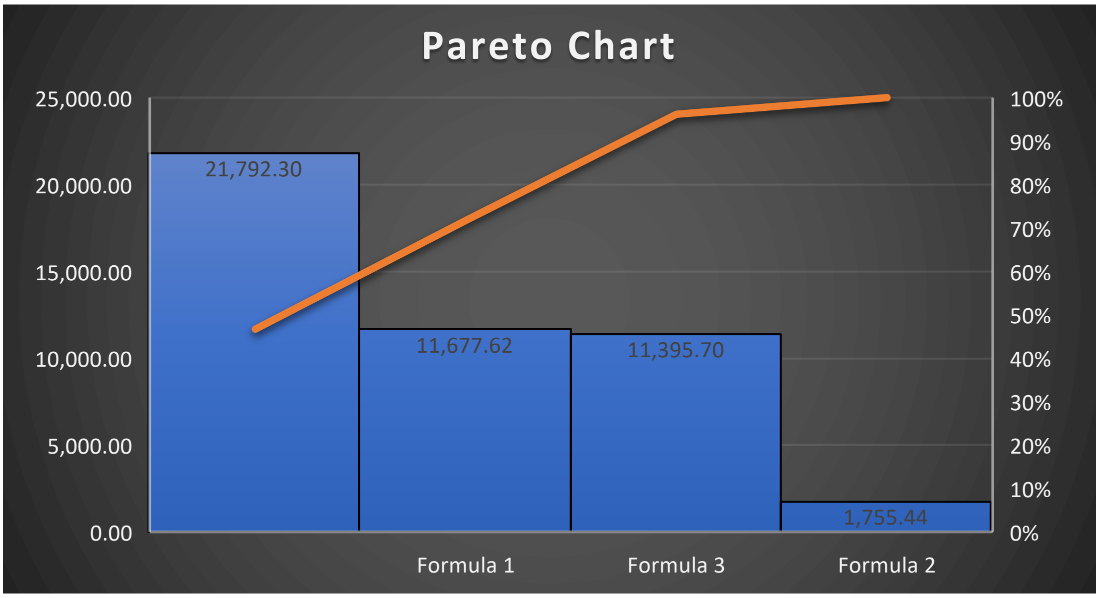


Graphs 13: Total emissions tons/year scenario 1 – 2 – 3 only CO_2.



Graphs 14: Total emissions tons/year scenario 1 – 2 – 3 only CO_2.

4.6 Chart Pareto – 3 Formulas



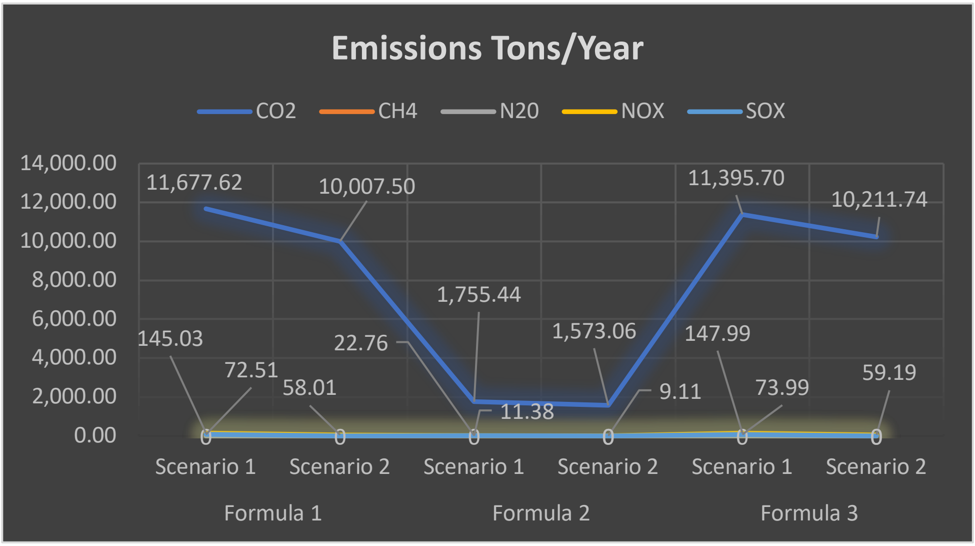
Graphs 15: Pareto analysis between 3 formulas.

Initially, Pareto analysis uses the principle that 80% of a project comes from 20% of the rest of the work [123]. Essentially, it is a way of identifying problem areas or studies that have the best performance [124]. The analysis was performed by identifying the problem, the emissions from the 3 calculation formulas, and at the same time what is the percentage difference between the 3 calculation formulas. This analysis helped to estimate the result, that formula 1 and formula 3 are methodologies that have almost common results, with a 2% difference. Through the dissertation suggest, that if the specific methodology that took place is followed, for more accurate results of calculation of emissions, formulas 1 and 3 should be selected. Finally, in this way we will focus optimally on the calculation factor and results.

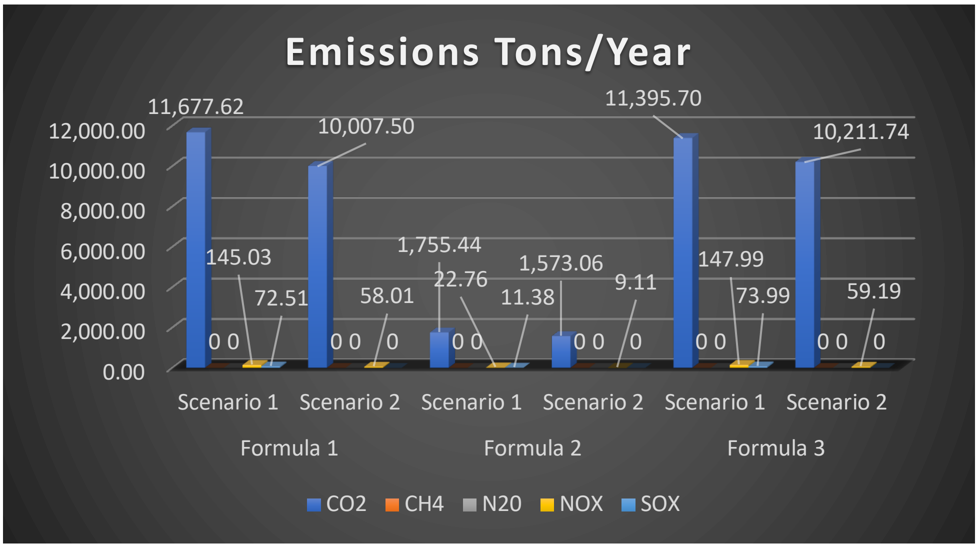
4.7 Results Justify

Table 24: Results calculations Tons/ Year. Formula 1 - 2 - 3 and justify results.

Tons/Year	FORMULA 1		FORMULA 2		FORMULA 3		VALIDATE
Compound	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**	**References**
CO_2	11,677.62	10,007.5	1,755.44	1,573	11,395.7	10,211.74	[125], [126, [127]
CH_4	0	0	0	0	0	0	Table [7], [8]
N_20	0	0	0	0	0	0	Table [7], [8]
NO_X	145.03	58.01	22.76	9,11	147.99	59.19	Table [7], [8]
SO_X	72.51	0	11.38	0	73.99	0	Table [7], [8]



Graphs 16: Present all emissions with 3 scenarios.



Graphs 17: Present all emissions with 3 scenarios / different option

According to the online database ‘EMSA / THETIS – MRV’, which is a patchwork of data from companies and countries of the European Union, the total emissions for the ship British Engineer were searched [125]. Unfortunately, no results were found related to this ship. For this reason, research was carried out on ships of the same type, same year of construction, same fuel consumption, similar main engine, and of course similar nautical miles.

To validate the results of this dissertation was used: for formula 1, in scenario 1 HFO, the calculations showed annual CO_2 emissions = 11,677.62 Tons/Year, the ship 'STOLT ACHIEVEMENT' made annual CO_2 emissions = 11,813.18 Tons/Year, 1% difference. If the fuel was methanol, the annual emissions in scenario 2 would be CO_2 = 10,007.5 Tons/Year, not validated according to table 7, there is a difference of 41% we assume that the difference is since methanol engine systems are not yet technologically advanced.

According to table 8, we have complete identification for CH_4 and N_20 pollutants because emissions factors = 0. NOx in scenario 1 is 104.85 Tons/Year while in scenario 2 it is 145.03 Tons/Year, a difference of 27%. Closing formula 1, in scenario 1 SOx = 72.51 while in scenario 2 it is 0, we accept zero ratio table 7, in scenario 1 ratio of absence of data will be compared to MGO, because they have almost common emission factor table 7 have a difference of 53%.

Unfortunately, for formula 2, in scenario 1 HFO, the calculations showed annual CO_2 emissions = 1,775.44 Tons/Year, the ship ‘NINA VICTORY’ made annual CO_2 emissions = 11,229.41.18 Tons/Year [126] chaotic difference. In addition, table 25 shows in detail all the results of the calculations in formula 2. As explained in the Pareto chart, formula 2 has no correlation with the results of the other 2 formulas.

Therefore, it is not possible to validate the results. For formula 3, in scenario 1 HFO, the calculations showed annual CO_2 emissions = 11,395.7 Tons/Year, the ship ‘ELANDRA WILLOW’ made annual CO_2 emissions = 11,492.05 Tons/Year [125], 0.008% difference. If the fuel was methanol, the annual emissions in scenario 2 would be CO_2 = 10,221.74 Tons / Year, not validated according to table 7, there is a difference of 43% assuming that the difference is since methanol engine systems are not yet technologically advanced.

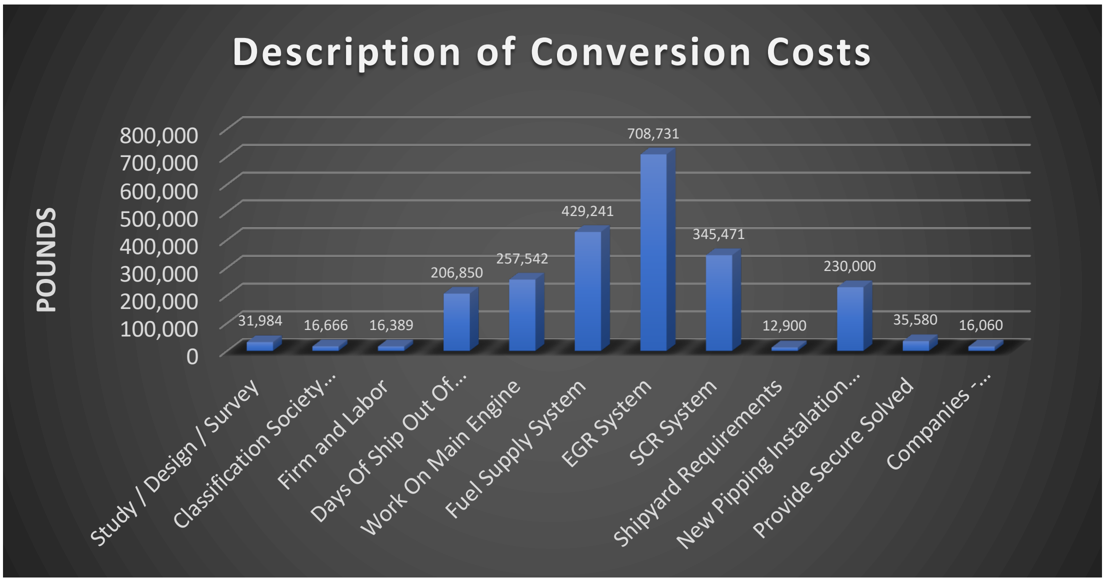
According to table 8, we have a complete match for CH_4 and N_20 pollutants because emissions factors = 0. NOx in scenario 1 is 147.99 Tons/Year while in scenario 2 it is 59.19 Tons/Year, a difference of 58%. Closing formula 1, in scenario 1 SOx = 73.99 while in scenario 2 it is 0, we accept zero ratio table 7, in scenario 1 ratio of absence of data will be compared to MGO, because they have almost common emission factor table 7 have a difference of 56%. In the above table 25 as well as graphs 16 - 17, all the numbers of the results from the 3 different calculation formulas are presented in detail, as well as the scenarios in each case separately.

4.8 Conversion Cost

Table 25: Analytical description of conversion cost.

CONVERSION COST	
TYPE OF WORK SYSTEM	**PRICE IN POUNDS**
Study / Design / Survey	31,984
Classification society approval	16,666
Subcontractor Firm and Labor	16,389
Days of ship out of operation	206,850
Work on main engine	257,542
Fuel supply system	429,241
EGR system	708,731
SCR system	345,471
Shipyard requirements	12,900
New pipping installation double wall	230,000
Provide secure solved	35,580
Companies – subcontractors coating	16,060
TOTAL COST	2,307,414 POUNDS

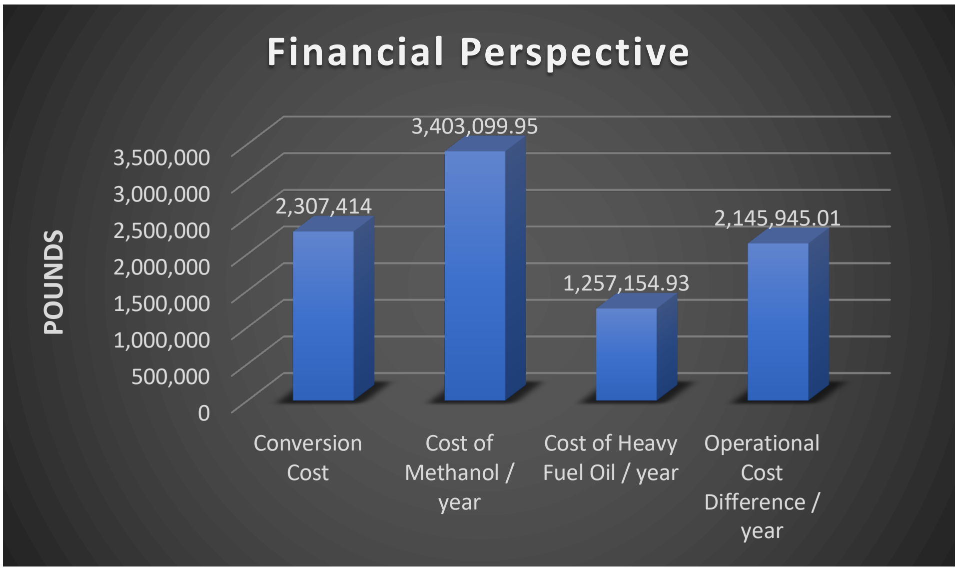
To validate the conversion cost of the main engine, a thorough research was for cost correlation. According to Transportation Research Part D: Transport and Environment, the cost of converting a conventional engine to a methanol engine is about 2,760,000 pounds [128]. In the economic study of the dissertation, the financial result of the conversion cost was 2,307,414 pounds. Essentially, there is a difference of 16% between them, it is an acceptable difference, because due to Covid-19 conditions, personal communication with the construction companies was not possible.



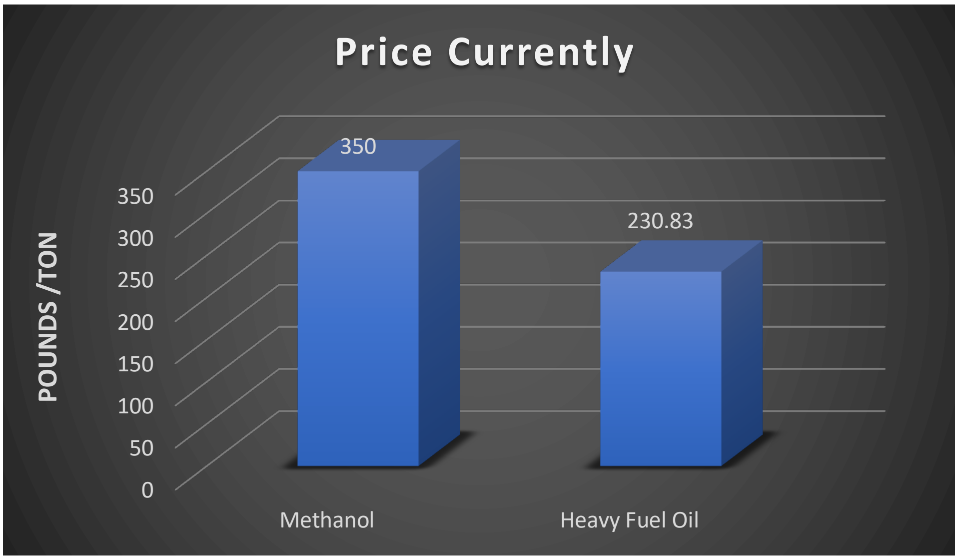
Graphs 18: Detailed graphic illustration of the categories that resulted in conversion costs (pounds)

Table 26: Analytical operational cost after conversion.

OPERATIONAL COSTS AFTER CONVERSION	
Methanol price	350 pounds/ton
Heavy fuel price	230.83 pounds/ton
Tons of methanol required	9,723.14 tons
Tons of heavy fuel oil required	5,446.19 tons
Cost of methanol per year	3,403,099.95 pounds/year
Cost of heavy fuel oil per year	1,257,154.93 pounds/year
Trip of British Engineer Chemical Tanker (km)	75,415.29 km
OPERATIONAL COST DIFFERENCE	2,145,945.01 pounds/year



Graphs 19: Description of financial perspective.

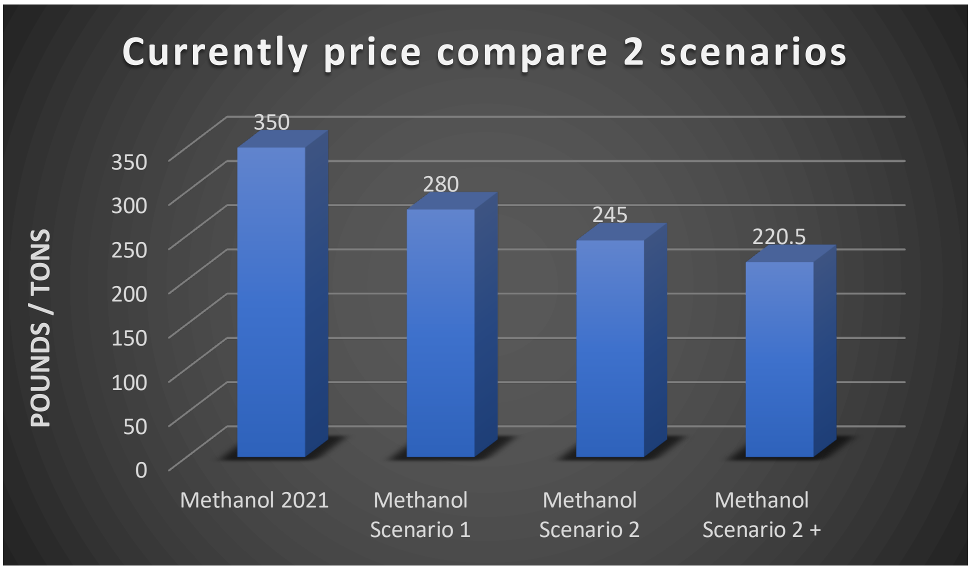


Graphs 20: Currently compare price of methanol and heavy fuel oil.

In the graphs 19 and 20 below, can observe the differences in costs between the 2 types of fuel, and how the conversion of the base engine affects the investment part of the present dissertation. Observe the normal price difference that follows, following the result of the research that Chemical Tankers have about 6,895 pounds / day profit, conclude that such an investment wants about 311 extra profit day to cover the difference in investment cost (2,145,945.01 pounds / 6,895 pounds = 311,232.05).

Profitability is essential for any business, as it will determine if such a conversion is worth it. In addition, must consider the purpose of the conversion (green funding to cover the conversion, future profit and alongside minimize emissions) and the time of sacrifice out of operation (opportunity cost). The business case will then be calculated according to the profit value obtained. The bar chart shows the financial results as focused.

4.9 Methanol Price (Currently Price – Scenario 1 – Scenario 2)



Graphs 21: Presents all scenarios for methanol that reduce the cost.

Assume that the selling price of methanol according to studies will increase and will be competitive with oil, and in this ideal scenario we will have a 50% faster repayment [106]. New ‘methanol green jobs’ will undoubtedly be created to help address the global post-Covid 19 economic crisis, dedicated to protecting the environment and tackling climate change, contributing to the goal of the 2050 Paris Agreement because it is an ideal of economic recovery with environmental coexistence.

5.0 Competitive Ways of Attracting Methanol Companies for Marine Fuel

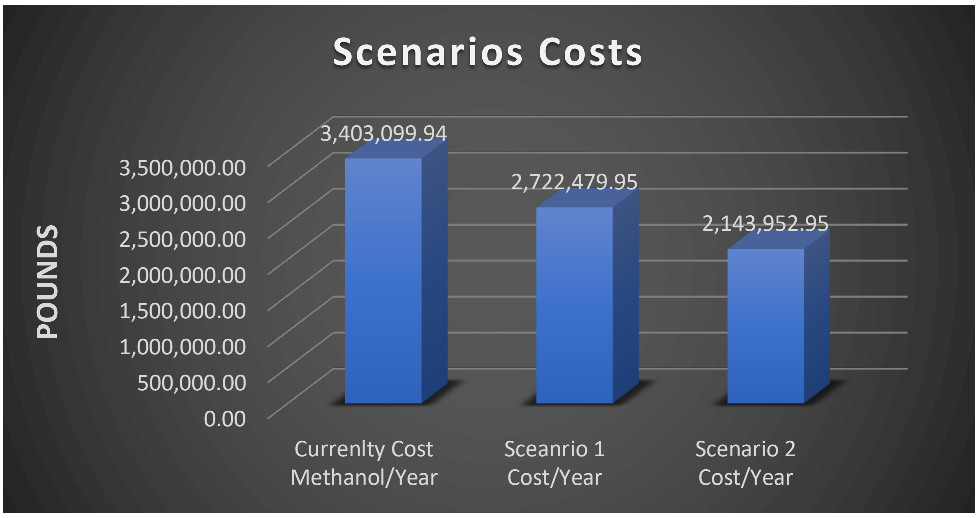
Undoubtedly, methanol as a marine fuel is very promising, but its cost so far is considered quite high and prohibited for new 'green' investors. However, the research carried out in the present dissertation has brought to the surface a rather large set of new and promising perspectives that open due to the maturation of technology and the increase in demand [95]. Therefore, the reasons that are directly related to price fluctuation, are the supply's the demand and of course the factor of rapid technological development [95].

In addition, if the market stabilizes and demand increases, much more interest is expected, which may have the effect of reducing prices and thus make Methanol a viable solution [95]. More specifically according to the Council on Foreign Relations, it has become clear that all the important factors that make new investment relatively economically difficult but not inaccessible are the following [96]. Initially, new investors are affected by the fact that the current market price of methanol does not necessarily reflect the cost of new capital investment [96].

In essence, this does not reflect the total cost of methanol limit values in a rapidly growing production world [96]. Next is the risk faced by investors in methanol production [96]. It is necessary to analyze and compare the most cost-effective way of production, for instance, if it comes from innovative ways of production such as biomass, green gas and raw glycerin minimizing the purchase price [96]. In addition, to the national and environmental benefits, it will result from the transition, of difference kind of oils to Methanol [96]. Because the increase in Methanol production reduces world prices by increasing supply relative to demand, creating different effects on short-term and long-term price increases [97].

From all the above, the answers to these questions are particularly important for the healthy future of investors worldwide [97]. Supporting Methanol for a healthy greener future aiming at the year 2050 and the Paris agreement, in this dissertation proposals will be presented in the form of two scenarios, to minimize production costs and at the same time through green economic programs to give an attractive character in investments with Methanol, choosing from all the ways of production of methanol those that are particularly green and more economical.

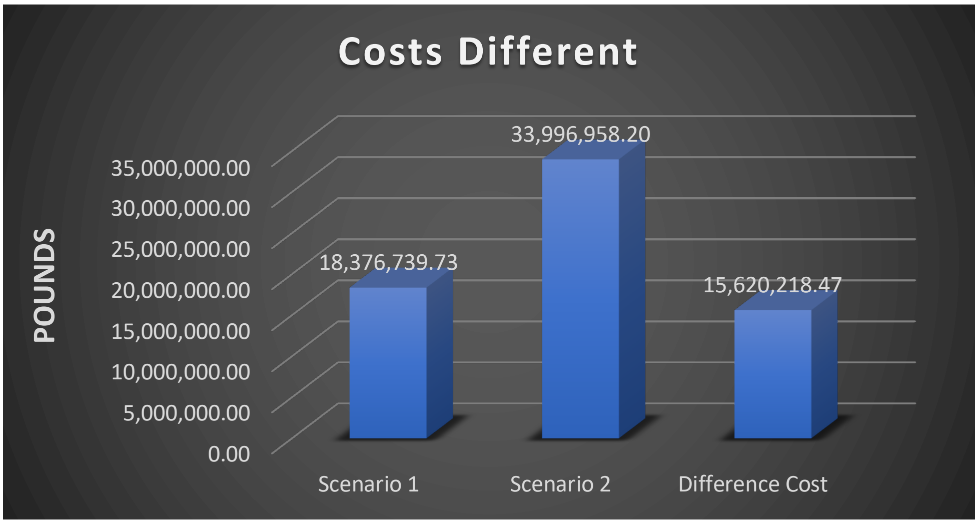
5.1 Cost / Year



Graphs 22: Scenario's costs / Year

Graphs 22 show in detail the annual methanol consumption of the ship, with current price set until 30 September 2021, 350 pounds/ton. Scenario 1 describes what the cost of methanol consumption would be if it came only from biomass production, the difference is 20% extra profit / year. Scenario 2 describes the cost of consuming methanol, if it came from electricity, the difference is 37% extra profit / year. Graphs 23, scenario 1 shows in detail the additional profit up to the year 2050, which will be derived from methanol produced from biomass. In addition, scenario 2 also describes the additional profit by the year 2050, which will come from methanol produced from electricity. Finally, we observe the financial difference between the 2 scenarios to be 45.9%.

5.2 Compare Scenario 1 Versus Scenario 2



Graphs 23: Description of the difference cost between 2 scenarios.

5.3 Business Plan

Table 27: Analytical description of financial values.

BUSINESS CASE	
Investment Cost Today	2,307,41 pounds
Breakeven of Investment	1.66 years approximately = 1.6
Total Months for Payroll	24 months
Amount Paid of the Month	96,142.35 pounds
Profit / Year	1,289,365 pounds/ year.

Table 2 describes a patchwork of financial terms that describe the investment cost, breakeven of investment, total months for payroll, amount paid of the month and the annual profit.

5.4 Financial Plan

Having calculated the operating costs, we are able to obtain the following data. More specifically, the conversion cost as estimated is 2,307,414 pounds. In addition, to calculate the recovery time or the investment Breakeven is 1,663 approximately 311 travel days. As a result, the investment will be profitable after 1,663 years. Therefore, it is necessary to calculate the total months for payoff, so:

- Total Months for Payoff = 2,307,414 pounds/24 months = 96,142.25 pounds/month for about 24 months a monthly payment of 96,142.35 pounds should be made, and Profit = 187 days * 6,895 pounds = 1,289,365 pounds/year.

It is generally accepted that the global shipping market can be described as unpredictable. Essentially, through the following methodology, the goal was set, to achieve a long-term contract with Methanol with a hypothetical daily charter amount of 25,000 pounds. Thus, in this way set the British Engineer chemical tanker to operate almost always, and thus provide a theoretical financial security for the shipping company. Based on the operating costs, the repairs were implemented to maximize the profit and of course the service fees, the optimal and meanwhile theoretically ideal cash flow policy (income).

Meanwhile, from the previous cost and profit calculations after the amortization of the investment, a clear and alongside clear view was expressed regarding the profitability of this conversion. The goal of the dissertation is, that the duration of the proposed project be 29 years. In this case, the economic analysis that follows concerns the specific future period. It is necessary to use a more subjective way of calculating the net worth of this type of investment. After all, it is possible to present a more ideally accurate economic approach to the study carried out.

According to 'Net Present Value' tool, having a specific investment time it is necessary to further analyze the exact return on capital value [92]. The NPV will be used, for a complete analysis of the profitability of the investment, which will result from the analysis from the financial capital budget [93]. Essentially, it is the value from the cash flows that the company has in its asset [92].

Represents the time value of money and is also a tool for comparing investment alternatives [93]. Furthermore, it is essentially based on a discount rate that in many cases comes from the cost of capital that is necessary to implement the investment [93]. In addition, it is reliable for a certain percentage of the 2% price and thus represents the value for money for a year that should be given a given [93]. The disadvantage is that it cannot know future aspects that will affect economic factors, for example Covid – 19 [94].

The basic equation used for calculating Net Present Value from British Engineer Chemical Tanker invest is [92], [93]:

$$\text{'Formula (NPV): NPV} = \sum_{t=0}^{n} \frac{Rt}{(1+i)t} \text{', Equation 5}$$

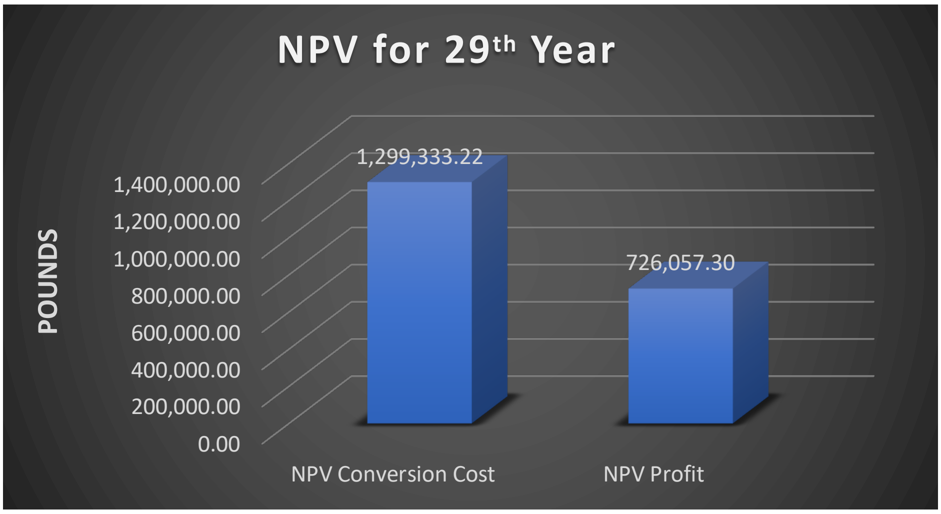
<u>Where:</u>

- 'Rt = Net Cash Inflow, outflow during a single period t'
- 'I =Discount rate or return that could be earned in alternative investments'
- 't = Number of timer periods'

i. $\text{NPVconversion cost} = \sum_{t=0}^{n} \frac{Rt}{(1+i)t} = \frac{2{,}307{,}414}{(1+0.02)29} = 1{,}299{,}333.22$ pounds.

ii. $\text{NPVprofit} = \sum_{t=0}^{n} \frac{Rt}{(1+i)t} = \frac{1{,}289{,}365}{(1+0.02)29} = 726{,}057.30$ pounds.

5.5 Financial Plan (Next 29 Years)



Graphs 24: Net Present Value (pounds) – 29 years.

To summarize, the end of the economic study showed that after the two years required for the amortization of the investment, there will be a profit for the next 27 years (small). Given the above, the investment seems to have a profitable aspect both (for Methanol data) for the financial and at the same time for the environmental part. Of course, the profit is theoretically small, because due to inflation capital loses value over the years.

The dissertation presents not only the technical conversion of the main engine and the comparison of gaseous pollutants into an existing ship and existing data, but also a financial analysis with economic indicators that prove the economic correctness of the study. Finally, an attempt was made through the technical and economic aspects as well as proposals to minimize the production costs of Methanol, to contribute to the “Methanol gap” where due to costs and production conditions it has not yet reached the levels of conventional fuels.

6.0 Further Work

However, as a future study, propose the energy analysis of a fuel production consortium specifically methanol. Theoretically, located in a geographical area close to the largest ports in the world, to further minimize the cost of transporting Methanol and have a positive impact on the shipping sector. Essentially, propose the analysis of a methanol production plant that can produce at least 1 ton of Methanol per day, as well as producing at least 1.5 tons of CO_2 per day. Finally, to be able to design optimal material recycling strategies and, in fact, to be able to estimate that this type of facility will have the power to produce Methanol with full respect for the value chain that is created. With the following schematic representation, present to you the field of study and the necessary installation systems that will make it up. Our vision for a healthy future.

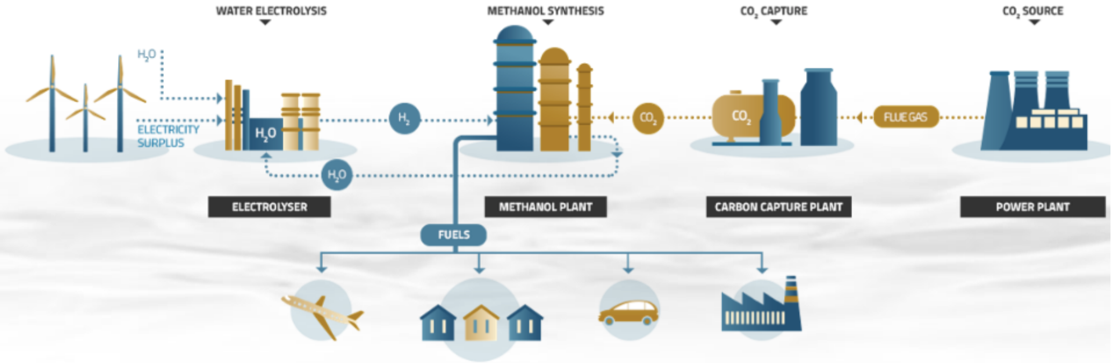


Figure 33: Methanol production vision for the next generations [107].

‘Finally, I am obliged to mention that the calculations that took place in the technical and financial part of the dissertation, are based exclusively on research data as well as assumptions. For this reason, they may not be accurate in real applications.’

7.0 Conclusions

Undoubtedly, this dissertation developed a methodical and at the same time thorough study of methanol as a marine fuel, and in addition created a new methodology for reducing gaseous pollutants. More specifically, further research through the 'literature review', revealed the need for an urgent reduction of the climate impact coming from the shipping sector. Further, research has revealed a 'gap' in the study literature that examines methanol as a marine fuel. The dissertation covered the 'literature gap' with the following new methodology, initially the transformation of the main engine into an engine that uses methanol fuel.

The results obtained from the conversion of the engine, in theory, are very interesting, essentially through the process of conversion of the engine of the British Engineer, now the ship is 'friendly' and meanwhile 'green' for the environment. More specifically, methanol fuel is a promising fuel that is combined with the easy storage process on board, and harmonizes perfectly with the engine conversion, always according to the theoretical conversion that took place.

In addition, the result of the conversion showed that it was the most optimal and at the same time effective solution, because according to the economic study, a perfect patchwork of engine conversion was achieved to minimize pollutants. In the economic study of the dissertation, the financial result of the conversion cost was 2,307,414 pounds. It was syndicated with the detailed methodology for calculating emissions from 3 different formulas, and of course with the achievable goal of lower investment costs with new innovative proposals to produce methanol from biomass products and from the production of electricity.

Inter alia, in calculation formula 1 there was a reduction of 14.3% in CO_2, in the pollutants CH_4 and N_20 we had a stable success with zero pollutants, in NO_X there was a reduction of 60% and in SO_X the optimal reduction result of 100%. Overall, with calculation formula 1, an overall cumulative emission reduction of 15.3% was achieved between scenario 1 which was the use of HFO and scenario 2 which was the use of methanol. Therefore, in calculation formula 2 there was a 10% reduction in CO_2, in CH_4 and N_20 we had a steady success with zero pollutants, in NO_X there was a reduction of 59.9% and in SO_X the optimal result of 100% reduction took place.

Overall, with calculation formula 2, a total cumulative emission reduction of 11.57% was achieved between scenario 1 which was the use of HFO and scenario 2 which was the use of methanol. However, in calculation formula 3 there was a 10.3% reduction in CO_2, in CH_4 and N_20 we had a steady success with zero pollutants, in NO_X there was a reduction of 49.3%

and in SO_X the optimal reduction result of 100%. Overall, with calculation formula 3, a total cumulative emission reduction of 11.59% was achieved between scenario 1 which was the use of HFO and scenario 2 which was the use of methanol.

According to the above, average annual emission minimization, is approximately 12.82% tons/year. According to the costs from the current industrial market, as well as the economic study of this case, the following cost categories emerged: the cost of conversion in combination with the operating costs, the cost as fuel for the use of methanol and a detailed plan was obtained regarding with factors such as Investment Costs Today = 2,307,414 table 26, Profit per/year = 1,289,365 table 28, Breakeven of Investment = 1.6 year (1.6 years of continuous travel or 24 months of regular travel) a Business Plan for the next 29 years table 28.

In fact, the results showed that the ship in the last 12 months had an energy need of 6,153,887.82 litres of heavy fuel oil. Therefore, the energy needs of methanol are 12,307,775.65 litres. Scenario 1 describes what the cost of consuming methanol would be if it came only from biomass production, the difference is 20% extra profit/year, 680,620 pounds. Scenario 2 describes the cost of consuming methanol, if it came from electricity, the difference is 37% extra profit/year, 1,259,147.94 pounds. In Scenario 1, the additional gain by the year 2050, which will come from biomass-produced methanol, is 18,376,739.73 pounds.

In addition, scenario 2 the additional gain by the year 2050, which will be derived from electricity-generated methanol is 33,997,958.20 pounds. Finally, we observe that the financial difference between the 2 scenarios is 45.9%, 15,620,218.47 pounds. In summary, the end of the financial study showed that after the two years required for the amortization of the investment, there will be a profit for the next 27 years (small). Of course, the profit is theoretically small, because due to inflation the capital loses value over the years.

Finally, the dissertation presents not only the technical conversion of the main engine and the comparison of gaseous pollutants in an existing ship and existing data, but also an economic analysis with economic indicators that prove the economic correctness of the study. In essence, the dissertation is a contribution to minimizing emissions from the maritime sector, with a view to a ‘healthy future’ and a 'green environment' for future generations, a harmonious patchwork of investment and environment.

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