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A new fund model for maritime decarbonization in the EU: the Blue Premium Fund

Alper Şaşmaz

WORLD MARITIME UNIVERSITY
Malmö, Sweden

A NEW FUND MODEL FOR MARITIME DECARBONIZATION IN THE EU:

THE BLUE PREMIUM FUND

By

ALPER ŞAŞMAZ
TÜRKİYE

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature):

(Date): **20/09/2022**

Supervised by: **Professor Dr. Aykut I. Ölçer**

Supervisor's affiliation: **Director of Research Nippon Foundation Professorial Chair in Marine Technology and Innovation Head, Maritime Energy Management**

Supervised by **Dr. Anastasia Christodoulou**

Supervisor's affiliation: **Research Associate**

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My last words as I close this special page,

Cha-cha-cha!

Abstract

Title of Dissertation: **A NEW FUND MODEL FOR MARITIME DECARBONIZATION IN THE EU: THE BLUE PREMIUM FUND**

Degree: **Master of Science**

The dissertation is a study of the development of a new decarbonization fund for the European Union (EU) shipping industry called “The Blue Premium Fund.” The concept of the Blue Premium is the shipping industry's “Green Premium” and used for the first time in the literature. It simply represents the price gap between existing traditional CO_2 emitting fossil fuels and outdated technologies and greener alternative fuels, technologies to reduce emissions, innovative and energy-efficient propulsion systems. The switching to alternative fuel and emission reducing technologies is crucial for the EU maritime industry to meet 2030 and 2050 the International Maritime Organization (IMO) and the EU emission targets. There are technical, operational and financial barriers in front of these transitions. The most important of these barriers is the financial barrier. This is because zero and/low carbon alternative fuels and other important emission reduction prevention technologies are expensive and this causes the investment decisions of ship-owners to be delayed. In other words, the Blue Premium of the maritime industry is high and it needs to be lowered and brought to competitive levels. It is possible to reduce the blue premium, increase the research and development (R&D) and innovation capacities of the maritime sector, develop the bluetech start-up and investor ecosystems and funding them in decarbonization solutions. The EU Blue Premium Fund wants to succeed by using Israel's YOZMA Venture Capital attraction program to strengthen the start-up and investor ecosystem.

The EU seems to be ahead with its legislative packages such as Fit for 55 it has prepared recently, with the funds it provides for developing R&D and innovation across all sectors, and many climate funds it provides to become the first zero-carbon continent. However, even at the EU level, no climate fund focuses specifically on the decarbonisation of shipping. This makes it difficult for the EU maritime sector to meet the targets and increases the importance of alternative financing instruments such as funds.

The Blue Premium Fund is designed as a solution to this problem. A new, innovative and inclusive funding mechanism for the EU has been revealed by examining some climate funds in the EU and in the world. Although it has many sources of financing, it is mainly based on a financing model with a tax of 5.5 € from EU ship-owners. While raising fund, carbon levy will subject it to a different calculation method, considering the Environmental, Social, and Governance (ESG) scores of the EU shipping companies.

KEYWORDS: Blue Premium Fund, Bluetech Start-up, Carbon Levy, ESG, EU, Financing Shipping Decarbonization, Fit for 55, Israel’s YOZMA Program, IMO

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List of Abbreviations

CO_2	Carbon Dioxide
EEDI	Energy Efficiency Design Index
EIB	European Investment Bank
EMFF	European Maritime and Fisheries Fund
ERDF	European Regional Development Fund
ESG	Environmental, Social, and Governance
ESS	Energy Storage Systems
ETS	Emissions Trading System
EU	European Union
FAME	Fatty acid methyl ester
GCF	Green Climate Fund
GHG	Green House Gases
HFO	Heavy Fuel Oil
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
ICS	International Chamber of Shipping
IEA	International Energy Agency
IMO	International Maritime Organisation
IMRF	IMO Maritime Research Fund
IRENA	International Renewable Energy Agency
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MDO	Marine Diesel Oil
MEPC	Marine Environment Protection Committee
MGO	Marine Gasoline Oil
MRV	Monitoring, Reporting and Verification
MSR	Molten Salt Reactors
NH3	Ammonia

NOx	Nitrogen Oxides
OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matters
PV	Photovoltaics
SDG	Sustainable Development Goals
SEEMP	Ship Energy Efficiency Management Plan
SME	Small and Medium-Sized Enterprises
SMR	Small Modular Reactors
SOx	Sulphur Oxides
SRIA	Strategic Research and Innovation Agenda
STRIA	Strategic Transportation Research and Innovation Agenda
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WASP	Wind-Assisted Ship Propulsion
WHRS	Waste Heat Recovery System

Chapter 1

1.0 INTRODUCTION

1.1 BACKGROUND

The shipping industry accounts for 2-3% of worldwide CO_2 emissions. The International Maritime Organisation (IMO), the United Nations (UN) organization that oversees the shipping industry, has set a goal to reduce carbon emissions in the sector by half by 2050 compared to 2008 levels, with the goal of eliminating them entirely (WOI, 2020). Shipping is primarily reliant on fossil fuels, and the vast majority of ships worldwide are now powered by hydrocarbon-based fuel oils, but the grades and specifications vary. The emission of massive amounts of carbon dioxide into the atmosphere when this fuel is burned contributes greatly to its insulative properties as well as global warming and climate change (Hoyland & McDonnell, 2021).

Therefore, the search for solutions to reduce carbon and GHG emissions for the maritime industry still continues. One of the most important tools for decarbonization is to ensure the transition from fossil fuels used by ships to alternative fuels with no emissions and/or too low emissions. As concerns about energy security, the environment, and the economy have grown, policymakers have started to turn their attention away from fossil fuels (Hoyland & McDonnell, 2021). LNG, LPG, methanol, biofuel, and hydrogen have been considered most promising fuels by DNV, which is a registrar and classification society with international accreditation, as the most viable alternative fuels for transportation. Battery systems, fuel cells, and wind-assisted propulsion are among the emerging technologies that the classification society believes have the potential for ship use (DNV, 2018).

1.2 PROBLEM STATEMENT

The decarbonization of the shipping industry is not an easy matter. There are many barriers in front of this radical transformation. Since the transition to alternative fuels brings with it many difficulties such as the differences in physical and technical characteristics, the need for significant investments in alternative fuel technologies, insufficient regulations, intensive innovation and research and development (R&D), and huge financial investments are required for the transition. As a result, the transition to alternative fuels is extremely difficult, requiring both a global perspective that encompasses various stakeholder demographics and collaboration with many players throughout the value chain (Foretich et al., 2021a).

The decarbonization of shipping is an important problem that needs to be resolved for the European Union (EU) countries as well. Shipping emissions account for around a quarter of all EU transportation-related greenhouse gas emissions (EU, 2022). With the aim of reaching net-zero greenhouse gas emissions in the EU by 2050 to stop climate change and prevent global warming, the EU enacted a European Climate Law in June 2021. The law has an intermediate goal of cutting GHG emissions by at least 55% by 2030 compared to 1990 levels (UNSDGN, 2021). In this respect, the EU is taking important measures to decarbonize the maritime industry. The European Commission (EC) established a strategy in 2013 to reduce GHG emissions from the shipping industry using accessible translations of the program (EU, 2022).

- Large ships (5,000 GT and above) using EU ports have their CO_2 emissions monitored, reported, and validated.
- The maritime transportation sector has set greenhouse gas reduction targets.

- In the medium to long term, further initiatives, including market-based measures.

In summary, the decarbonization of the maritime sector is a crucial issue for the EU. In this respect, it is also important for the medium and long-term targets of the EU that ship owners switch to alternative fuel technologies. So, the EC has set its priority on the production and deployment of sustainable alternative transport fuels for various modes of transportation in the European Green Deal (Europarl, 2022b).

However, as mentioned above, the targets set for European ship-owners are challenging. In this regard, ship-owners have important demands from the EC. One of the most important of these is to create a fund under a market-based measure and use the revenues to fund R&D initiatives and close the price gap between new-clean alternatives and conventional fuels and technologies (ECSA, 2021).

This price gap will be referred to as "**Blue Premium**" in this study. In fact, Blue Premium should be considered the "**Green Premium**" of the maritime industry. The Green Premium is the extra expense of selecting a clean technology over one that produces more greenhouse gases (BE, n.d.-b). Blue Premium, on the other hand, describes the extra cost of switching to emission-free and low-emission fuels and/or technologies for the decarbonization of the maritime industry.

In this study, it will be aimed to reduce the "Blue Premium" by designing an innovative and inclusive fund mechanism for European ship owners, blue start-ups, researchers, angel and individual investors, corporate investors, venture capitals (VCs), climate philanthropist, and other relevant stakeholders, by examining all the support and imposed mechanisms applied, especially the market-based measures and funds aiming to solve climate and global warming issue (Emission Trading System, ETS, etc.) applied in the EU.

1.3 AIMS AND OBJECTIVES

This study, within the scope of the 2030 and 2050 targets set by the EC to reduce carbon emissions and greenhouse gas emissions aims to design an innovative, inclusive and applicable fund mechanism across the EU to reduce "Blue Premiums" to enable the maritime industry to transition to zero and/or low-emission alternative fuels and other energy-efficient technologies such as propulsion and design.

The following are the specific objectives of this research:

1. To examine existing measures/policies/incentives implemented and under implementation for the decarbonization of the EU maritime sector in the scope of the EU Green Deal Program and Fit for 55.
2. To examine public and/or private climate, green and blue funds covering the maritime sector in the EU. (R&D and Investment Funds)
3. To examine best practice fund mechanisms around the world to reduce GHG emissions
4. To evaluate the current situation of the EU shipping industry in the context of ESG criteria by referring to international indexes (MSCI ESG Index, S&P ESG Index, etc.)
5. To address Israel's Yozma VC Program
6. To examine alternative clean solutions for maritime decarbonization
7. To discuss the applicability of the Blue Premium Fund also at the IMO level

1.4 RESEARCH QUESTION

This research work will answer the following research questions:

1. What are the obstacles for the European shipping industry to reach the EU's 2030 and 2050 targets for decarbonization?

2. Are current policies, measures, and practices for the decarbonization of the shipping industry across the EU sufficient?
3. What funds are available for the decarbonization of shipping at the EU level? What are other best practices in the world?
4. What are the most feasible alternative fuels and/or technologies for shipping? How much are the Blue Premiums of alternative fuels and emission reduction technologies?
5. What is the current state of shipping companies in terms of sustainability and the ESG criteria? What will be the relationship between the Blue Premium Fund and ESG?
6. How should the sustainability of the fund be established for the financing of maritime decarbonization? How will the fund be financed?
7. How will the Blue Premium Fund to be established be used?

1.5 METHODOLOGY

The study will be conducted quantitatively, with secondary data already supplied by the relevant authorities as a starting point. In order to find answers to the questions of the research, research will be put forward using the secondary data of the relevant institutions in the EU and from worldwide sources.

This data will be used to reveal opportunities and barriers fronting the decarbonization of the EU shipping industry. In the study, the policies implemented at the EU level to mitigate the climate change impact on the shipping industry and to reach the IMO and the EU 2030 and 2050 emission targets will be analysed. Then, the current situation of the R&D and innovation ecosystem in the world and at the EU level will be discussed and inferences will be made about the status and importance of the bluetech start-up and investor ecosystem for the decarbonization of the maritime industry. Then, the financing of the decarbonization of shipping will be explained and various funds applied at the EU level will be mentioned. Additionally, other good funding practices in the world will be examined and the adequacy of the financial support provided to the EU maritime industry will be questioned. A comparison will be made by evaluating the advantages and disadvantages of these funds.

After all, alternative fuels, new propulsion systems and other emission reducing technologies will be explained and solutions will be discussed on how to reduce Blue Premium by evaluating the financial barriers in the shipping industry's zero-emission target transition. In particular, besides the financial barriers of new alternative fuels and emission-reducing technologies, technical and operational barriers will be examined, and the role of blue technology start-ups and researchers will be discussed.

In this study, open and closed source data such as the EU and EC Database, World Bank Data Bank, Rodium Group Emission Data, International Energy Agency, International Renewable Energy Agency (IRENA), Statista for statistical data and other secondary data from various sources will be used.

In this study, before the Blue Premium Fund model is proposed, a new, innovative and inclusive funding mechanism for the maritime industry will be revealed by comparatively examining the existing funds and other good practice examples around the world. The methodology of the study is illustrated as shown in Figure 1.

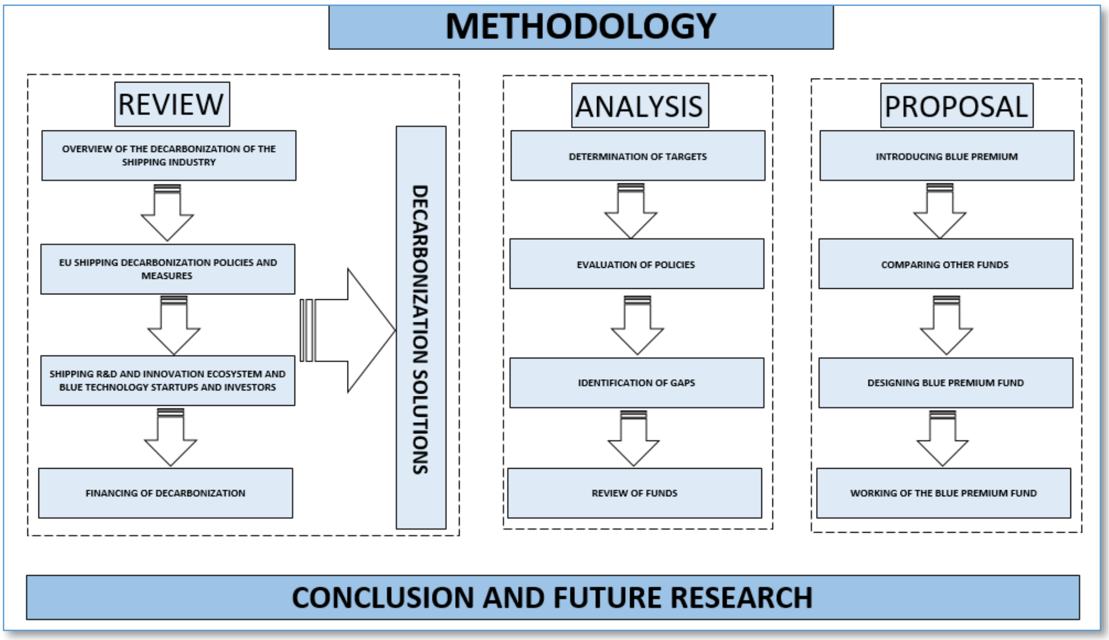


Figure 1 The Methodology of the Study
(Source: Author)

1.6 SCOPE

This study covers the policies implemented for the decarbonization of the maritime sector in transportation in the context of the EU's policy to reduce greenhouse gas emissions by at least 55% in 2030 and to net-zero in 2050, within the scope of the European Green Deal, a set of policy initiatives.

In order to achieve this goal, solutions are listed for a series of policy proposals in order to remove the barriers to European ship owners' ability to use clean alternative fuels and batteries, fuel cells and wind-assisted propulsion systems. Most importantly, a new, inclusive and innovative fund mechanism has been designed in addition to the existing R&D funds in order to make new clean technologies more advantageous than traditional existing technologies in terms of finance and commerce.

The study will propose a new, innovative and inclusive R&D and investment fund within the borders of the EU. However, it is hoped that the results of the study will open the door to cross-border agreements and new collaborations. In particular, it is planned to be a good practice example for the new R&D funds that can be established within the IMO.

1.7 JUSTIFICATION

The current GHG and CO_2 emissions of the shipping industry are not at the desired level in the EU. At the EU level, maritime transport is a substantial CO_2 emitter, representing 3 to 4% of the EU's total CO_2 emissions, or more than 144 million tonnes of CO_2 in 2019 (EC, n.d.-n). In this regard, the EU is taking a series of measures for the maritime industry in order to achieve its 2030 and 2050 targets and to become completely carbon neutral. Some of these measures are technical, some are operational, and some are market-based.

This study is compatible with the EU's goals and policies, and discusses how clean alternative fuels, which are one of the most important tools for the maritime industry to be carbon neutral, and important technologies such as batteries, fuel cells and wind assisted propulsion systems, will be competitive by considering them in the context of EU 2030 and 2050 targets.

1.8 OUTLINE OF THE STUDY

The dissertation is structured into six chapters. Chapter one contains the introduction, problem statement, aims and objectives, research question, methodology, scope, justification, outline, limitations, and assumptions of the study. Chapter two contains the literature review – an overview of the EU shipping decarbonization policy measures, R&D and innovation ecosystem of the maritime industry, the EU and other global funds used to finance decarbonization, Green Premium concept, which forms the basis of the study, the Israel Yozma VC Program, which the Blue Premium Fund used as a concept for attracting investors to develop bluetech start-up ecosystem, and finally, the concept of ESG and financial sustainability are given.

In Chapter 3, clean alternative fuels, alternative marine propulsion technologies, and ship design measures (such as air lubrication, propeller design and hull coating), which are important solutions for maritime decarbonization, are mentioned.

In Chapter 4 "Blue Premium," which will be introduced in the study for the maritime industry, will be explained. Then, the new Blue Premium Fund will be explained and how this fund will be financed and how this fund will be used for the decarbonization of shipping will be explained.

In Chapter 5, the working principle of the Blue Premium Fund, described in Chapter 4, using various decarbonization solutions, in five different cases will be explained in more detail. In addition, based on some simple assumptions, the financial contribution of the EU to decarbonization will be mentioned by calculating the cash inflow and outflow of the Blue Premium Fund. In Chapter 6, the conclusion and possible future research are described.

1.9 LIMITATIONS AND ASSUMPTIONS

The study focuses on the decarbonization of the EU shipping industry and aims to design a new, innovative and inclusive funding mechanism to reduce financial barriers to the transition to alternative fuels and innovative emission reduction technologies. Blue Premium is the market price difference between alternative fuels and/or new emission reducing technologies and currently used fossil fuels and energy inefficient technologies. Here, while calculating the blue premium, the price of the economic, social and environmental effects of climate change and global warming on the EU is not included. More research and data are needed for this calculation.

Chapter 2

2.0 LITERATURE REVIEW

2.1 OVERVIEW

Shipping accounts for 2%-3% of global greenhouse gas (GHG) emissions. If it were a country, it would be the sixth-largest emitter in the world with emissions that are higher than those of Brazil and Germany (Schlanger, 2018). Sadly, it is predicted by the IMO that by 2050, emissions will rise from around 90% of 2008 emissions in 2018 to 90%-130% of 2008 emissions for various realistic long-term economic and energy scenarios (IMO, 2020). As shown in Figure 2, according to more general global economic scenarios that would limit the rise in global temperature to less than 2 °C, the fourth greenhouse gas study from the IMO, published in 2020, contained projections for how emissions from international maritime transport will evolve in the future (Concawe, 2022). As a result, the global community's goal to keep the increase in GHG emissions below 2 and even 1.5 degrees Celsius has a sizable gap. Moreover, the shipping industry still has a long way to go before meeting its global commitment given the predicted ongoing growth in GHG emissions.

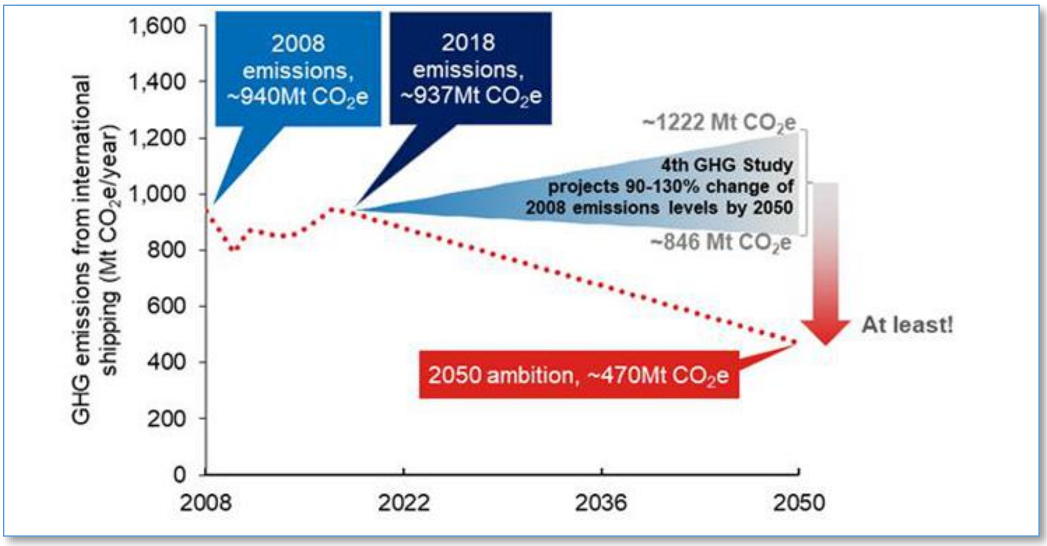


Figure 2 The Trajectory of International Maritime Transportation Emissions

(Source: (Concawe, 2022)

Therefore, there are many steps to be taken for the decarbonization of the maritime sector at the point of reaching the mentioned targets. The following are some important ways to reduce shipping's GHG emissions (Concawe, 2022).

- Operational measures including weather routing, improved voyage planning, and/or slow steaming
- Using alternative low-carbon and/or zero-carbon fuels using alternative clean energy sources
- Technical measures such as altering the design of paint, or hull coatings

In the 2018 IMO initial GHG strategy, there are multiple candidate measures in the short term, such as further refinement of the existing energy efficiency framework with a focus on the EEDI and SEEMP, considering the results of the review of EEDI regulations in the short term; existing fleet development programs and incentives for the first movers to develop and adopt new technologies, in the medium term, there are such candidate measures such as new/innovative emission reduction mechanism(s) possibly including Market-Based Measures to promote GHG emissions reduction (IMO, n.d.-b).

Also, there are candidate measures, such as operational energy efficiency measures for both new and existing ships, including indicators conforming to the three-step approach that can be used to indicate and improve the energy efficiency performance of ships in the medium term. In the longer term, there are candidate measures to monitor the development and delivery of zero-carbon or non-fossil fuels to enable the shipping industry to assess and evaluate decarbonization in the second half of the century; and other possible new/innovative emission reduction mechanism(s) to encourage and facilitate general adoption (IMO, n.d.-b). The calculations done by IMO as in Figure 3 show the effect of each measure on the reduction of GHGs. For example, the use of hydrogen or synthetic fuel in ships reduces emissions by 90 to 100 percent.

Figure 3 IMO's Candidate Technical, Operational and Economical Measures *(Source (IMO, n.d.-b)*

Thus, according to IMO, switching to alternative fuels is the most radical way to decarbonize shipping. This is because the cost of fuel is the largest expense for shipping companies, accounting for more than 50% of the total shipping cost (Gohari et al., 2018). The aim of the EU Blue Premium Fund is to help alternative fuels and technologies become more competitive and give them financial incentives to switch to alternative sources. Heavy fuel oil and marine diesel oil are typically the fuel kinds for ships that are used the most (both fossil fuels). Electricity, methanol, hydrogen, ammonia, liquefied natural gas, and biodiesel are examples of alternative shipping fuels (Law et al., 2021). These fuels may have no emissions, but how much carbon they actually contain depends on the manufacturing method. For instance, crude oil or renewable resources can be used to produce ammonia (Ghavam et al., 2021). Therefore, how alternative fuels are supplied and how they are produced is extremely important.

Decarbonization of the maritime sector in the IMO context is also crucial for the EU, especially considering its impact on the economy and society. According to 2018 data, the European Maritime industry contributes 54 billion Euros to EU GDP. The entire contribution equals to €149 billion when you factor in the effects on other sectors, such as supply chain and worker spending implications. When considering the impact on other sectors, the industry supports up to 2 million employment in addition to the 685,000 people it directly employs (ECSA, 2020). Along with these, the EU plays a significant role in global logistics and trade because it is home to some of the biggest and most significant ports, including the ports of Rotterdam, Antwerp, and Hamburg. (ESPO, n.d.). The traffic of these ports has increased approximately three fold in the last twenty years (World Bank, 2022). As shown in Figure 4, according to the data for the last quarter of 2021, the major EU ports processed 862 million tonnes of cargo (Eurostat, 2022).

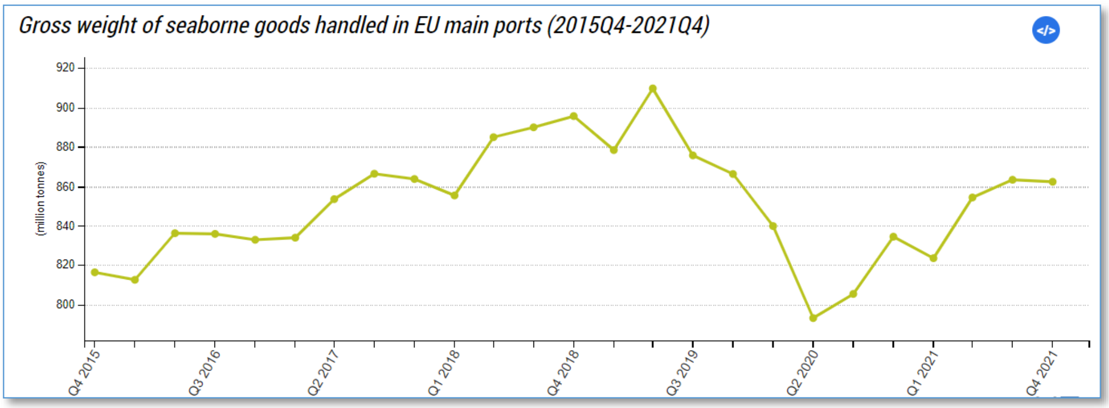


Figure 4 Gross weight of seaborne goods handled in the EU main ports
(Source: (Eurostat, 2022))

This economic dimension of the sector naturally increases the emissions and carbon footprint and is on the EU agenda as an important issue. A significant source of CO_2 emissions at the EU level, maritime transport contributed 3 to 4% of the EU's overall CO_2 emissions in 2019, or more than 144 million tonnes of CO_2 (EC, n.d.-n). Figure 5 shows that greenhouse gas emissions from transportation have increased over the years in the EU as well as in the world. Considering its share in maritime transportation, it is around 13 percent (see Figure 6). Additionally, according to FuelsEurope data, approximately 50 million tonnes of marine fuel is used according to 2021 data (FEU, 2022).

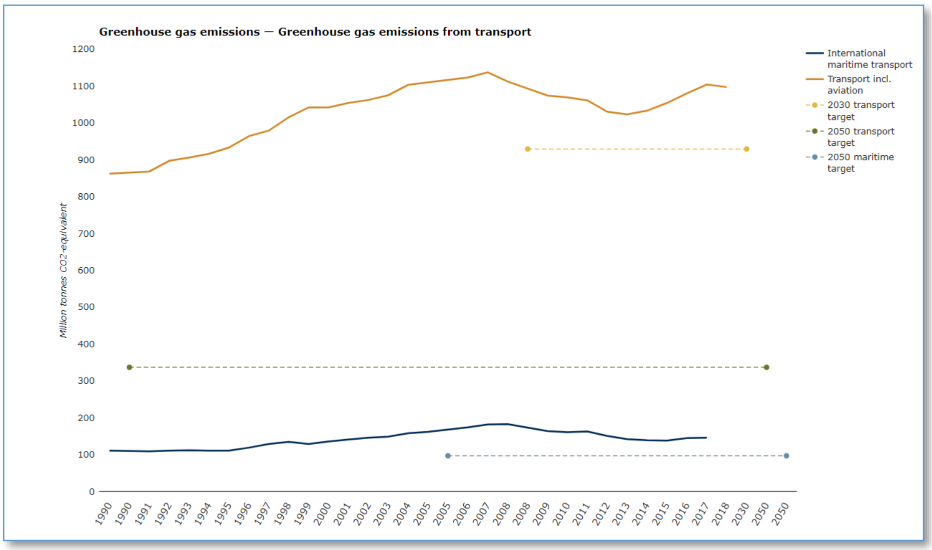


Figure 5 EU GHG emissions from transport
(Source:(EEA, 2020)

In a nutshell, decarbonization of the EU shipping industry is also an essential goal for the EU, as it is at the IMO level. With an ambitious goal of reducing greenhouse gas emissions by at least 55% by 2030, the EU is on track to achieve climate neutrality by 2050 (EC, n.d.-a). In this respect, the size of the EU maritime sector and the effort required to reduce energy efficiency and GHG emissions are significant.

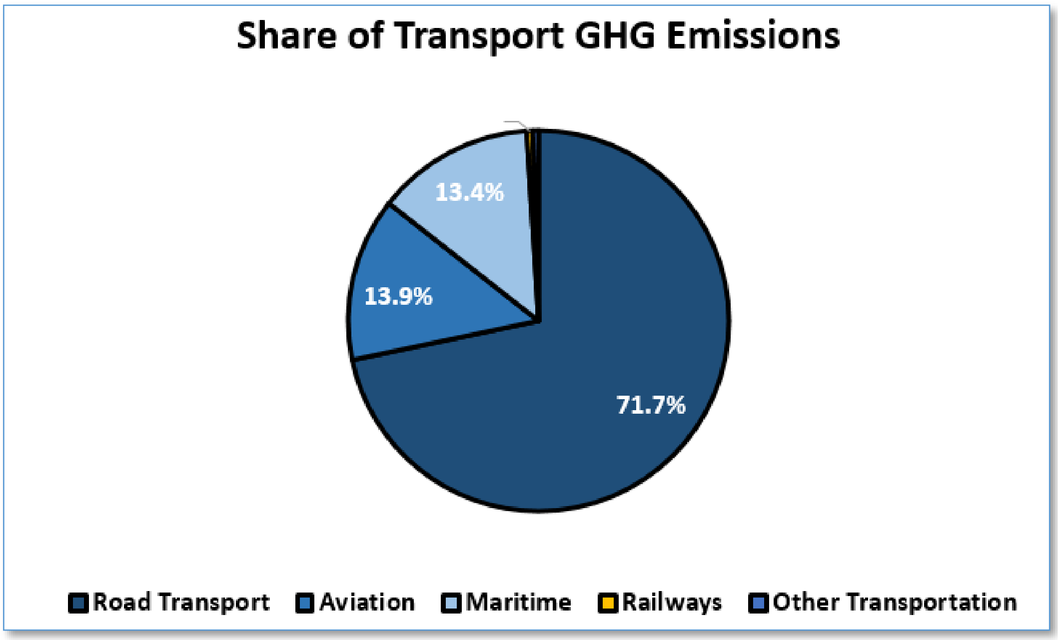


Figure 6 EU Share of transport GHG Emissions
(Source: (EEA, 2020)

In this regard, the EU is developing important policy measuring tools and practices to decarbonize all sectors including maritime industry as a whole, to reach the climate targets by 2030 and 2050. These policies were gathered under the main policy called, the Green Deal. The EC launched the European Green Deal in 2020, which is a collection of policy initiatives with the overarching objective of making the EU carbon neutral by 2050 (EC, n.d.-b).

The EU is the leading continent to initiate its policies on climate change and global warming earlier in the world as in the maritime industry. The IMO's sluggish development of a strategy for a global campaign against shipping emissions has prompted the EU to announce its strategy much earlier in 2013. The EC and Parliament approved and put into effect the EU MRV Regulation (EU) 2015/757 on "Monitoring, Reporting and Verification (MRV) of carbon dioxide emissions from maritime transport" on July 1, 2015 (ICS, n.d.). The EU MRV regulation, however, was the only tangible step that was put into effect. Large ships with a 5000 gross tonnage are required to monitor and report their CO_2 emissions in January 2018 in accordance with the required EU MRV regulation (EC, n.d.-n). Even though the regulation does not aim to reduce emissions directly, it is suggested that gathering information is crucial so that participants can use it to reduce emissions. Additionally, it is required for the inclusion of shipping in the EU ETS and the FuelEU Maritime, as the MRV data will be used in order to set the baselines for both initiatives.

On July 14, 2021, the EC unveiled the "Fit for 55" package, which includes measures to perform the targets specified in the Green Deal. The plan seeks to cut GHG emissions from all types of transportation by 90% (EC, 2021a).

The EU hopes to direct its R&D activities and ensure this transition quickly and effectively to be the first climate-neutral continent with the policy tools and legal regulations mentioned above (EC, n.d.-c, p.). It wants to increase the share allocated to R&D in all sectors including shipping industry. Looking at the share allocated to R&D in GDP, it is seen that the EU allocates a budget of 2.2% for R&D (see Figure 7).

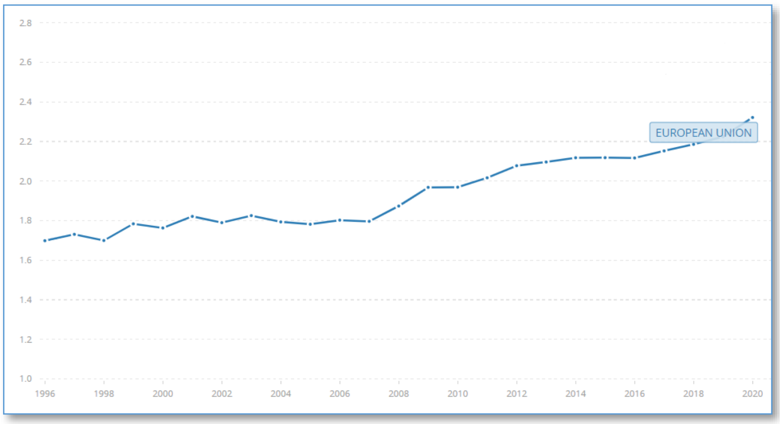


Figure 7 R&D Expenditure (%GDP), EU
(Source: (World Bank, 2020)

The R&D expenditure of the EU transport sector is constantly increasing. In particular, the automotive and other transport sectors (aviation, shipping) industry occupy a leading position in the world (Grosso et al., 2020).

In particular, R&D and innovation play a critical role in reaching the targets within the scope of the EU green deal, ensuring the decarbonization of all sectors including shipping industry, and helping companies and researchers overcome obstacles by developing innovation (Rissman et al., 2020). In this sense, the EU carries out many direct and indirect funding and grant programs for R&I projects. The most important of these are as listed in Table 1. This fund concerns all sectors in the EU from the programs except the European Maritime and Fisheries Fund (EMFF).

Table 1 The EU R&I Funding Programs
(Source: (EC, n.d.-e)

Horizon Europe, the new EU R&I Framework Program
ETS Innovation Fund
InvestEU
European Regional Development Fund (ERDF)
European Bank for Reconstruction and Development (EBRD)
European Social Fund (ESF)
Cohesion fund (CF)
Connecting Europe Facility (CEF)
European agricultural fund for rural development (EAFRD)
European Investment Bank (EIB)
InvestEU Connecting Europe Facility (CEF)
European Maritime and Fisheries Fund (EMFF)

These supports and funds alone are not enough alone themselves. Shipping companies also need to invest in full decarbonization. According to research commissioned by the Global Maritime Forum, a total investment of US$1 trillion to US$1.4 trillion, or an average of US$50 billion to US$70 billion annually for 20 years, is required to reach the 50% emission target between 2030 and 2050. Shipping will need an additional $400 billion in expenditures over the following 20 years to fully decarbonize by 2050, shown in Figure 8, increasing the total to $1.4 to 1.9 trillion (Krantz et al., 2020). For the EU, it is estimated by McKinsey that in order to become net-zero, a budget of at least 28 trillion euros should be allocated in the next 30 years (McKinsey, 2020). In other words, an annual investment of at least €1 trillion is required. As shipping contributes 3-4 percent to emissions for both the EU and the maritime industry, at least 4-5 billion euros are required each year for the maritime industry.

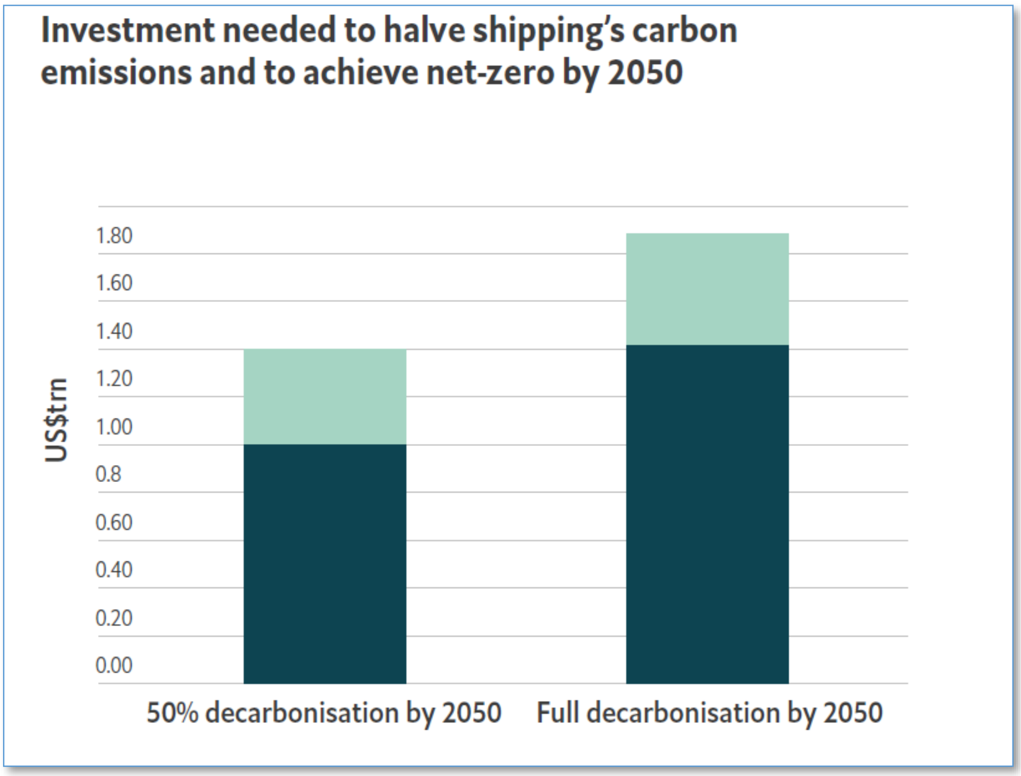


Figure 8 Necessary Investment for Full Decarbonization of Shipping
(Source (WOI, 2020)

2.2 EU REGULATIONS AND PROPOSALS

As stated earlier, to reduce the EU's overall GHG emissions by 55% by 2030 and establish the framework for full EU decarbonization by 2050, the EC released its Fit for 55 package on July 14, 2021. The EU and its 27 member states intend to implement the Fit for 55 package of legislative reforms to meet the EU's 2030 climate goal. It contains legislation regarding below that is shown in Figure 9 (EC, n.d.-g). In this package, four of them are of particular maritime concern. These;

- The European Trading System Directive (EU ETS)
- The FuelEU Maritime Regulation
- The Alternative Fuels Infrastructure Regulation
- The Energy Taxation Directive

Figure 9 EU Fit for 55 Package
(Source: Noyens & Rosa, 2021)

2.2.1 Shipping and the EU ETS

A carbon market, the EU ETS runs on the "cap and trade" idea. This indicates that a corporation is free to release a specific total amount of GHG emissions. The company should purchase additional emission permits if its emissions exceed this cap. An economic incentive to cut emissions is offered by the EU ETS (EC, n.d.-d). The maritime sector was also decided to be included in the Emissions Trading System by the EC in 2023. According to this proposal, EU ETS Scheme is as follows in Figure 10 (Hagberg, 2022).

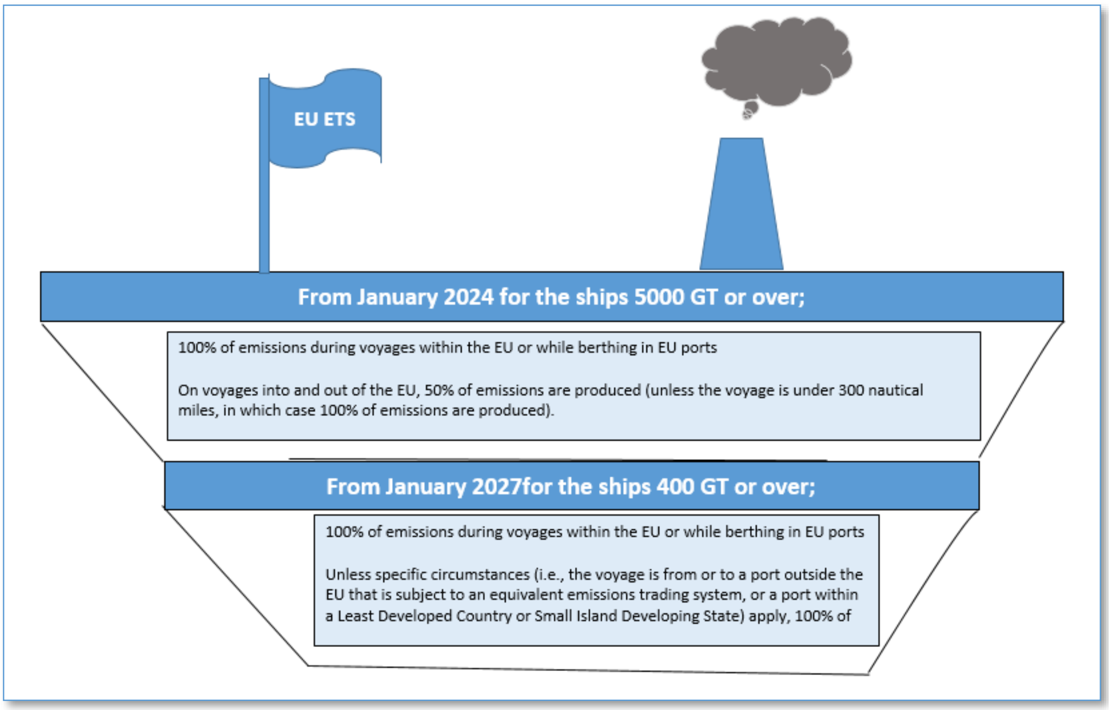


Figure 10 EU ETS Maritime Scheme
(Illustrated by Author)

2.2.2 The FuelEU Maritime Regulation

Starting in 2025, this legislation restricts how much energy is consumed by vessels. In terms of grams of CO_2 emissions per tonne of nautical miles, carbon intensity measures how effectively a ship transports cargo or passengers (Europarl, 2022b).

The legislation functions by placing a cap on the quantity of GHG emissions that ships are allowed to emit while in European ports. It stipulates, more particularly, that carbon intensity must be reduced by 2% in 2025 and 6% in 2030. Carbon intensity should be 75% lower in 2050 than it was in 2020 (DNV, 2021a)

2.2.3 The Alternative Fuels Infrastructure Regulation

According to the regulation, the EU countries are obligated to create national policy frameworks to build publicly accessible refuelling and charging stations for alternative fuel vehicles and vessels under the Alternative Fuels Infrastructure Regulation (Europarl, 2022a).

2.2.4 The Energy Taxation Directive

This directive is to encourage a shift to cleaner energy and more environmentally friendly industries by bringing the taxation of energy products in line with the EU's current energy and climate policy. It regulates minimum consumption tax rates to promote a low-carbon and energy-efficient economy. (EC, n.d.-h).

2.3 R&D and INNOVATION FOR DECARBONIZATION

R&D and innovation are crucial for all sectors to transition to a zero and/or low-carbon economy, reduce greenhouse gas emissions and do so cost-efficiently (Bergset & Fichter, 2015). Numerous technologies promise to lower the usage of carbon-based energy sources or greenhouse gas emissions, including fusion energy, bio-based fuels, carbon capture and storage, photovoltaics (PV) panels, and so-called smart energy systems (Labanca et al., 2020). These technologies are essential for increasing the energy efficiency and reducing emissions to zero in all sectors.

The situation is not different for shipping. One of the most important factors in reaching the 2050 targets at IMO and/or EU level is technological development. Various solutions are either actively being developed or have been adopted in ship fleets to reduce emissions from waterborne transportation. The maritime sector hopes to increase technological innovations in this sector by investing its R&D expenditures to achieve its decarbonization targets.

According to the International Energy Agency (IEA), it is observed that the R&D spending made in the maritime sector between 2007 and 2019 unfortunately remained constant and lagged behind other sectors. While the maritime industry spent 1.6 billion dollars in 2019, the automotive industry, another transportation industry, spent 130 billion dollars in R&D, about 80 times that the maritime industry (see Figure 11) (IEA, 2020).These figures show how much the maritime industry needs R&D and innovation. The maritime industry is also aware of this situation and is trying to develop some solutions. For example, there is the "Trade & Transport Impact" Program initiated by important companies such as Inmarsat, Wilhelmsen, Cargotec, Shell, HHLA and Wärtsilä to raise awareness of this lagging and to create start-ups focusing on decarbonization, supply chain resilience, and safety solutions (T&TI, n.d.). Another example in this regard is the proposal of the ICS to IMO to establish an R&D fund (described in more detail in 2.4.3.), emphasizing the need for more R&D and innovation for the decarbonization of shipping (ICS, 2021).

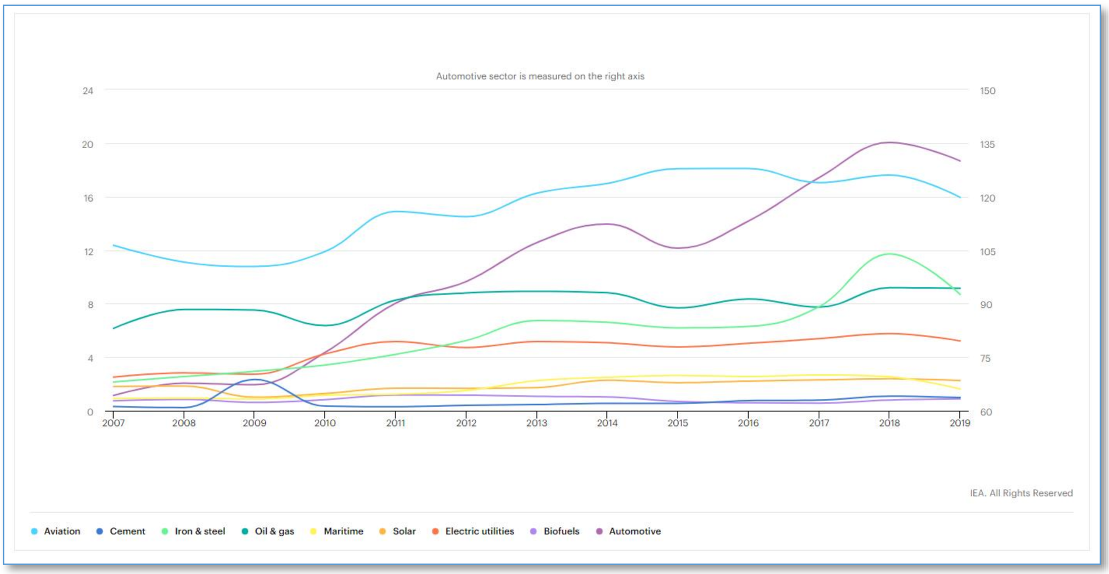


Figure 11 R&D Spending of Selected Sectors, 2007–2019
(Source: (IEA, 2020)

The EU is also trying to increase R&D and innovation in the maritime sector and in all other sectors to reach emission targets by 2030 and 2050. As part of the "Europe on the Move" initiative, the EC adopted the Strategic Transportation Research and Innovation Agenda (STRIA) in May 2017. STRIA outlines the key R&I priorities and areas in transport for connected, competitive, and clean transportation (Grosso et al., 2020).

2.3.1 Bluetech Start-Ups

Start-ups and researchers play a great role in making for the R&D, innovations, and technological developments required for the decarbonization of the maritime industry. Especially since 2010, innovation, and economic growth have increasingly come from start-ups (Heinonen et al., 2016). For this reason, today clean-tech start-ups are getting more investment and attention from investors than ever. For instance, according to Larry Fink, CEO of the Blackrock, world's largest asset manager, climate-tech start-ups will be key to achieving net zero carbon emissions by 2050, and the next 1,000 unicorn (tech start up having a total market value of more than $1 billion**)** companies will be climate-tech start-ups (Clifford, 2021). This expectation also causes an increase in investors' interest in clean-tech start-ups. The average time it takes for early stage start-ups to become unicorns is seven years (Embroker, 2021).

When the sectoral distribution of start-ups funded by VC companies is analysed in 2022, it is seen that clean-tech start-ups have a rate of 8 percent, as shown in Figure 12.

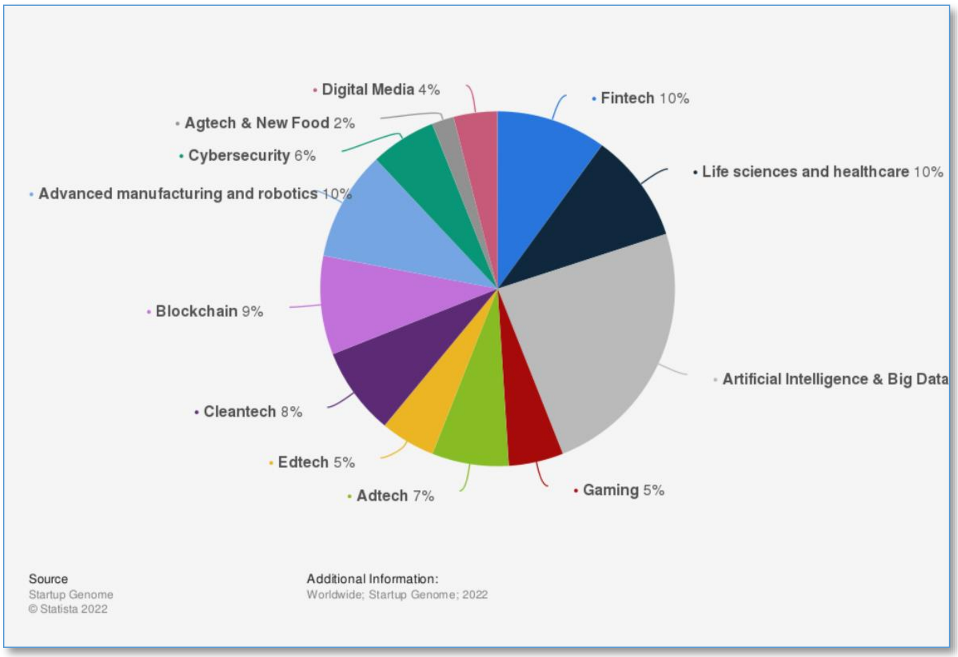


Figure 12 Global Distribution of VC-Funded Start-ups by Industry,2022
(Source: (Statista, 2022b)

Especially after the COVID-19 pandemic in 2020, investment in clean-tech start-ups is also increasing. According to the report prepared by a global consulting company called PwC, while 28.4 billion dollars were invested in the whole of 2020, it is stated that more than 60 billion dollars were invested in these solutions from private sector and VC funds in the first half of the 2021(PwC, 2021). When the trend in the funding of VC companies to these start-ups during 2017–2022 is examined, it is observed that there is an increase of 35 percent, as shown in Figure 13 (Statista, 2022a). Although this increase is positive, it is not yet at a sufficient level for the world to be fossil-free, there should be more start-ups and more investment.

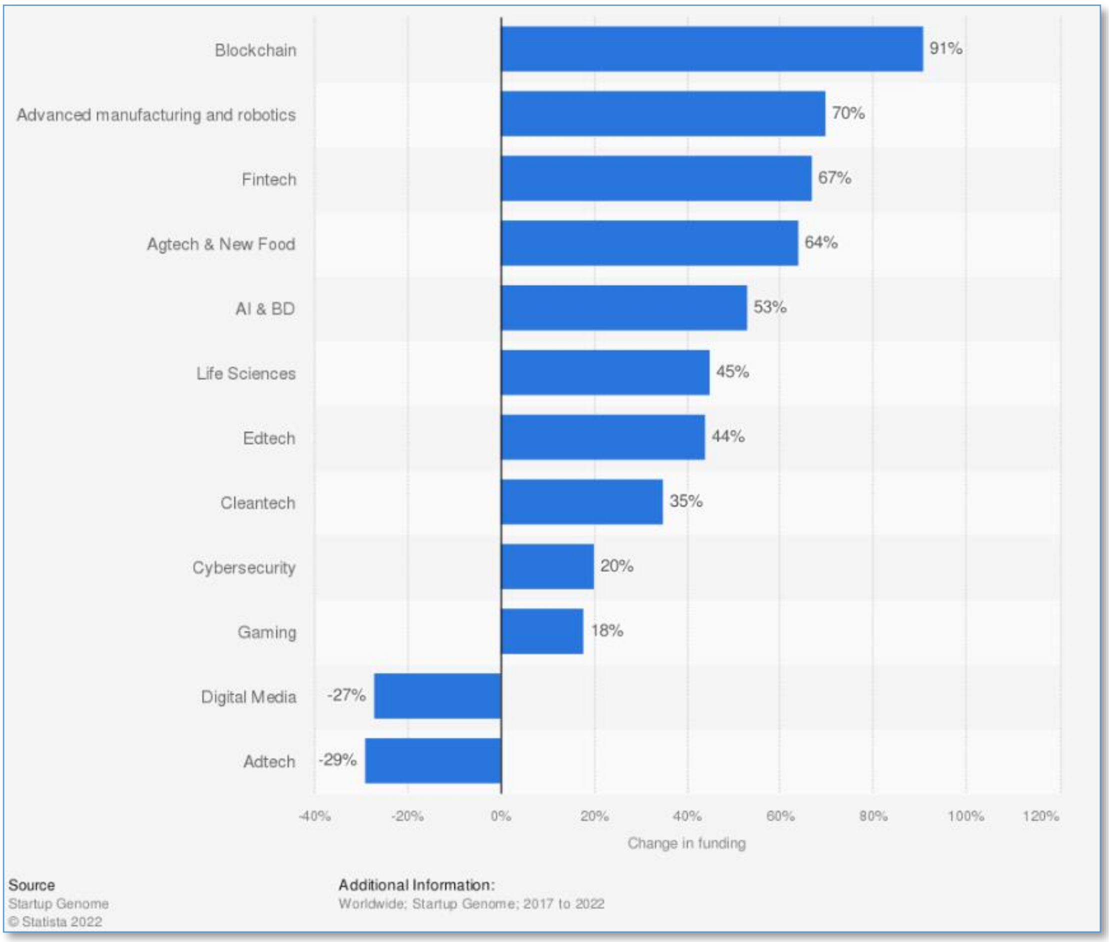


Figure 13 Changes in Start-up Funding (2017-2022)
(Source: (Statista, 2022a)

Start-ups that try creating value for the blue economy with environmentally friendly and sustainable innovations are also called blue or bluetech start-ups. Bluetech, which can be broadly described as any technology used in the ocean, frequently focuses on technology that promotes environmental, social, and economic sustainability in the ocean (CIC, 2020). The sustainable development goals (SDGs) for sustainable ocean development are significantly advanced by Bluetech (Hansen et al., n.d.).

Examining unicorn companies that focus on maritime decarbonisation, there is no unicorn operating in this sector yet. There are some unicorn companies in the logistics and supply chain, renewable energy and transportation industries. For example, in the

US there is a unicorn named “Shippo” that helps the shipping operation of e-commerce companies. These companies also contribute to the green economy, but the lack of unicorns covered by the shipping industry stands out as a major shortcoming. When unicorns are examined by industry in Table 2, it is seen that there are the most unicorns in the world in the fintech, and then; It is observed in e-commerce, software as a service, health technologies, and artificial intelligence industries (Hurun, 2022).

Table 2 Unicorns by Industry

Rank	Industry	No. of Unicorns	% of Total Value
1 (0)	FinTech	168	17.6%
2 (+1)	E-commerce	127	9.1%
2 (0)	SaaS	127	9%
4 (+1)	Health Tech	97	5.3%
5 (-1)	Artificial Intelligence	94	5.7%
6 (0)	Cyber Security	61	3.3%
7 (+1)	Blockchain	52	5.4%
8 *	Enterprise Services	40	2.1%
8 *	Logistics	40	3.1%
10 (-3)	Biotech	37	1.9%

** New to index*
Source: Hurun Research Institute

2.3.2 Bluetech Investors

Financing is one of the most important instruments for start-up ecosystem to achieve the zero-carbon targets of shipping. Increasing the interest of investors in start-ups and/or maritime companies that develop these decarbonization solutions by developing the blue investment ecosystem is extremely important. Especially with the importance of sustainable blue finance recently, financing the decarbonization of maritime has become extremely important. According to the International Finance Corporation (IFC), Blue Finance is one of the developing fields of the Climate Finance with increasing interest from investors, financial institutions, and issuers. By promoting economic development, bettering the standard of living, and maintaining the health of marine ecosystems, it aids in resolving urgent issues (IFC, n.d.).

2.4 FINANCING OF DECARBONISATION OF THE EU SHIPPING INDUSTRY

How to close the cost gap between conventional marine fuels, technologies and zero-carbon fuels and innovative technologies is one of the most important challenges facing the shipping industry that wants to move to a zero-carbon system. Key stakeholders in the maritime industry state that funding decarbonization is the main challenge (LR, 2021). The establishment of maritime funds for the transition to zero carbon is of critical importance. In the next five years, 62% of ship-owners are likely or very likely to form joint ventures to finance the innovation, according to a report authored by Lindsey Keeble and George Paleokrassas, co-heads of the WFW Global Maritime Sector (Keeble et al., 2021).

The International Chamber of Shipping (ICS) has also submitted a proposal to IMO to establish a fully automated R&D fund "IMO Maritime Research Fund (IMRF)" of 5 billion dollars over 10 years for developing zero-carbon technology and fuel solutions in the maritime sector to achieve the IMO 2030 and 2050 targets. A $2 tax per tonne of marine fuel used is intended to raise US$ 5 billion (ICS, 2022). Although this proposal was rejected, the fact that the urgency to establish a fund is being discussed is positive for the maritime sector.
The situation in the EU is more advanced than in the IMO, it is at the stage of action, and there are effective funds to combat climate change within the scope of the EU Green Deal. A significant budget has been allocated for the development and support of the R&D and innovation ecosystem.

2.4.1 EU Decarbonization Funds

There are funds designed and carried by the EU to serve the 2030 and 2050 climate goals. The EU had planned 20% of the total budget for the years 2014–2020 in the fight against climate change and spent 220.8 billion euros more than it targeted. For the 2021–2027 period, at least 30 percent of the budget is planned to be spent on combating climate change (EC, n.d.-g). These expenditures also effectively use some funds for the transition of EU member countries to climate neutrality.

The funds are not directly specific to the maritime sector, but are funds that the maritime sector can benefit from. These funds are described below.

2.4.1.1 EU ETS Innovation Fund

The ETS Innovation Fund was created to fund highly innovative emission reduction technologies and solutions, with funding from EU Emissions Trading System (ETS) revenues. This fund is expected to have a budget of approximately 38 billion euros between 2020 and 2030. The size of the fund is also variable, as the fund depends on the change in carbon prices in the ETS. The overview of this fund is shown in Figure 14.

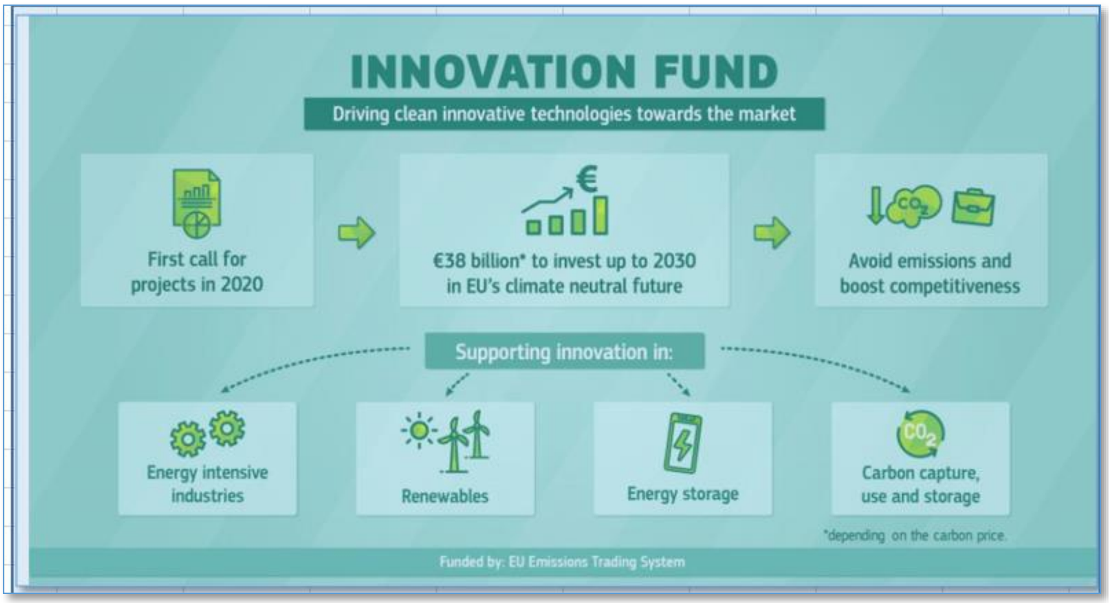


Figure 14 EU Innovation Fund
(Source: (EC, n.d.-o)

As explained in 2.2.1, the shipping sector has also been decided to be included in the ETS in 2023. The European Parliament (EP) has recently brought a proposal to establish an Ocean Fund to support maritime decarbonisation. According to the proposal, to promote the transition to an energy- and climate-resilient EU maritime industry, 75% of the revenues from the auctioning of ETS maritime allowances will go into an Ocean Fund for the period from 2023 to 2030. 20 percent of the fund will be used to effectively manage, protect and restore marine ecosystems affected by global warming (Europarl, 2022c).

2.4.1.2 Modernisation Fund

The Modernization Fund is a special funding initiative designed to assist 10 lower-income EU Member States in their transition to climate neutrality by assisting in the modernization and improvement of their energy infrastructure. This fund will support investments in the production and use of energy from renewable sources, energy efficiency, energy storage, modernization of energy networks, including district heating, pipelines, and grids, just transition in carbon-dependent regions, redeployment, education, job-search programs, start-ups, and worker re- and up-skilling. Funding for this fund comes from the proceeds of the auctioning of 2% of the total allowances for 2021–30 under the EU Emissions Trading System (EU ETS) as well as additional allowances transferred to the Modernization Fund by beneficiary Member States—5 of which chose to do so (Lithuania, Slovakia, Croatia, Czechia and Romania) (EC, n.d.-l)

2.4.1.3 Life Program

The Life program consists of four main parts.

- Adaptation and Mitigation of climate change,
- Transition of Clean Energy
- Biodiversity and Nature

- Quality of Life and Circular Economy

The program has three priorities: climate change mitigation, climate change adaptation and climate change management. LIFE assists in transforming the Union into a resilient, climate-neutral society. About € 905 million is managed by the LIFE Climate Change Mitigation and Adaptation sub-programme to create and put into practice innovative solutions to climate concerns (EC, n.d.-k)

2.4.1.4 NER 300 Program

A funding program called NER 300 pools about EUR 2 billion for cutting-edge low-carbon technology, with a focus on the commercialization of CCS (Carbon Capture and Storage) and cutting-edge renewable energy technologies in the EU. It is intended to support both renewable energy technologies, such as wind, concentrated solar power, photovoltaics, ocean, hydropower, geothermal and smart grids, as well as CCS technologies, such as pre-combustion, post-combustion, oxyfuel, and industrial applications (EC, n.d.-m).

2.4.1.5 Horizon Europe Program

With a budget of €95.5 billion, Horizon Europe is the primary EU funding program for research and innovation. This program is carried out according to the co-financing model principles. It combats climate change, aids in the accomplishment of the Sustainable Development Goals set forth by the UN, and increases the EU's competitiveness and growth. There are 6 main clusters, and one of them is “climate, energy, and mobility”. It provides funds for innovative and cutting-edge projects in this field (EC, n.d.-i).

2.4.1.6 European Regional Development Fund (ERFD)

By addressing regional imbalances, the European Regional Development Fund (ERDF) seeks to promote the economic, social, and geographical cohesion of the EU. This fund aims to support the competitiveness of small- and medium-sized enterprises (SME), the generation and application of cutting-edge information and knowledge, and the advancement of the low-carbon economy. Because the financing is applied to incurred expenditures incurred, the applicant must have "buffer funding."). Under this fund, there are some funds that the maritime sector can benefit from. The Cohesion Fund is one of them (EC, n.d.-f).

2.4.1.7 InvestEU Fund

Initiated by the European Investment Bank (EIB) and the EC, InvestEU aims to stimulate the economy by leveraging private capital for key investments. This program supports the EU recovery efforts and offers long-term assistance to businesses. To complement the reforms and investments made by Member States, it will make loans and grants totalling €672.5 billion accessible (EU, n.d.).

2.4.2 Other decarbonization funds in the world

2.4.2.1 Green Climate Fund

The Green Climate Fund (GCF) is a fund established as an operating entity of the financial mechanism within the framework of the United Nations Framework Convention on Climate Change (UNFCCC) to assist developing countries in adapting and mitigating climate change. 194 parties to the UN Framework Convention on Climate Change established the GCF in 2010. A Board of 24 people oversees it, with a Secretariat providing administrative assistance. Over time, the GCF strives to achieve a 50:50 balance between investments in mitigation and adaptation. In terms of promises from 49 nations, regions, and cities as of July 31, 2020, the GCF had raised

USD 10.3 billion. 23 EU members contributed approximately 3.6 billion dollars to this fund (GCF, 2020).

2.4.3.2 The Catalyst Energy Program

A new framework for how businesses, governments, and private charity can finance, manufacture, and purchase new solutions to speed up a low-carbon economy is called the Catalyst Energy Program, which is part of Breakthrough Energy. The primary goal of Catalyst will be to hasten the creation and adoption of clean technologies. An important example of these is the agreement with the EU.

The EC and Breakthrough Energy Catalyst Program have entered into a new partnership that aims to mobilize new investments of up to €820 million/$1 billion between 2022 and 26 to build large-scale, commercial demonstration projects for clean technologies, lowering their costs, accelerating their deployment, and delivering significant reductions in CO_2 emissions in accordance with the Paris Agreement. This new collaboration plans to invest initially in four sectors of high-impact projects situated in the EU that have the potential to contribute significantly to the achievement of the economic and climatic goals of the European Green Deal shown in Figure 15.

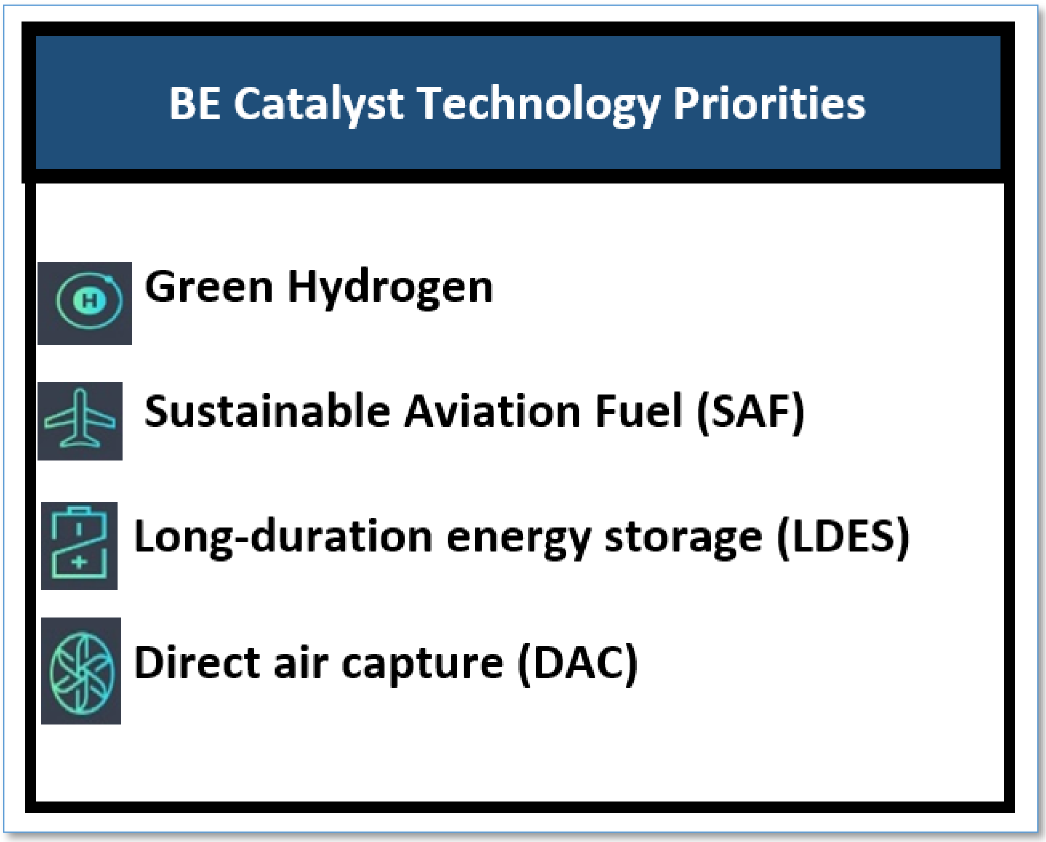


Figure 15 Breakthrough Catalyst Technology Priorities
(Source: (BE, n.d.-a)

2.4.2.3 NO_x Fund – Norway

An effective program to encourage emission reductions is the Norwegian NO_x Fund. Norwegian nitrogen oxide (NO_x) emissions have fallen by 44,000 tonnes since the NO_x Fund was established in 2008. The NO_x Fund supports the industry's adoption of green technologies financially, accelerating efforts to reduce NO_x emissions. Over NOK 4 billion (US $467 million) has been distributed by the Fund to help NO_x reductions, with Norwegian businesses leading the globe in this area. Instead of paying the state's NO_x tax, businesses that join the NO_x Fund pay a lower fee per kilogram of NO_x to the Fund. The payment rates for high rate and low rate NO_x have increased as of January 1, 2019, to 14.5 NOK and 8.5 NOK, respectively. The supplier industry has benefited from the NO_x Fund. Since 2008, the Fund's support has increased demand for NO_x-reducing solutions by NOK 14 billion, particularly in the maritime industry, which has received most of the Fund's support. This has helped Norway's maritime sector maintain its competitive edge on the global market. The working mechanism of the fund is summarized in Figure 16 (NOx-fondet, 2022).

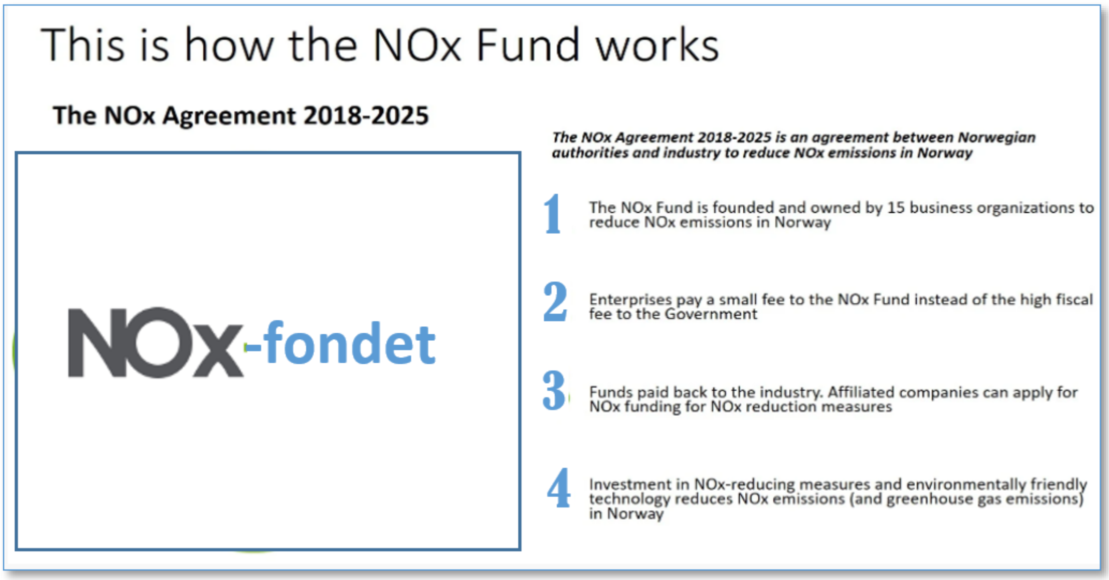


Figure 16 Norway NOx Fund
(Source: (NOx-fondet, 2022)

2.4.2.4 Emission Reduction Fund – Australia

One of the exemplary funds in the world to reduce GHG emissions is the Emission Reduction Fund implemented by the Australian government. Projects that prevent the release of greenhouse gas emissions or extract and sequester carbon from the atmosphere can be carried out in Australia with the help of the Emissions Reduction Fund (ERF), which is available to landowners, communities, and enterprises.

2.4.2 Philanthropic Funds

Another important funding tool in the fight against climate change and the reduction of GHGs is charitable foundations.

To raise more money for research and innovation, the EC is exploring potential initiatives to expand the role of philanthropic organizations and plans to spend more common philanthropic funds in the US and UK on R&D and innovation within the EU as well. Efforts have been made for years to create an expert group at the EU level to ensure that these funds are more accessible (EC, n.d.-j). Global philanthropic giving of all kinds reached a record high of €660 billion ($750 billion) in 2020. Despite this encouraging expansion, fewer than 2% of European foundations' total giving goes toward efforts to combat climate change. However, there have also been positive developments. Some leading European foundations have started to committing to allocating significant resources to combat climate change. For example, IKEA pledged to allocate 1 billion euros and the “Quadrature Climate Foundation” 100 million dollars (Roeyer et al., 2021). As Figure 17 shows, it is seen that European foundations have also increased their funds recently in the fight against climate change, although it is lower than foundations outside of Europe.

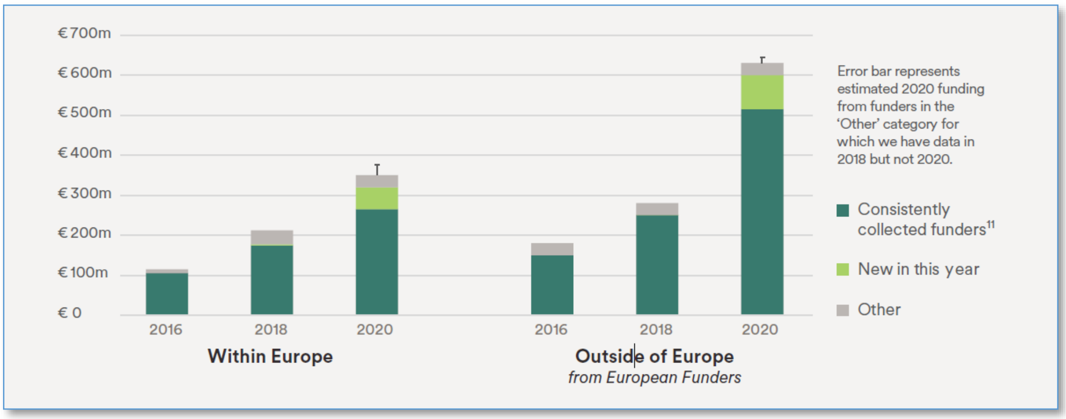


Figure 17 Climate Funding of Foundations
(Source: (Roeyer et al., 2021)

When looking at the funds that foundations contribute to climate change in Europe by country (See Table 3), it is observed that the United Kingdom, Netherlands, Denmark and Germany provide the most funding.

Table 3 Distribution of Funding by Country
(Source: (Roeyer et al., 2021)

Country	Value of grants received 2016, 2018, 2020 combined €m	($m)	Number of grants received 2016, 2018, 2020 combined	% of funding received by European countries *Excluding funding to "Europe, regional"*	% of population of the 45 countries covered
United Kingdom	€150	($170)	770	30%	9.8%
Netherlands	€95	($110)	115	19%	2.5%
Denmark	€70	($80)	85	15%	0.9%
Germany	€43	($50)	320	9%	12.1%
France	€27	($31)	695	5%	9.8%
Sweden	€24	($27)	40	5%	1.5%
Italy	€22	($25)	175	4%	8.7%
Switzerland	€17	($19)	115	3%	1.3%
Finland	€15	($17)	215	3%	0.8%
Poland	€8.2	($9.6)	165	2%	5.5%
35 other European countries combined	€26	($30)	554	5%	47.1%
TOTAL Excluding funding to "Europe, regional"	**€495**	**($570)**	**3,250**	**100%**	**100%**

It is seen in Table 4 that the fund allocated by foundations in Europe for the decarbonization of the maritime sector was 1.4 million Euros in total in 2016, 2018, a

Table 4 Funding for Transportation Sector by Foundations
(Source:(Roeyer et al., 2021)

Sector	Strategy	To Europe 2016, 2018, 2020 combined €m	($m)	Outside Europe, from European funders 2016, 2018, 2020 combined €m	($m)
Transportation	**Transportation Sector Total**	**€28**	**($33)**	**€22**	**($25)**
	Aviation	€0.4	($0.4)	€0.5	($0.5)
	Maritime Shipping	€1.4	($1.6)	€4	($4.5)
	Vehicle Efficiency	€4.6	($5.3)	€0.8	($0.9)
	Zero Emission Vehicles	€13	($15)	€3.2	($3.7)
	Other Transportation Strategies	€9	($10)	€14	($16)

2.5 GREEN PREMIUMS

A proposition put forward by the US businessman and philanthropist Bill Gates, who has important projects and investments on climate change, is "Green Premium." The cost difference between doing something in a method that emits greenhouse gases and doing the same thing without the emissions is known as the "Green Premium." (see Figure 18)." Currently, clean solutions are typically more expensive than those with high emissions, in part because the full economic and environmental costs of current energy sources like fossil fuels are not considered when determining the price paid for them (BE, n.d.-b).

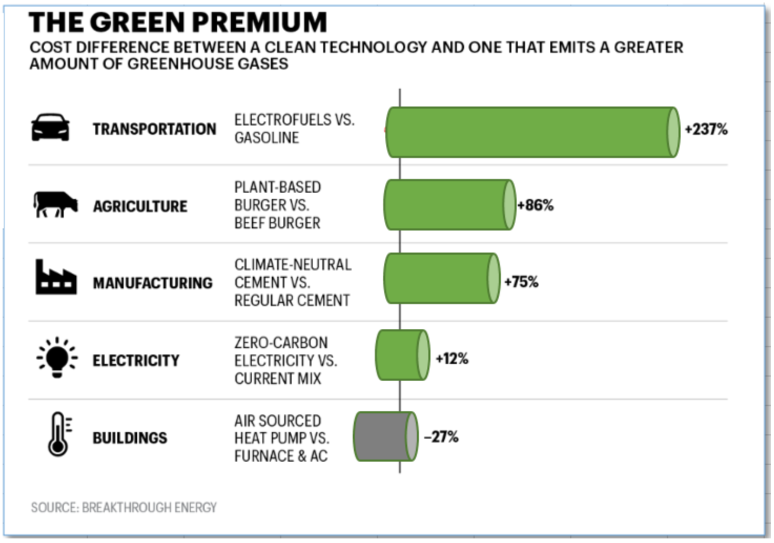


Figure 18 The Green Premium
(Source: (BE, n.d.-b)

2.6 ISRAEL YOZMA FUND MODEL

The Israeli Government started a program called "YOZMA FUND" in 1993 in order to mobilize and attract foreign VCs in the country. With this program, the state created a $100 million fund basket to be used as core capital for the private sector. In this program, which is shown as an example of success worldwide, an investment company named “Yozma Private Equity” was established to manage the main fund. Yozma achieved great success in a short time (attracting many foreign investors as listed in Table 5) and was privatized after four years. The size of the VC industry in Israel, which was 58 million dollars in 1991, increased to more than 6.5 billion dollars in 2000 thanks to this program (Yozma, n.d.).

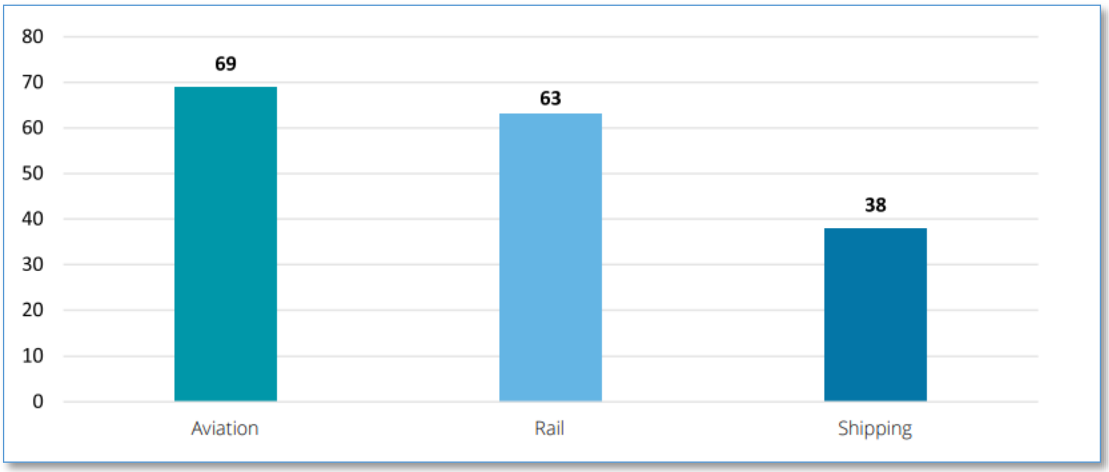
What made the Yozma Program most attractive was that the state was a 40% partner in each initiative. If the venture was successful, it would contribute to the sustainability of the fund by earning its profit from the venture. In case of failure, it did not have any expectation from the attempt. In this way, it revived the entrepreneurship ecosystem by bringing foreign VC companies to the country (Avnimelech, 2009).

Table 5 YOZMA Funds – Capital, Foreign Investors and Portfolio
(Source: (Avnimelech, 2009)

Name	Est.	Capital	Foreign LP	LP Orion	Portfolio	Exits
Eurofund	1994	$20M	Daimler-Benz, DEG	Germany	14	7 (50%)
Gemini	1993	$36M	Advent Venture Partners	USA	25	13 (52%)
Inventech	1993	$20M	Van Leer Group	Netherlands	33	16 (48%)
JVP	1993	$20M	Oxton	USA	12	10 (83%)
Medica	1995	$15M	MVP	USA	10	5 (50%)
Nitzanim	1994	$20M	AVX, Kyocera	Japan, Japan	13	7 (54%)
Polaris (Pitango)	1993	$20M	CMS	USA	19	13 (68%)
Star	1993	$20M	TVM Siemmens	Germany	27	15 (56%)
Vertex	1996	$39M	Vertex Int., Singapore tech	USA , Singapore	29	16 (55%)
Walden	1993	$33M	Walden International	USA	21	10 (48%)
Yozma	1993	$20M	None	IL Gov.	16	10 (63%)
Total		**$263M**			**217**	**122 (56%)**

2.7 ESG and FINANCIAL SUSTAINABILITY

The capital market investment choices of investors and the availability of funding for shipping companies are now influenced by recent developments in sustainability, or Environmental, Social, and Governance (ESG) performance (PwC, n.d.). It has become important for shipping companies to increase their ESG scores as the capital invested by the funds in companies that meet the ESG criteria has increased by 170% from 2015 to 2021. As of October 2021 data, according to the evaluations of Refinity, one of the ESG rating organizations, the ESG score of maritime seems to lag behind aviation and railway, as shown in Figure 19 (Deloitte, 2021).



Refinity ESG Score

Figure 19 ESG Scores for Transportation Sectors
(Source: (Deloitte, 2021)

Chapter 3

3.0 DECARBONIZATION SOLUTIONS OF THE SHIPPING INDUSTRY

3.1 ALTERNATIVE FUELS

Several industrialized nations have recently shown interest in clean fuels as potential alternatives to traditional fossil fuels. As mentioned earlier, among the long-term goals of IMO is to enable the maritime sector to switch to alternative fuels. Currently, various alternative fuel sources are offered for shipping, including biomethanol, ammonia, dimethyl ether (DME), biodiesel, and gaseous fuels like LNG (liquefied natural gas) and bio-LNG. Electricity is another viable energy vector, particularly for short-haul voyages (Prussi et al., 2021). Some of the most promising fuels and energy sources have the following impact on the maritime industry's ability to reduce emissions, according to an OECD report as listed in Table 6 (OECD, 2018)

Table 6 GHG Reduction of some decarbonization solutions on the shipping
(Source: (OECD, 2018)

	GHG Emission Reduction Rate
Advanced Biofuels	25-100%
LNG	0-20%
Hydrogen	0-100%
Ammonia	0-100%
Fuel Cells	2-20%
Electricity	0-100%
Wind	1-32%
Solar	0-12%
Nuclear	0-100%

Based on the CO_2 emission reduction impact above, alternative fuels are critical for decarbonization. However, the switch to alternative fuels is extremely complicated and calls for collaboration with several players along the value chain as well as a global perspective that transcends various stakeholder groups (Foretich et al., 2021a). A challenge is that there is no consensus in the shipping industry over which low-carbon alternative fuel to switch to. Alternative marine fuels include LNG, methanol, LPG, ethane, hydrogen, and more cutting-edge options including solar, wind, and biomass energy (Zincir, 2020). Moreover, according to the DNV, which is one of the most important classification societies, battery systems, fuel cell systems, and wind-assisted harbour propulsion would be promising sources of energy for the shipping industry, but these technologies are still in the development stage (Butarbutar et al., 2022). Even though some of these fuels and technologies may ultimately prove to be merely interim solutions, they are nonetheless crucial to the industry's transition to a carbon-neutral future. While hydrogen, methanol, and ammonia are the most viable solutions from a socioeconomic cost standpoint, there is no clear winner because of the huge cost uncertainty. LNG is an alternate intermediate solution with a limited window of opportunity (Xing et al., 2021).

The issue of which alternative fuel should be used by ship owners includes many technical, economic and operational considerations. For example, as shown in Figure 20 below, alternative fuels have different technical properties from each other (Ulstein, 2021).

	MDO	LNG	Methanol	Biodiesel	Ammonia	Hydrogen	Battery
SO_x, NO_x, PM Emissions	X	✓✓	✓✓	X	✓	✓✓✓	✓✓✓
Carbon (CO_2) Emissions	XX	X	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓
Flammability	✓✓✓	✓✓✓	✓	✓✓✓	✓✓	XX	
Toxicity	✓✓✓	✓✓✓	✓	✓✓✓	XX	✓✓✓	
Technological Maturity	✓✓✓	✓✓✓	✓	✓✓	X	X	✓✓
Energy Cost	✓✓	✓✓✓	✓	X	XX	XX	XX
Bunkering Availability	✓✓	✓	X	X	X	X	✓

	Pros		Cons
"+"		"-"	
"++"		"--"	
"+++"			

Figure 20 Comparison of Alternative Fuels
(Source: (Ulstein, 2021)

However, among these proposed alternative fuels currently have large-scale production capabilities, therefore comparing the broad volumes needed by a particular market could provide a realistic view of the potential contribution to a particular solution (Prussi et al., 2021). In some studies, alternative fuels are ranked according to some criteria. For example, study based on ten performance criteria of alternative fuels including economic, environmental, technical, and social aspects conducted by Hansson et al., for seven alternative fuels, LNG has been revealed as the fuel with the most potential, followed by heavy fuel oil (HFO), fossil methanol, and biofuels. However, since LNG is a fossil fuel, it is not a suitable solution for long-term zero carbon targets at IMO and EU levels, so it was not preferred for the alternative fuel scenario in the fifth chapter.

3.1.1 Liquefied natural gas (LNG)

Natural gas is a reasonably inexpensive, green, and energy-efficient fossil fuel that is becoming more and more popular since it can be used in so different industries (Zanne & Fabić, 2009). In terms of decarbonization of the shipping industry, LNG is an important alternative solution, especially for reducing CO_2 emissions and promoting environmental sustainability. For this reason, the maritime industry has had a significant interest in investment in LNG recently. The most recent data from DNV's Alternative Fuels Insight platform (see Figure 23) shows that there are 313 LNG-fuelled ships in use and 503 orders and (AFI, 2022).

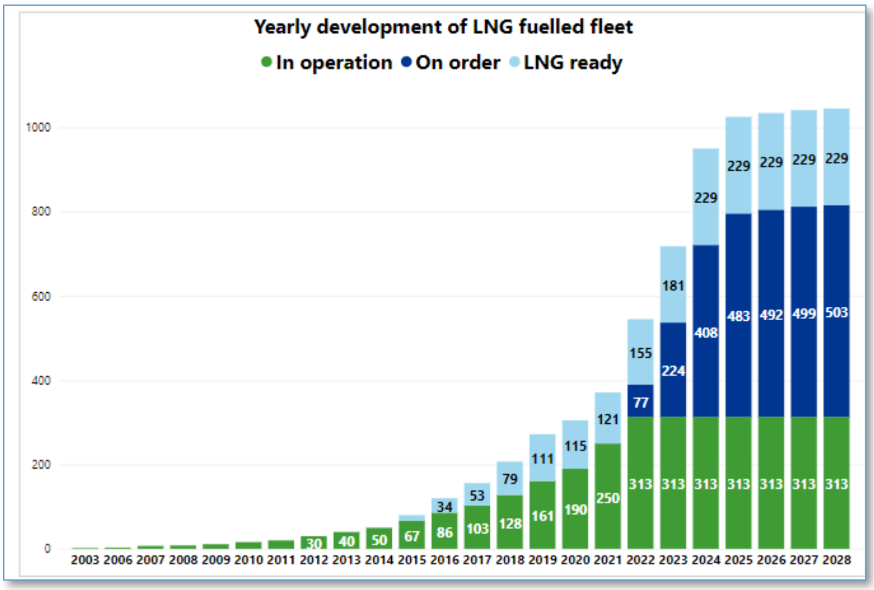


Figure 21 LNG-Fuelled Ships
(Source: (AFI, 2022)

Compared to distillate fuels and very low sulphur fuel oil (VLSFO) products, its carbon dioxide emissions are around 20% lower (Pribyl, 2022). There are some other important advantages as well. For example, LNG is a good alternative for ship-owners to meet IMO's low sulphur requirements (Wu & Lin, 2021). It also provides up to 80% reduction in NO_x emissions (DNV, n.d.). Besides these, the particulate matter (PM) emission rate is for LNG is very low (Lopez-Aparicio & Tønnesen, 2015). Briefly, it can be said concerning NO_x, SO_x, CO_2 and particulate matter emissions, LNG is a good "transition" fuel for the shipping industry.

Although, LNG has significant advantages as mentioned above as well as disadvantages. In this respect, there are important barriers to the transition to LNG, even if it is a solution considered during the transition period. The first problem that can be said is the incompatibility of the existing engines with LNG. This increases the operating and retrofitting costs of the engines, resulting in more space and weight requirements (Mohseni et al., 2019). Another negative feature is methane slip in LNG-fuelled engines. In some engine types, methane slip appears to be at unacceptable levels (Balcombe et al., 2022). More important than any drawbacks, however, is that while LNG is a solution for the maritime industry in the transitional period, it is not a sufficient solution for the complete decarbonization of the maritime industry because it is a fossil fuel. Studies on the advantages and disadvantages of LNG are shown in Table 7 in briefly (Mohseni et al., 2019).

Table 7 Advantages and disadvantages of LNG
(Source: (Mohseni et al., 2019)

Advantages	MAN Diesel & Turbo, (2011)	Kołwzan & Narewski (2012)	McGill et al., (2013)	Stulgis et al., (2014)	Aronietis et al., (2015)	den Boer and Hoen, (2015)	Lindstad et al., (2015)	Moirangthem & Baxter, (2016)	Bauen et al., (2017)	Žaglinskis et al., (2018)
Availability		x	x					x		
Cost	x	x	x	x			x			
Availability of marine gas engines			x			x				
Lower exhaust emissions	x	x	x	x					x	x
Energy density 60% of diesel		x						x	x	x
Disadvantages										
Not compatible with existing engines and fuel systems			x	x	x		x	x		
Requires space and adds weight			x		x		x	x		x
Future fuel price of LNG is uncertain				x		x				
Limited bunkering infrastructure			x	x				x	x	
Methane slip from larger marine engines burning gas	x		x				x	x		
Flammability and low freezing temperature			x							

LNG is also critical fuel for the EU. Given the emphasis on promoting LNG as a maritime fuel in the Fit-for-55 package, the usage of LNG as ship fuel is also anticipated to increase. Although liquefied natural gas (LNG) just makes up 6% of all fuel used by ships today in the EU, it is estimated that it will increase to 23% in 2030 according to the report prepared by Transport & Environment, which is an influential non-governmental organization working in the field of transport and the environment, promotes sustainable transport in Europe (T&E, 2022). In parallel with this, the EU is increasing its work on LNG infrastructure and making the necessary arrangements, especially for bunkering at inland and maritime ports. Currently, the LNG facilities located at the ports in the European Economic Area are shown in Figure 22 (EEA, 2021).

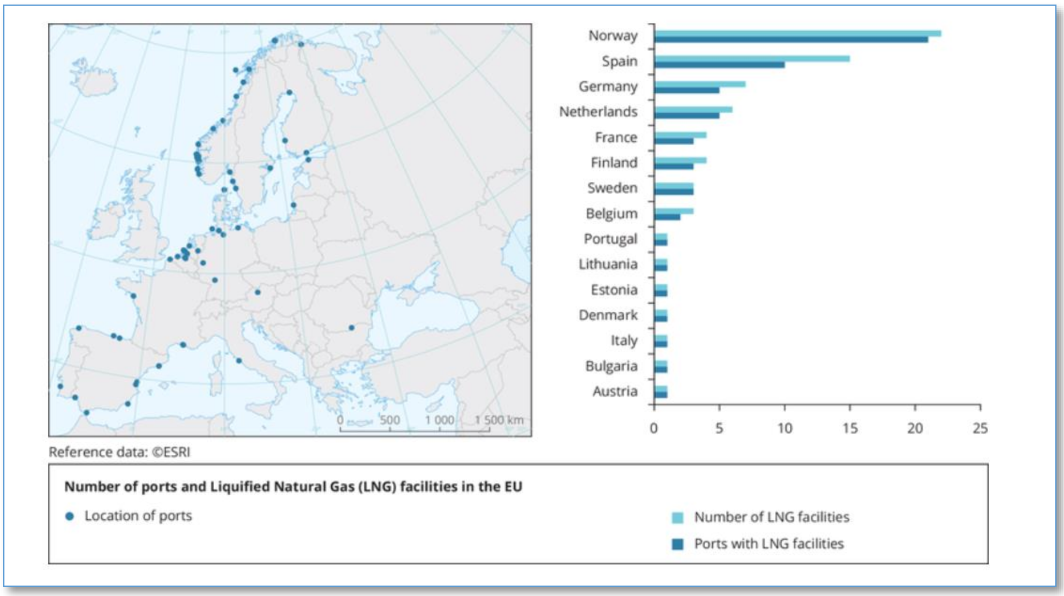


Figure 22 Available LNG facilities in the EEA
(Source: (EEA, 2021)

3.1.2 Hydrogen

An increasing number of hydrogen supporters think that it might provide a zero-GHG energy pathway as a marine fuel, commodity, or cargo. A colourless, odourless gas known as hydrogen is non-toxic. It is not a greenhouse gas, less dense than air, and does not trap heat in the atmosphere. Nevertheless, it has a broad flammability range and a low-ignition energy (Pribyl, 2021).

The use of a color-coded approach to describe hydrogen generating technology is becoming more common. The following are the key colours considered, as shown in Figure 23 (Noussan et al., 2021).

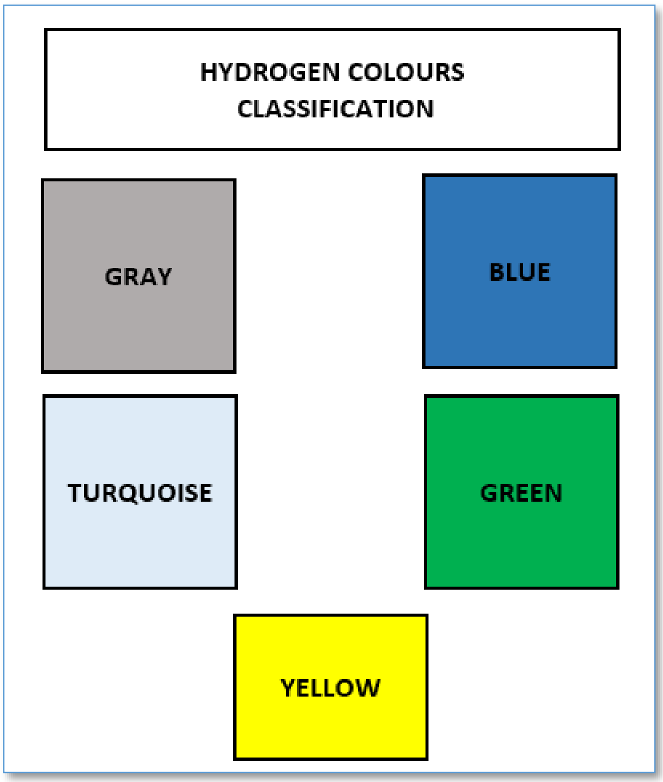


Figure 23 Hydrogen Colours Classification
(Illustrated by the Author)

Among the abovementioned technologies, the most important one for decarbonization is green hydrogen produced from renewable resources. Green hydrogen is produced through a technique that uses an electric current to transform water into oxygen and hydrogen, and it creates no carbon emissions if it is fuelled by renewable energy (O'Callaghan, 2018). Hydrogen is a good energy carrier for applications that aren't connected to the grid or demand a lot of energy, and it may be used as a feedstock in chemical reactions to make various synthetic fuels and feedstock (IRENA, 2020). For many greenfield applications, renewable hydrogen or green hydrogen will soon become the cheapest clean hydrogen supply source. However, more technological progress is required to reduce the cost of greenhouse (GHG) production while also boosting the efficiency of the overall system (Thapa & Thapa, 2020).

Hydrogen and its derivatives fuels, such as ammonia, with fuel cells are an important piece of the decarbonization of the shipping. Assuming an adequate supply, hydrogen and its derivative fuels can provide potentially zero GHG emissions and the possibility of a rapid decrease in the average GHG emissions for shipping (CHP, n.d.).

Hydrogen applications have come a long way in the last decade. Many hydrogen technologies/applications are ready for commercialization today, although they are still more expensive than competing technologies. Significant R&I efforts are still required to increase the efficiency, cost, durability, and manufacturability of hydrogen generation, distribution, and end-use technologies, as well as to maximize their market readiness and scaling up (EC, 2022).

There are significant barriers to the commercialization of hydrogen and its ability to replace conventional fossil fuels. For example, the storage of hydrogen is one of the greatest issues since hydrogen requires effective storage since, under ideal circumstances, it has a low volumetric energy density (Hoecke et al., 2021). The other barrier to decarbonize shipping via hydrogen is its availability in ports. The bunkering infrastructure of the ships has not yet been developed for hydrogen. So, especially government action is required to encourage private investment in green hydrogen technologies and to build the refuelling and hydrogen transportation infrastructure required for blue and green hydrogen to be cost competitive with grey hydrogen (Reinsch, 2021).

Moreover, there may be safety issues due to some technical characteristics of hydrogen. Because hydrogen is the lightest of all atoms, it is more difficult to confine, and it can embrittle materials that are safe to use with natural gas (DNVGL, 2021).

On a global scale, hydrogen is an important energy resource that the EU attaches importance to and sets targets by publishing its strategy, which was adopted in 2020. Less than 2% of the energy consumed in Europe today comes from hydrogen, which is mostly used to create chemical products like plastics and fertilizers. Natural gas is used to produce 96% of this hydrogen, which results in high CO_2 emissions (EC, 2022a).

In order to solve the above-mentioned problems of hydrogen to be more feasible for shipping, priority areas have been determined in the EU Strategic Research and Innovation Agenda (SRIA) 2021–2027 of the Clean Hydrogen Joint Undertaking (hereafter also Clean Hydrogen JU3) (CHP, n.d.). In line with these priorities, the EU allocates significant financial resources for the further development of R&D and innovation in the hydrogen field. For example, in 2022, to support the development of cutting-edge hydrogen technologies, a total of €300.5 million grant was allocated available for projects.

3.1.3 Ammonia

Ammonia, which is predominantly used in the fertilizer industry, accounting for 80% of production, is a preferable alternative for shipping due to its extensive infrastructure for production, storage, and distribution, high energy density, affordable pricing, and relatively low greenhouse gas emissions (Al-Aboosi et al., 2021). DNV forecasts that ammonia is one of the most potential carbon-neutral fuels, but adding it still needs some effort to become a practical choice in the future (DNV, 2021b). Also, according to a study of stakeholders in the shipping sector conducted by the maritime journal Lloyd's List and LR, ammonia was one of the top three fuels with potential for 2050 (Haskell, 2021). Ammonia has many highlights. Ammonia can be accepted for use in gas turbines and internal combustion engines (ICEs) in the near future with just modest modifications. Additionally, it has a promising future as a direct fuel cell component (Ayvalı et al., 2021). More importantly, it has no carbon content and its scalability is one of its positive features (Jacobsen et al., 2022). Another important thing to remember is that ammonia is its large capacity for hydrogen storage, which is 17.6 weight percent based on its molecular structure (Thomas & Parks, 2015)

Ammonia is expressed with different colour classifications according to their production routes, as in hydrogen. These colours are brown, blue, and green ammonia. Depending on the feedstock, brown ammonia has worse (137.7%) or slightly lower (3%) CO_2 emissions than marine diesel oil (MDO). Green ammonia from solar energy has a similar reduction capability to blue ammonia, and green ammonia from wind energy yields 79.2% CO_2 reduction and complies with the IMO 2050 target. Blue ammonia reduces CO_2 by 42.8%, meeting the IMO 2030 target (Zincir, 2022). Eventually, the desired solution is green ammonia. It is similar to the process of producing green hydrogen, but the nitrogen needed for ammonia synthesis is produced using air separation technology, whereas green hydrogen is created by electrolyzing water to separate its hydrogen and oxygen (Craston, 2021). Figure 24 shows the colour classification of ammonia.

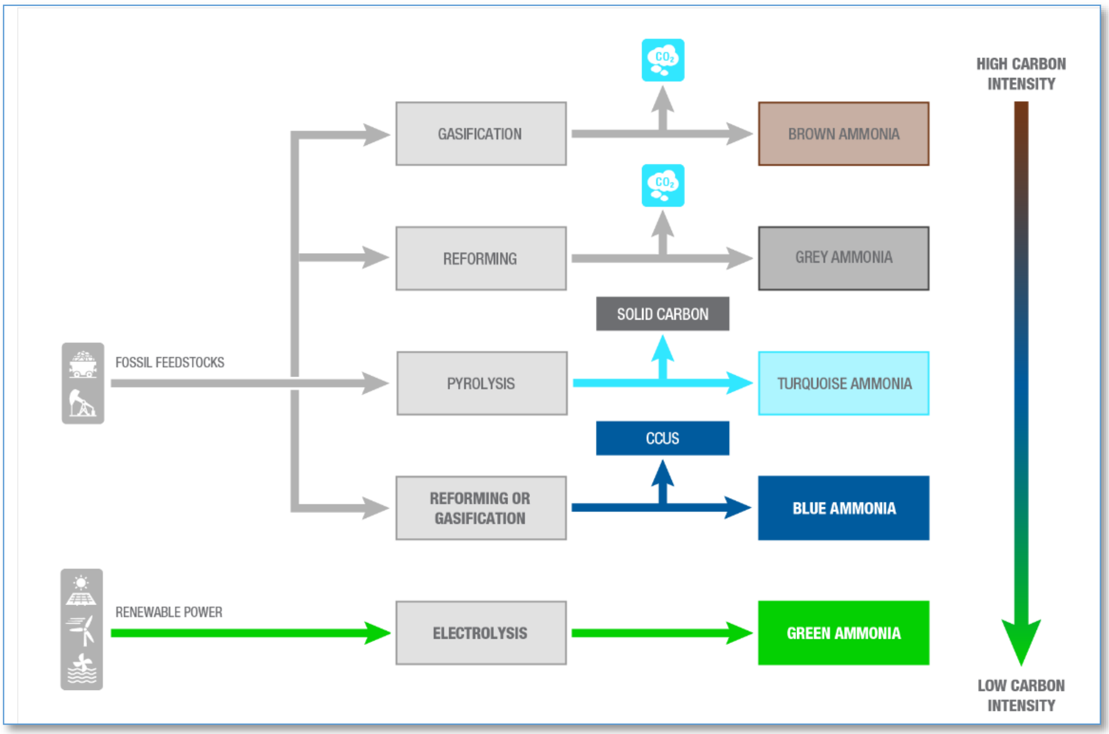


Figure 24 Ammonia Colour Classification
(Source: (Casale, n.d.)

Ammonia is one of the best candidates for hydrogen storage since having hydrogen density in its molecular structure (Aziz et al., 2020). When hydrogen and ammonia are evaluated as two alternative fuels, ammonia has some advantages over hydrogen such as storing capacity since it is relatively easy to liquefy (at −33 °C)(Rivarolo et al., 2019). Also, ammonia can be transported more easily than hydrogen. Producing, storing, and delivering hydrogen as ammonia (NH_3) is significantly more economical and energy-efficient than doing it with compressed and/or cryogenic hydrogen (Lan & Tao, 2014). Its advantages over hydrogen are briefly described in Figure 25.

	LIQUID AMMONIA	LIQUID HYDROGEN
STORAGE & TRANSPORTATION	Can be stored & transported as a liquid at a practical temperature of -33°C	Requires deep cryogenic temperature (-253°C or lower)
INFRASTRUCTURE	Can be distributed using existing infrastructure	No existing infrastructure
ENERGY DENSITY	Low volumetric energy density, however 50% better than liquefied hydrogen	Very low volumetric energy density
SCALABILITY	Easily produced from H2 & N2 No CO_2 needed	

Figure 25 Liquid Hydrogen vs. Ammonia
(Source: (Total, 2021) Illustrated by the Author

As with other alternative fuels, ammonia has some disadvantages. The important disadvantages are that ammonia production is expensive, there are safety problems (in case of an accident), storage and supply to ports for bunkering (Hansson et al., 2020). In addition to these, there are some technical (combustion-related) drawbacks as well such as low flame velocity, slow chemical kinetics, and high ignition temperature (Erdemir & Dincer, 2021).

The EU aims to support the deployment of hydrogen and derived fuels such as ammonia, in the maritime sector, as set out in its national hydrogen strategy (EC, 2022a). Ammonia plays an important role in the target of producing 10 million tonnes of green hydrogen by 2030 within the scope of the REPowerEU plan, which was launched after the energy crisis after the Ukraine-Russia war in 2022.

3.1.4 Biofuels

Biological materials, primarily from plants, animals, trash, and microorganisms, are the main source of biofuels, a significant alternative fuel for shipping (Berla et al., 2013). Biofuels have the potential to reduce CO_2 by up to 88% during their entire life cycle, making them carbon-neutral energy sources (Kim et al., 2020).The potential for lower life cycle emissions, high energy density, and compatibility with current marine engines and bunkering infrastructure make biofuels intriguing candidates for the next generation of marine fuel (Foretich et al., 2021b). Biofuels have some positive features. These; due to its low sulphur content, it meets IMO's near-term targets and it can be more easily adapted to existing diesel engine technologies thanks to having similar properties (Kalligeros et al., 2017). However, in addition to these advantages, it is still more expensive than conventional fuels and the possibility of competing with food production directly/indirectly due to excessive use of agricultural land is one of its important drawbacks (Kim et al., 2020). Using biofuels, which are primarily made from edible oil, could result in a shortage of food and an increase in food costs (Viesturs & Melece, 2014).

For the EU, biofuels are an important alternative fuel considered for transportation. According to the Renewable Energy Directive, it has set a specific lower target of 3.5% for advanced biofuels and an upper limit for some biofuels by encouraging the use of biofuels in the transportation sector (Europarl, 2022b). In the EC 2009 directive, the blending rate of biofuels to be targeted for 2020 and to be used in transportation have been made mandatory for all member countries of the EU as 10% (Delican et al., 2020). Besides these, the EC under the package of Fit for 55 established a legally enforceable sub-target for advanced biofuels, incorporating the addition of double counting for these fuels, at 0.2% in 2022, 1% in 2025, and 4.4% in 2030 in the share of renewable energies delivered to the transportation sector (EC, 2022b). In summary, biofuels have an important place in the EU goals of becoming a carbon-neutral continent.

3.1.5 Methanol

Methanol is a viable alternative fuel that can help shipping companies to operate cleaner and emit less pollution. Because it burns cleanly, it produces less NO_x and particulate matter emissions during combustion. It also contains no sulphur (SSPA, n.d.). Based on its availability, ability to reduce emissions, and energy density, it is particularly significant in the short to medium term (Harmsen, 2021). Another important reason why it draws attention in the maritime industry is that the cost of modification required to be used in diesel engines is lower than that of LNG (McGill et al., 2013).

As with hydrogen and ammonia, there are different colour classifications for methanol according to the level of sustainability and how it is produced. These colours are brown, grey, blue and green, as shown in Figure 26.

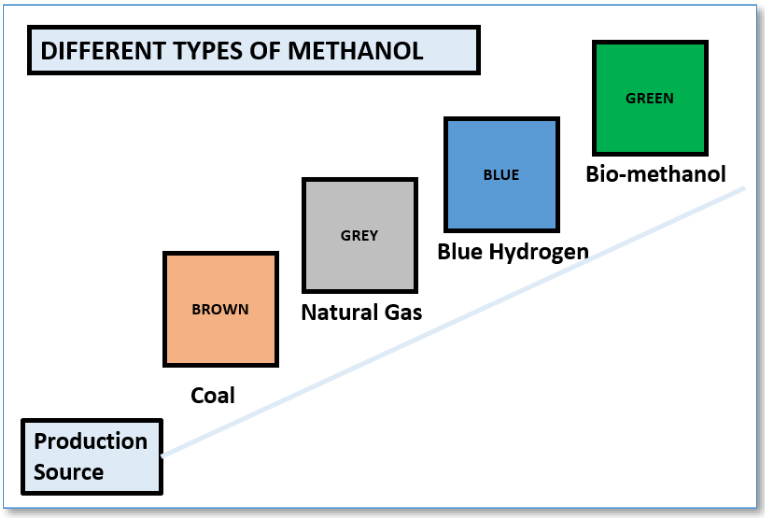


Figure 26 Methanol Colour Classification
(Source: (Bureau Veritas, n.d.) Illustrated by Author

The most sustainable and clean colour is green methanol as in the others. A low-carbon fuel known as "green methanol" can be produced using either biomass gasification or renewable electricity and captured carbon dioxide (CO_2) (Martin, 2021). There are no significant difficulties with prospective supply chains, and green methanol is a technically feasible solution to lower shipping emissions (Svanberg et al., 2018).

However, there are some obstacles before methanol can be used in the maritime industry as in alternative fuels. Especially, the low-energy content compared to conventional fuels and the need for twice (showing similar properties with LNG) as much space as diesel fuel for the same energy density are serious disadvantages (Andersson & Salazar, 2015). Another major disadvantage is that green methanol (full decarbonization) is still more expensive than conventional fuels. According to a 2021 report from the American Bureau of Shipping, it is estimated that the cost of green methanol is $643/tonne while marine gasoline oil (MGO) cost is estimated to average $600/tonne (Martin, 2021). Another shortcoming about methanol is the need for ships to be redesigned to use methanol as ship fuel, such as bigger fuel tanks to allow deep sea voyages (Schwarz, 2022).

3.2 MARINE PROPULSION TECHNOLOGIES

An important energy demand source on board a ship is the propulsion of a maritime vehicle (Baldi et al., 2019). According to a study by the OECD, it is stated that technological improvements to be made in the propulsion systems of ships can provide fuel savings between 1 percent and 25 percent and therefore increase energy efficiency (OECD, 2018).

The literature provides several options for meeting a ship's propulsion energy needs, including single fuel/propulsion engines (such diesel engines or engines powered by other fuels like LNG), steam turbine, wind turbine, gas turbine, solar and nuclear, biodiesel, water-jet, solar, and fuel cell propulsion (Al-Enazi et al., 2021). The propulsion systems used in ships are shown in Figure 27.

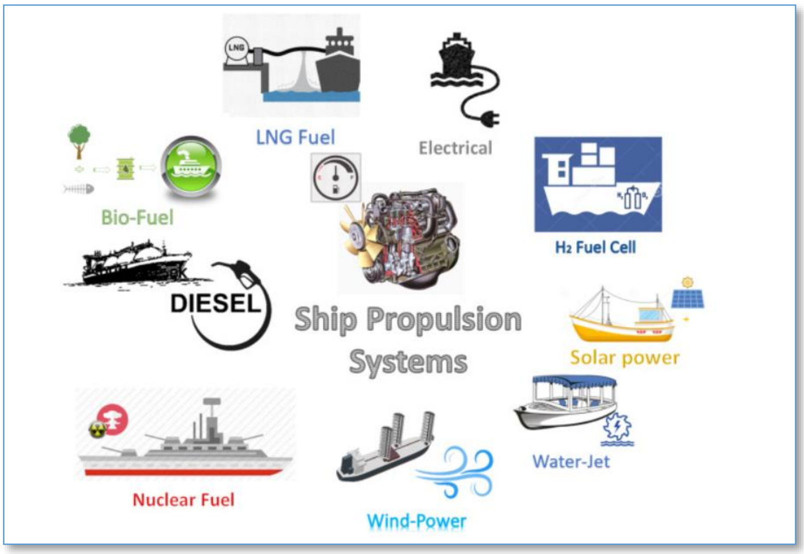


Figure 27 Ship Propulsion Technologies
(Source: (Al-Enazi et al., 2021)

3.2.1 Wind-Assisted Propulsion

From the above propulsion systems, as it uses the wind to partially replace the propelling power produced by fossil fuels, wind-assisted ship propulsion (WASP) technology appears to be a promising alternative for speeding the shipping industry's decarbonization efforts (Chou et al., 2021). It is estimated that there are 30,000 ships currently in operation worldwide that can be equipped with wind-assisted propulsion. According to the International Wind Ships Association (IWSA), although wind-assisted propulsion may not be the complete solution to ships' zero emissions, it is claimed to be an important auxiliary energy source with its ability to reduce emissions by up to 30% (Buitendijk, 2020b).

The use of fossil fuels and primary engine running is lessened by the wind-assisted systems' generation of thrust from the wind (Kukner et al., 2016). Several sources suggest that wind technologies on ships have an abatement potential of between 10% and 60% (Rehmatulla et al., 2017). Wind-assisted ship propulsion (WASP), one of the many design solutions currently accessible, exhibits the highest potential to minimize GHGs as shown in Table 8 (Khan et al., 2021). Also, wind-assisted propulsion is one of the few viable mitigation measures that reduces other pollutants, like SO_x and NO_x (Bows-Larkin et al., 2014).

Table 8 Impact of Design Technologies on Reduced GHG Emissions
(Source: *(Khan et al., 2021)*

Technology	Potential GHG Savings
WASP	In excess of 30%
Slender Design	Up to 15%
Air Lubrication	Up to 13%
Increased Cargo	Up to 10%
Materials	Up to 10%
Propeller Design	Up to 10%
Bulbous Bow	Up to 7%
Heat Recovery	Up to 6%
Hull Surface	Up to 5%

Various wind-assisted propulsion systems are already available on the market, and the revival of this energy source is fuelled by rising fuel prices and a population that is increasingly aware of the effects of CO_2 emissions (Hochkirch & Bertram, 2010). The shipbuilding industry has developed and tested various wind-assisted ship propulsion technologies, including rotors, towing kites, wing sails, soft sails, suction wing sails, wind turbines, hull sails, etc. to harness wind power to save energy and reduce emissions on modern ships. Rotators, towing kites, wing sails, and soft sails are a few of them that offer higher energy-saving capability (Wang et al., 2022).

Wind energy has some advantages as well as some disadvantages. That the wind does not blow continuously is the most significant of these. If the weather conditions are not suitable, there is a risk of being without electricity. Additionally, the initial investment cost and technological immaturity of wind energy are other negative aspects. In addition to these, other important disadvantages that can be said are that it causes noise and visual pollution, may pose a threat to wildlife (especially for birds), and poses some security problems, especially at night (Lloyd, 2014).

In order to meet their carbon reduction targets for the maritime sector, the EU countries place a high priority on wind energy as one of the renewable energy sources (Solarin & Bello, 2022). It provides financial support with its funds and encourages wind-assisted propulsion projects in line with the emission reduction targets of the EU and IMO. For example, at the end of a project funded by the European Maritime and Fisheries Fund (EMFF), companies named Spanish bound4blue and Norway's Kyma AS installed eSAIL® systems on the world's first fishing vessel using wind-assisted propulsion technology (EC, 2021b). Another important example is the WASP (Wind Assisted Ship Propulsion) project carried out in partnership with seven different countries (Netherlands, Belgium, Germany, Denmark, Norway, Sweden, United Kingdom) in the North Sea region with the support of the European Regional Development Fund (ERDF) (WASP, 2022).

3.2.2 Nuclear Ship Propulsion

Some have suggested building ships that directly employ nuclear propulsion to reduce emissions in addition to fuel shifting and alternative fuels (Fowler et al., 2021). There are two solutions for zero-emission shipping powered by nuclear energy. Both as a direct source of energy for ship propulsion and as a zero-carbon energy source for the synthesis of green fuels like hydrogen/ammonia and synthetic fuels (Clark et al., 2021). Nuclear propulsion systems can emit up to 98% less CO_2 than traditional fuel-based systems, according to research by Koen (Houtkoop, 2022). In addition to saving fuel and less emitting CO_2, nuclear-powered ships travel faster 50% more than similar-sized oil-fuelled ships (Safety4Sea, 2021). The capacity to operate for extended periods without refuelling promotes autonomy and enables independence from swings in fuel prices, which is another significant benefit of nuclear propulsion (Mallouppas & Yfantis, 2021).

Developing a civilian nuclear fleet is challenging due to public and political perception, regulation, training, safety against catastrophic accidents, terrorism, and non-proliferation, although nuclear power is frequently used for military ships and submarines (Balcombe et al., 2019). However, new technologies like molten salt reactors (MSR) and small modular reactors (SMR) may be able to address these issues (Ferrell, 2022). However, as shown in Figure 30, nuclear propulsion systems are the only cheapest option when analysing the lifetime cost of ships driven by various fuel sources (such as LNG, heavy fuel oil, very low sulphur fuel oil, green ammonia, and green methanol) (Buitendijk, 2022).

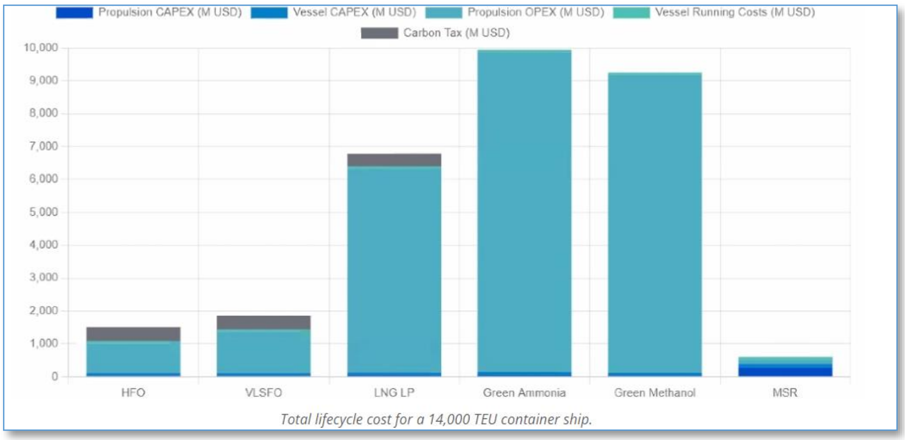


Figure 28 Total Life Cycle Cost
(Source: (Buitendijk, 2022)

3.2.3 Battery Propulsion

One of the most practical ways to meet the 2050 goal is now being recognized as the usage of battery systems to replace diesel engines (Yang et al., 2021). The potential for the reduction varies from 15% to 30% of total ship fuel consumption depending on parameters such as vessel operational profile, power production, and consumption (Glomeep, n.d.-c). Recent developments in large-scale marine applications have made battery use fascinating. This is caused by a variety of elements, including advancements made in the field of lithium-ion batteries, which have increased capacity, reliability, and battery pricing (Lundbäck, n.d.). Cruise ship operators have started to use batteries, or "energy storage systems" (ESS), for deployment in emission-control zones since they are excellent for short maritime trips (not longer than 500–1000 km) and for meeting peak power needs (Buitendijk, 2020a). Auxiliary motors are used with batteries to provide the power needed for long voyages (Chin et al., 2022). In practically every future ship's hybrid system, batteries can play a significant role in longer trips (Craig, 2020). Hybrid battery solutions come to the fore as long-haul voyages are more important in the decarbonization of maritime.

Battery propulsion systems have some disadvantages. Most notably, electric marine propulsion systems and components, including the stern thruster and tunnel propeller, are more expensive than diesel propulsion ones. Also, some spare parts are hard to find and this pushes the price even higher. Finally, it is also difficult to find a skilled workforce with the expertise and knowledge of installing electrified marine propulsion systems (CB, 2022).

3.2.4 Solar Electric Propulsion

An option for generating a small amount of power on board ships is the use of PV technology (Raeng, 2013). Due to eco-friendly energy legislation and an increasing awareness of environmental protection, the solar PV systems have continued to increase in usage and installed capacity, but it is very difficult to acquire enough space for PV systems on-board because power generation from solar energy is largely reliant on environmental factors such as the position of PV panels, latitude, angle, solar radiation, convection-conduction heat losses, etc. (Park et al., 2022, Inal et al., 2022). So, creating a multi-energy hybrid power system for ships employing multi-physics control systems is more effective at making up for the solar energy's drawbacks. As demonstrated in Figure 29, creating multi-energy hybrid power systems for ships has grown highly appealing (Yuan et al., 2020). For instance, while solar-wind hybrid systems can save between 10% and 40% of their fuel, solar energy generation on board ships can reduce CO_2 by 0.2 to 12% (Bouman et al., 2017).

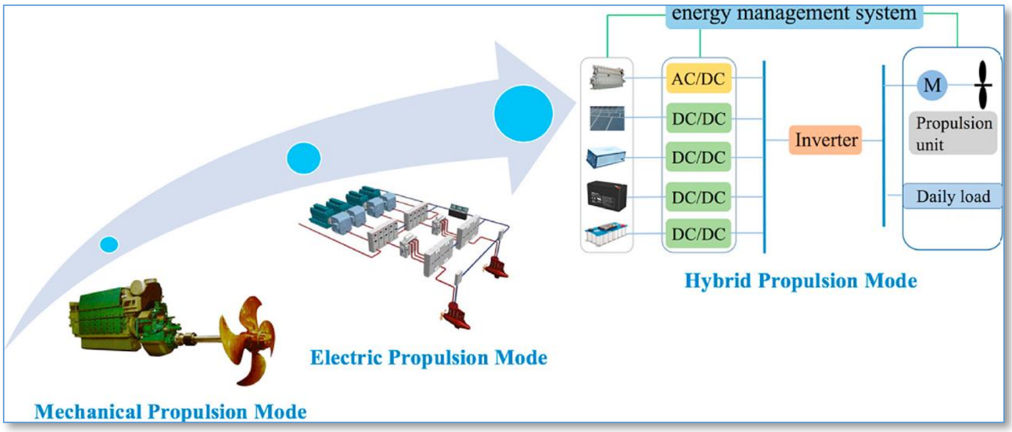


Figure 29 Multi-Energy Hybrid Power System
(Source: (Yuan et al., 2020)

3.3 SHIP DESIGN TECHNOLOGIES

The design of the ship is extremely important in terms of energy efficiency and fuel saving. The innovative hull design, according to Bouman et al., can dramatically lower CO_2 emissions. By increasing ship size, emissions are decreased per unit of transported goods, and by optimizing the hull shape for less drag, power usage and emissions are also greatly reduced. Additional measures like light weighing, hull coating, and lubrication can help to further enhance boat performance, but, their effectiveness as a stand-alone measure is constrained (Bouman et al., 2017). Table 9 shows the emission reduction impact of the improvements made in the design.

Table 9 Design Measures and Potential Impact on Energy Efficiency and CO_2 Emissions
(Source: (Bouman et al., 2017)

Type of measure	Main measures reviewed	Short description	Potential CO_2 reduction
Hull design	Vessel size	Economy of scale, improved capacity utilization	4–83 %
	Hull shape	Dimensions & form optimization	2–30%
	Lightweight materials	High strength steel, composite	0.1–22%
	Air lubrication	Hull air cavity lubrication	1–15%
	Resistance reduction devices	Other devices/retrofit to reduce resistance	2–15%
	Ballast water reduction	Change in design to reduce size of ballast	0–10%
	Hull coating	Distinct types of coating	1–10%

3.3.1 Hull Air Lubrication

Ship designers are being forced to consider cutting-edge ideas or review tried-and-true approaches and employ new technologies to achieve them due to international regulations and high fuel prices that need fuel consumption reduction (Wikander & Shiri, 2018). One of them is the improvements to be made in air lubrication systems. As shown in Table 8, the greenhouse gas reduction impact of air lubrication systems is up to 13 percent. A typical ship needs about 60% of its propelling force to overcome frictional drag, but there are various ways or practices that can greatly lower the frictional resistance of a ship, which has a huge effect on both the economy and the environment. So-called air lubrication (shown in Figure 30) is one of the most promising methods for a ship to reduce viscous drag (S N & S., 2018).

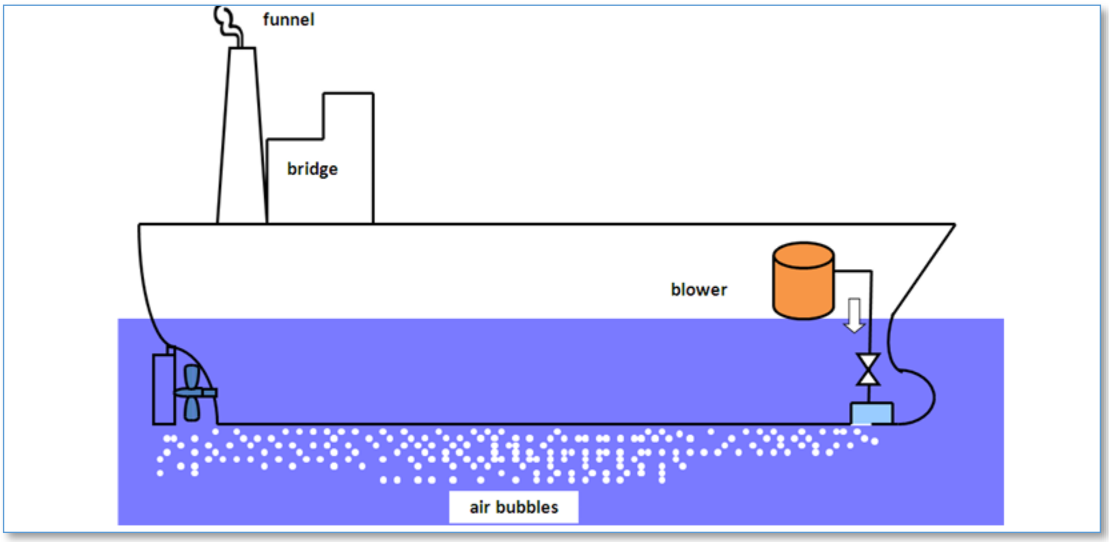


Figure 30 IMO MEPC.1/Circ. 815 Annex, Air Lubrication System
(Source: (IMO, n.d.-a)

Techniques including microbubbles, air films, or air cavities can be used for air lubrication (Gökcay & Insel, 2011). Without changing a ship's current hull form, the micro-bubble approach offers the opportunity to reduce friction. The use of the micro-bubble technique (see Figure 31) lowers surface friction by altering the viscosity of the fluid surrounding the ship (Dogrul et al., 2010).

Figure 31 Micro-Bubble Air Lubrication
(Source: (S N & S., 2018)

Another air lubrication technique is air film. Air films are used because they naturally reduce friction by keeping the water away from the hull (Foeth, 2008). The basic idea is that by applying a thin layer of air to a portion of the hull, less friction and thus less fuel consumption are created. This can be done by reducing air layer drag, partial cavity drag, or air bubble drag (Xing et al., 2020). Another effective method of air lubrication is the use of air cavities. This method involves injecting air onto wetted hull surfaces to enhance a ship's hydrodynamic properties. For "low Froude number" ships, such as bulk carriers, tankers, and containers, where frictional resistance predominates, air cavity lubrication is appropriate for new buildings (Glomeep, n.d.-a).

3.3.2 Propeller Design Optimization

The primary engine, transmission shaft, and propeller make up the traditional ship propulsion system on board. The marine propeller is a crucial component of this system (Tadros et al., 2021). A good propeller design will influence the thrust obtained to be ideal so that the ship can operate at the appropriate speed (Suratno et al., 2020). Improvements in propeller design, as indicated in Table 8, result in a reduction in GHG emissions of up to 10 percent.

3.3.3 Hull Coating

The advanced hull coating, in contrast to conventional coatings, keeps the hull clean and decreases hydrodynamic resistance, which lowers fuel consumption for ship propulsion (GS, 2014). The coating provides a reduction of up to 8% of the vessel's frictional resistance, contributing to a solid 1%-4% reduction in main engine fuel consumption. The cost of the hull coating is estimated by $30,000 to $500,000 (USD) can be anticipated depending on vessel size, segment etc. (Glomeep, n.d.-b).

3.3.4 Waste Heat Recovery System

Using the heat energy that thermal processes release into the environment, waste heat recovery systems (WHRS) generate electricity without the use of additional fuel (Singh & Pedersen, 2016). Waste heat recovery can be used to lower greenhouse gas emissions and improve the energy consumption efficiency (Ma et al., 2017). The total energy efficiency of ship engines is increased by WHRS from 50% to roughly 55%. The energy balances with and without the WHRS are shown in Figure 32. This illustration demonstrates how the combination of WHRS and an engine boosts the engine's efficiency, further ensuring a reduction in the level of CO_2 emissions (Olaniyi & Prause, 2020).

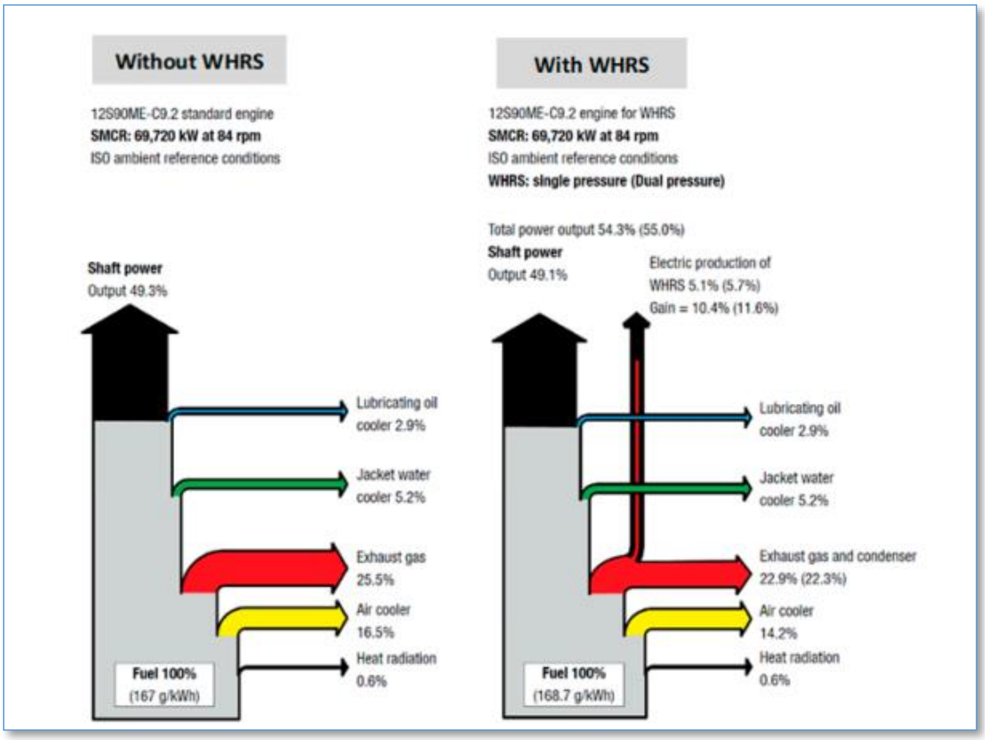


Figure 32 Waste Heat Recovery System
(Source: (MAN, 2014)

It is seen that the biggest barrier in waste heat recovery system technologies, as in other technologies, is again the financial constraint. A WHRS system is projected to cost between US$2,000,000 and US$10,000,000, depending on the size of the ship and its engine (Olaniyi & Prause, 2020).

Chapter 4

4.0 BLUE PREMIUM

Innovative decarbonization solutions have been mentioned in Chapter 3 for the decarbonization of the shipping sector and for achieving the desired IMO and EU targets. Still, it is not yet possible for low-carbon and zero-carbon solutions to compete with traditional fossil fuels and technologies in terms of cost, rather than technical, and operational hurdles. This is why financing the decarbonization of shipping is critical. The most financially appealing alternatives for lowering CO_2 emissions are improvements in ship technology and operational procedures (costs range from US$5 to $50/t CO_2) but alternative fuels, ship-assisted propulsion and design measures such air lubrication are more costly as seen in Table 10 (Concawe, 2021).

Table 10 Cost Analysis of the Decarbonization Solutions
(Source: (Concawe, 2021)

FUEL	MAXIMUM GHG REDUCTION	TRL FOR TRANS-OCEANIC	CURRENT COST (US$/GJ)	CURRENT COST-EFFECTIVENESS (INCLUDING FUEL COSTS) (US$/TCO$_2$)	COMPABILITITY
LNG	10%	9	7.1	340.1	Requires gas/dual-fuel engine and associated cryogenic storage
BioLNG	169%	9	11.3	49.5	Same requirements as for LNG.
Methanol	92%	8/9	28.7	305.3	Not drop-in. Compatible with internal combustion engines.
Ammonia	79%*	3/4/5	31.9	400.5	Compatible with internal combustion engines (spark ignition with a hydrogen blend to promote combustion, and dualfuel with pilot diesel).
Hydrogen	95%*	3/4/5	89.2	1028.7	Compatible with internal combustion engines (spark ignition and dual-fuel) but requires development and a supporting fuel).
FAME	84%	9	17.0	174.0	Drop-in (blended only <20% FAME). May face competition for feedstock availability from other sectors.
HVO	91%	9	17.2	163.3	Drop-in (blended and neat). May face competition for feedstock availability from other sectors.
Batteries (Lithium-Ion)	66%	4/5/6	-	-	Not compatible with internal combustion engines as part of a prime mover. Have a role in coastal or shortsea shipping. May have a role in reducing emissions from auxiliary power in deep-sea shipping. Require their own storage systems and equipment.

Note: Maximum potentials are shown, with the exception of ammonia, hydrogen and battery electric. In theory, 100% reduction (or higher) may be achievable with 100% renewable electricity for these fuels; however, the time frame and costs for these production pathways are not clear at present, therefore data for the pathways with the next highest reduction potential are shown.

As stated earlier, according to the research commissioned by the Global Maritime Forum, US$1 trillion to US$1.4 trillion, or an average of US$50 billion to US$70 billion investments yearly for 20 years, will be required to meet the IMO's target of 50% emissions between 2030 and 2050 (Carlo et al., 2020). In this respect, IMO works to finance decarbonization and to develop green and clean alternative solutions with technological innovations to close the gaps and overcome the barriers. One of these initiatives is the IMO-UNEP-Norway Zero and Low Emissions Innovation Forum, which is held every year. In this forum, stakeholders offer solutions especially for financing the decarbonization and innovations needed by the maritime industry.

In this study, for the first time in the literature, the "Green Premium" of the maritime industry is called Blue Premium. The additional cost of choosing a clean technology over one that creates more greenhouse emissions is known as the "green premium." For the decarbonization of the maritime industry, Blue Premium, on the other hand, reflects the additional cost of shifting to emission-free and low-emission technologies such as alternative fuels, innovative marine propulsion technologies and design technology solutions, as mentioned in Chapter 3. A solution is sought with the blue premium proposal for financing, which is the most important element for the full decarbonization in the EU maritime sector. In this respect, it is aimed to contribute to the achievement of the 2030 and 2050 targets of the shipping industry with a sustainable fund to be established at the EU level in order to replace traditional fossil fuels and/or shipping technologies with more environmentally friendly, less and/or zero-emission alternatives. Moreover, the applicability and functionality of the proposed fund model with an illustrative example of one of the clean decarbonization solutions at the EU level, will also be mentioned and discussed in the fifth chapter. These alternative solutions are green hydrogen, wind-assisted propulsion and air lubrication system. It will be explained how ship owners can benefit from the Blue Premium Fund if they make investment and/or R&D studies in these solutions.

For instance, the blue premium represents the price difference between HFO used in the shipping industry and green hydrogen, a zero-carbon fuel as shown in Figure 33 simply. The aim of this fund is to contribute to the R&D, innovation studies, and/or investments made in the relevant drawbacks and/or EU priorities by reducing this price difference to reasonable and feasible levels in terms of both producers and end-users compared to existing conventional fuels and/or technologies.

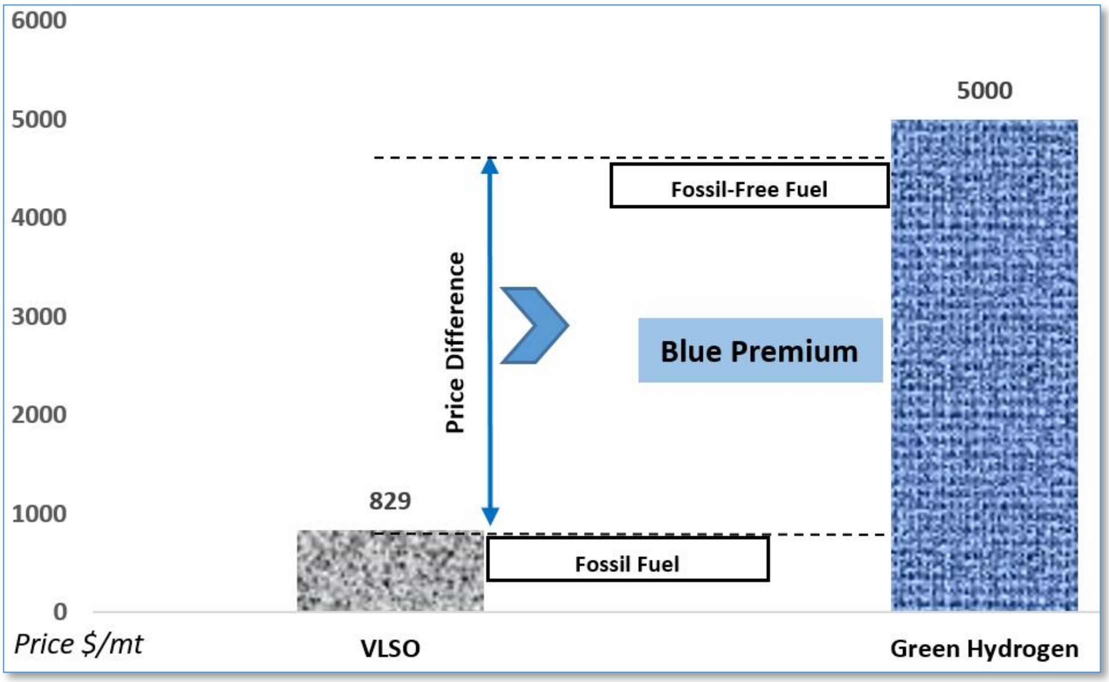


Figure 33 The Blue Premium
(Source: Author)

4.1 THE EU BLUE PREMIUM FUND

The aim of the EU Blue Premium Fund is to help alternative fuels and technologies become more competitive by reducing Blue Premium. By financing the decarbonization of the maritime ecosystem, the Fund aims to enable the ecosystem to meet its 2030 and 2050 targets at both the IMO and the EU levels.

In Chapter 2, the importance of financing decarbonization has been mentioned and the EU and some global climate funds have been included and the funds have been compared. Moreover, the gap areas to be completed in the fund to be created for the maritime sector have been determined. To list these funds again in Table 11. As can be seen again, there is no decarbonization and/or R&D fund based on shipping in the EU yet.

Table 11 List of Funds

Fund	Scope	Industry	Type
EU ETS Innovation	EU	All*	Climate
ICS IMRF*	IMO	Shipping	Climate
Ocean*	EU	Shipping	Climate
Modernisation	EU	All*	Climate
Life	EU	All*	Climate
NER 300	EU	All*	Climate
Horizon Europe	EU	High-Tech	R&D
ERDF	EU	All	Development
InvestEU	EU	Strategic Investments	Investment
Green Climate	Global	All*	Climate
The Catalyst	Global	All*	Climate
NO_x	Norway	Shipping	Climate
Emission Reduction	Australia	All*	Climate
YOZMA	Israel	High-Tech	Start-up & VC
Philanthropic	EU & Global	All	Social

Note 1: *All* covers the sectors with high emissions.*

Note 2: *IMRF* is just a proposal done by ICS to IMO. It was rejected by member states of the IMO.*

Note 3*: The Ocean Fund* is still at the proposal stage.*

The Blue Premium Fund is specifically designed directly for the maritime industry. The Blue premium fund also inspired from some of the good practices in other fund examples and, it has been prepared in line with EU policies, as shown in Figure 34. Based on the carbon levy system (still only at the proposal stage in the IMO), which has not yet been implemented at the EU and IMO level, by raising funds to the fund it is aimed to develop the R&D and innovation capacity of the maritime industry in alternative fuels and technologies, which are essential for decarbonization. A carbon tax is also considered on the basis of ESG, and it is based on the principle that shipping companies with high ESG scores pay less tax.

The Blue Premium Fund was inspired by the YOZMA program, which is the VC program initiated by Israel in the 1990s, to raise fund for the fund and attract investors to this field, especially to draw investors' attention to the blue finance. Individual and institutional investors are also allowed to invest in the fund to raise funds and contribute to its sustainability. Additionally, as in the example of the green climate fund, a similar concept has been created in this fund, and it is aimed that EU member countries can also contribute to the fund. Apart from these, it is planned to generate funds from the donations of the important philanthropic funds, foundations, trusts and the biggest shipping companies in the EU and world.

Additionally, it is ensured that bluetech start-ups benefit from this fund to support them and attract more investment from the VCs and other investors. The fund will be a partner in the deal by investing 40 percent of the total investment amount to the bluetech start-ups that have already raised funds from the partner investors and VCs based on the YOZMA model in supporting the start-ups. Income generated from successful blue start-up exits will be transferred to the Blue Premium Fund. If the venture fails, the fund will not have any expectations from this investment.

The Blue Premium Fund will also support universities, research centres and researchers seeking innovative solutions for decarbonization. If they apply to R&D

funds such as Horizon Europe, the Blue Premium Fund will provide the necessary co-financing.

Companies that contribute to the fund by paying carbon tax from the Blue Premium Fund will also be able to receive financial support from the fund if they conduct decarbonization and emission-reducing corporate R&D activities and submit to the fund (if the independent evaluators of the Blue Fund committee approve).

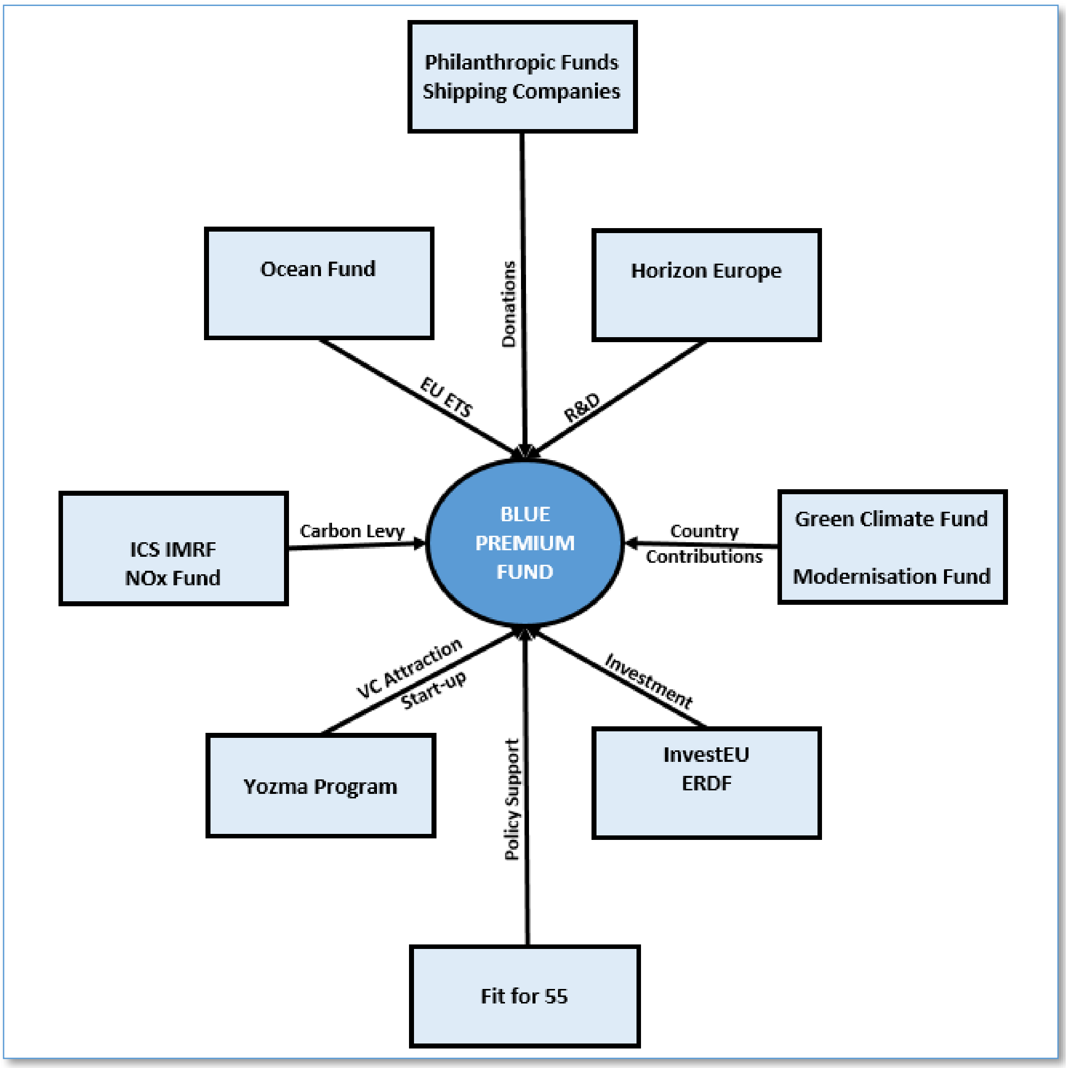


Figure 34 Inspired Programs
(Source: Author)

4.2 SOURCES OF THE BLUE PREMIUM FUND

The Blue Premium Fund has two different fund sources: main sources and possible returns from investments as shown in Figure 35. The main sources are as follows;

- Carbon Levy
- The Ocean Fund
- Private Investors
- InvestEU Fund
- EU Member States
- Philanthropic Funds, Foundations and Trusts

Revenue coming from the Blue Premium Fund's investments is also available. These sources are as follows;

- Startup Exits
- ESG Fund Returns

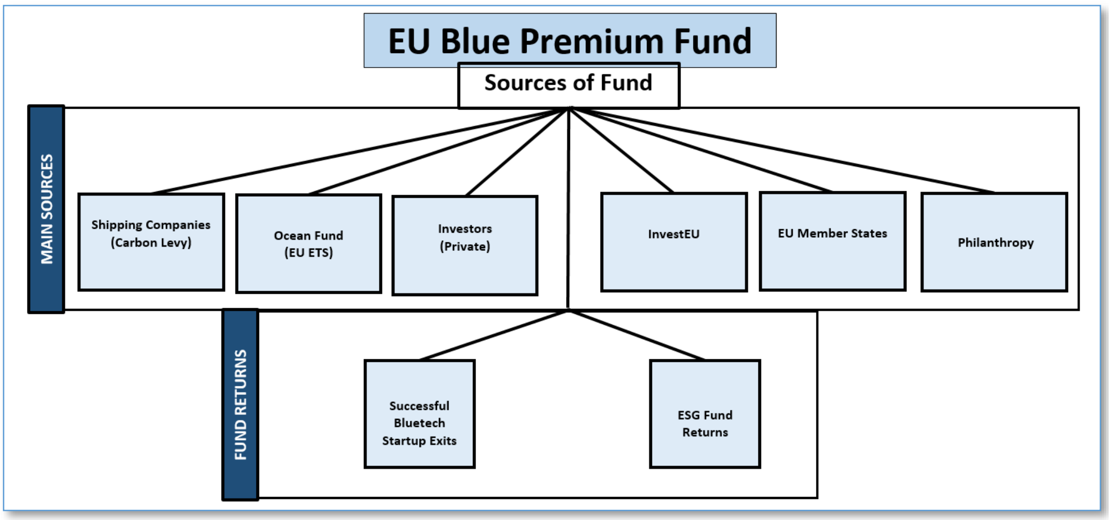


Figure 35 Sources of the Blue Premium Fund
(Source: Author)

4.2.1 Carbon Levy

As in the example of the ICS proposal to IMO or the Norway NO_x fund, which has been explained before, the mandatory carbon levy application in case of emissions and/or use of fossil marine fuel by shipping companies also applies to the Blue Premium Fund. It is planned that the taxes obtained from this will be transferred to the fund to be used in R&D and innovation investments to decarbonize the shipping industry. Blue Premium Fund has an innovative aspect that distinguishes it from other applications. This is an ESG-based carbon tax calculation method (see Figure 36). If the company has a high ESG score, the carbon tax it will pay is less. (The ESG index will be scored between 0 and 1. 1 represents the highest score, 0 is the lowest score.) A carbon tax of 5.5 Euros is taken as the base value for the marine fuel consumed per tonne. It has already been stated that the EU's "Fit for 55" package has a target to reduce GHG emissions by at least 55% by 2030. A value of 5.5 euros has also been set to emphasize the 55% target.

$$\text{Carbon Levy} = \frac{\text{Per Tonne Marine Fuel} \times \text{€}\,5.5}{\text{ESG Index Score (0-1)}}$$

Figure 36 Calculation of the Carbon Levy
(Source: Author)

Data from providers such as Refinitiv, MSCI, &P ESG Index, Sustainalytics and ESGI will be used to determine ESG scores. Data from independent ESG score providers will be adjusted to a score between 0 and 1 by the Blue Premium Fund. For example, as previously shown, the ESG score is 38 in a study by Refinitiv by including some shipping companies. When calculating the carbon tax, this rate will be taken as 0.38. Considering the use of approximately 50 million tonnes of marine fuels, with an average ESG score of 0.38, the carbon levy accumulated in the Blue Premium Fund will be around 700 million Euros as illustrated in Figure 37.

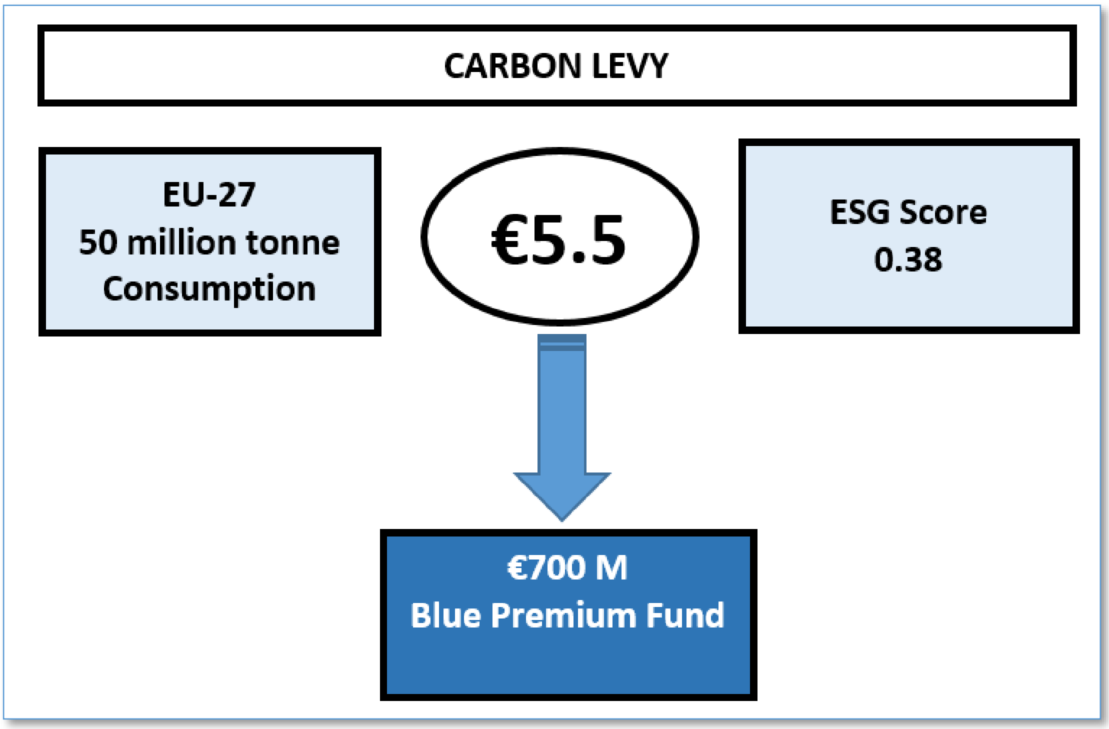


Figure 37 Carbon Levy Annual Return (estimated)
(Source: Author)

4.2.2 The Ocean Fund

As noted earlier, for the energy efficient and climate resilient EU maritime sector, the European Parliament has proposed that between 2023 and 2030 75% of the revenues from the auction of ETS maritime allowances be transferred to a maritime fund called the Ocean Fund. It is clear that if this proposal enters into force, it will be important in terms of maritime decarbonization. It is recommended that the revenues accumulated in the ocean fund be transferred to the Blue Premium Fund as shown in in Figure 38.

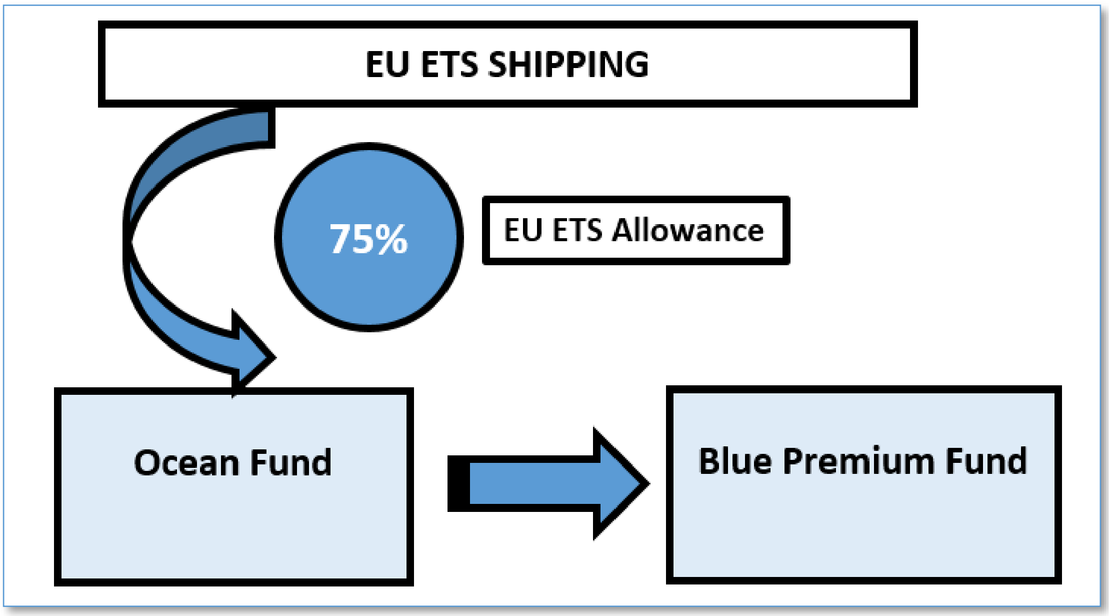


Figure 38 Ocean Fund Contribution
(Source: Author)

4.2.3 Private Investors

A contributor to the Blue Premium Fund is the investor ecosystem. It aims to encourage VC companies, institutional and individual investors to invest in bluetech start-ups. For instance, if a VC invests in a bluetech start up, the Blue Premium Fund also becomes a partner in the investment at a rate of 40 percent, as shown in Figure 39. As in Israel's YOZMA program, if the investment is successful, it returns to the fund as revenue. But if it fails, the Blue Premium Fund has no expectation from the joint investment. This funding scheme will be managed under the InvestEU. Investors and/or VCs should submit the projects they want to fund to InvestEU and get approval. Approved projects will be financed by the Blue Premium Fund.

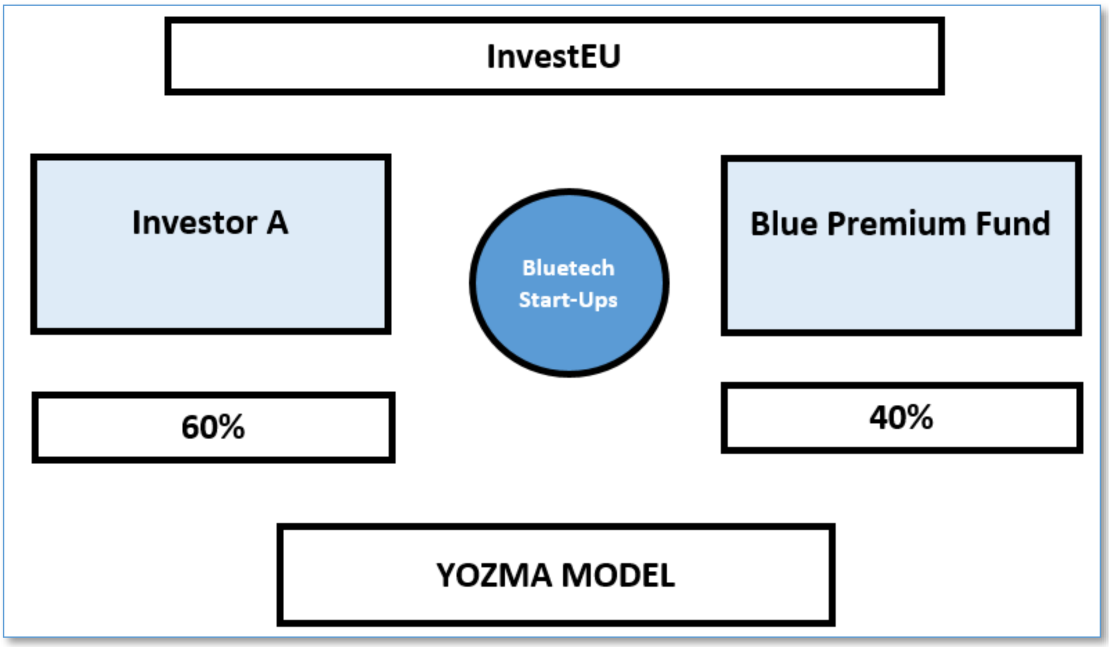


Figure 39 Investor Contribution to the Fund
(Source: Author)

4.2.4 InvestEU Fund

One of the important contributors of the Blue Premium Fund is the InvestEU Fund. With various grants and loan options, it will provide funds for strategic alternative fuel and clean technology investments to be made within the scope of the Blue Premium Fund. Especially in terms of co-financing, Blue Premium Fund will be one of the biggest contributors to the decarbonization investments of shipping companies. Figure 40 shows InvestEU's Blue Premium Fund simply. As stated earlier, InvestEU will also assume the management role between private investors and the Blue Premium Fund, while investing in bluetech start-ups with the YOZMA model partnership.

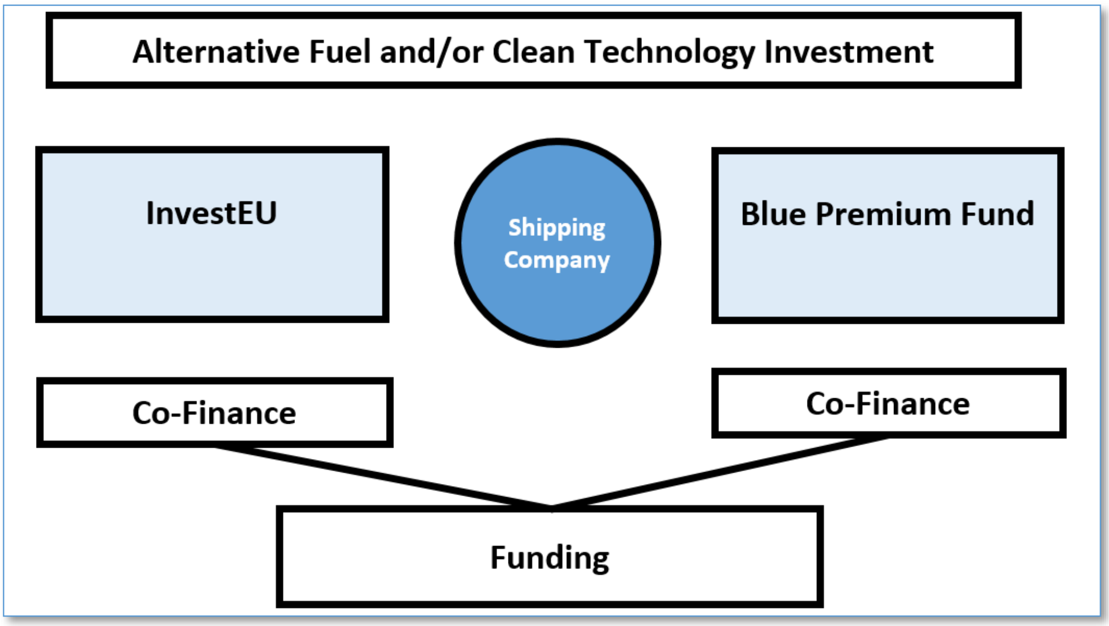


Figure 40 InvestEU Contribution to the Fund
(Source: Author)

4.2.5 The EU Member States

As in the example of the GCF, the Blue Premium Fund will also try to ensure a homogeneous and fair decarbonization of maritime transport within the EU borders, with contributions, as depicted in Figure 41, from higher income and much more decarbonized EU member states. Similar to its implementation in the Modernization Fund, one of the EU climate funds described earlier, the Blue Premium Fund will seek to support the low-income and fragile EU Member States in their transition to climate neutrality by helping to modernize energy systems in the maritime sector and by increasing energy efficiency.

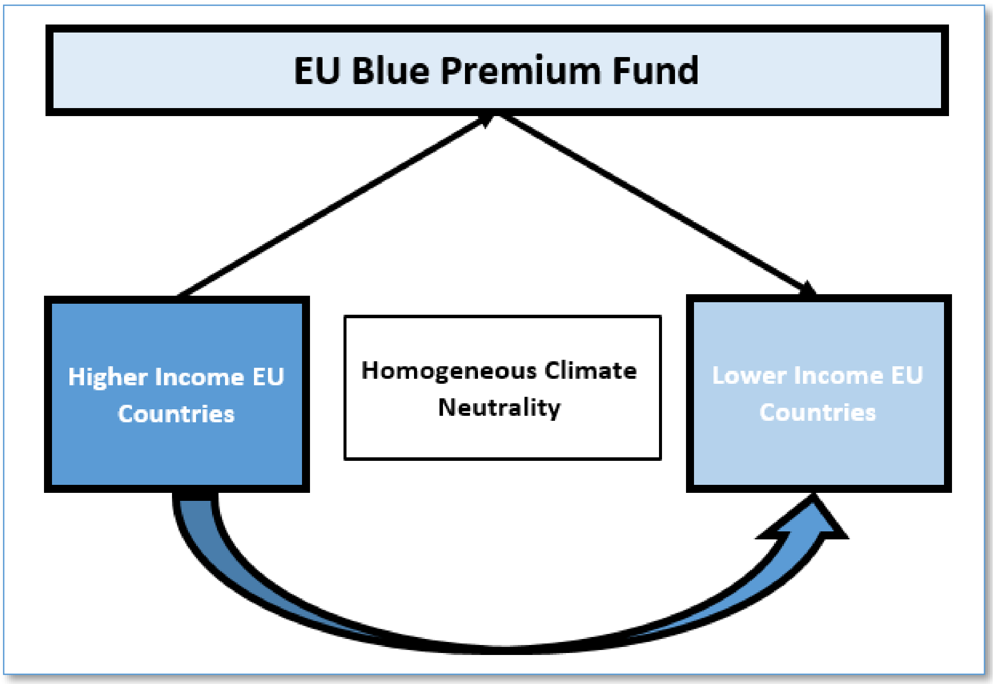


Figure 41 EU Higher Income Countries Contribution
(Source: Author)

4.2.6 Philanthropy

Donations to this fund from philanthropic funds, foundations, trusts and large shipping companies are also among the objectives of the Blue Premium Fund. As mentioned earlier, the EC has set up an expert group to explore possible initiatives to enhance the role of philanthropy (charity, foundations and trusts) as a means of providing additional funding for research and innovation. in the US and UK, it is important that European philanthropic organizations and also the biggest shipping companies such as the Danish company Maersk to be more active contributors to mitigate climate change and to prevent global warming. In terms of the maritime ecosystem, it will be important for this philanthropic ecosystem to donate to the Blue Premium Fund (as simply depicted in Figure 42) and use these donations for the decarbonization of the EU maritime industry and reaching a zero-emission target.

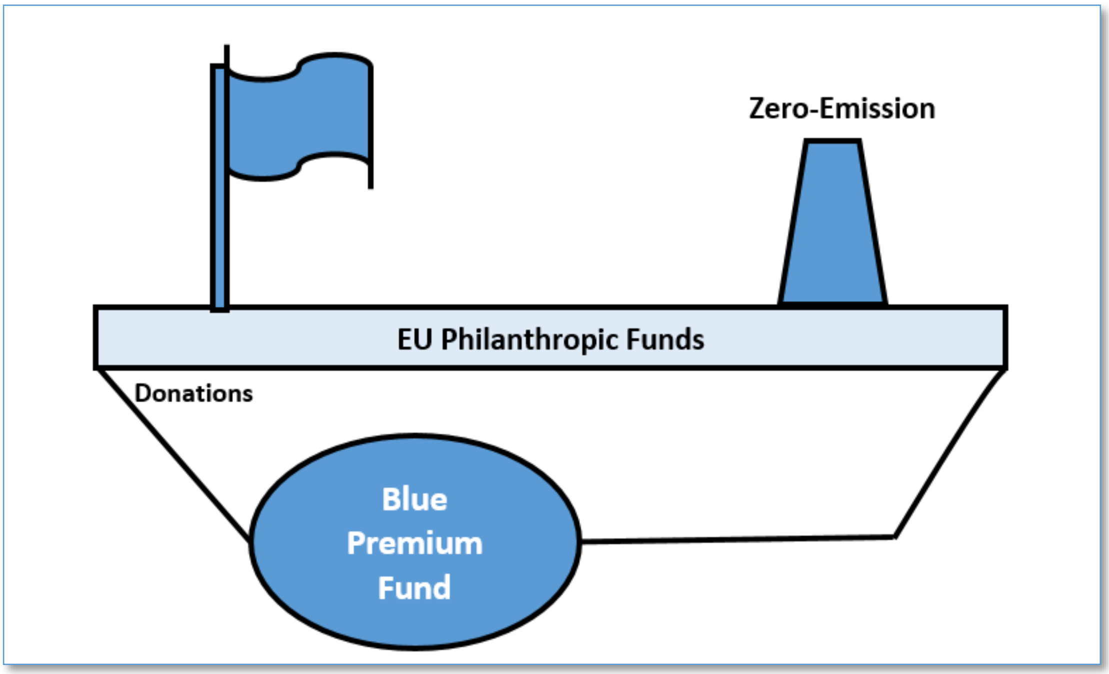
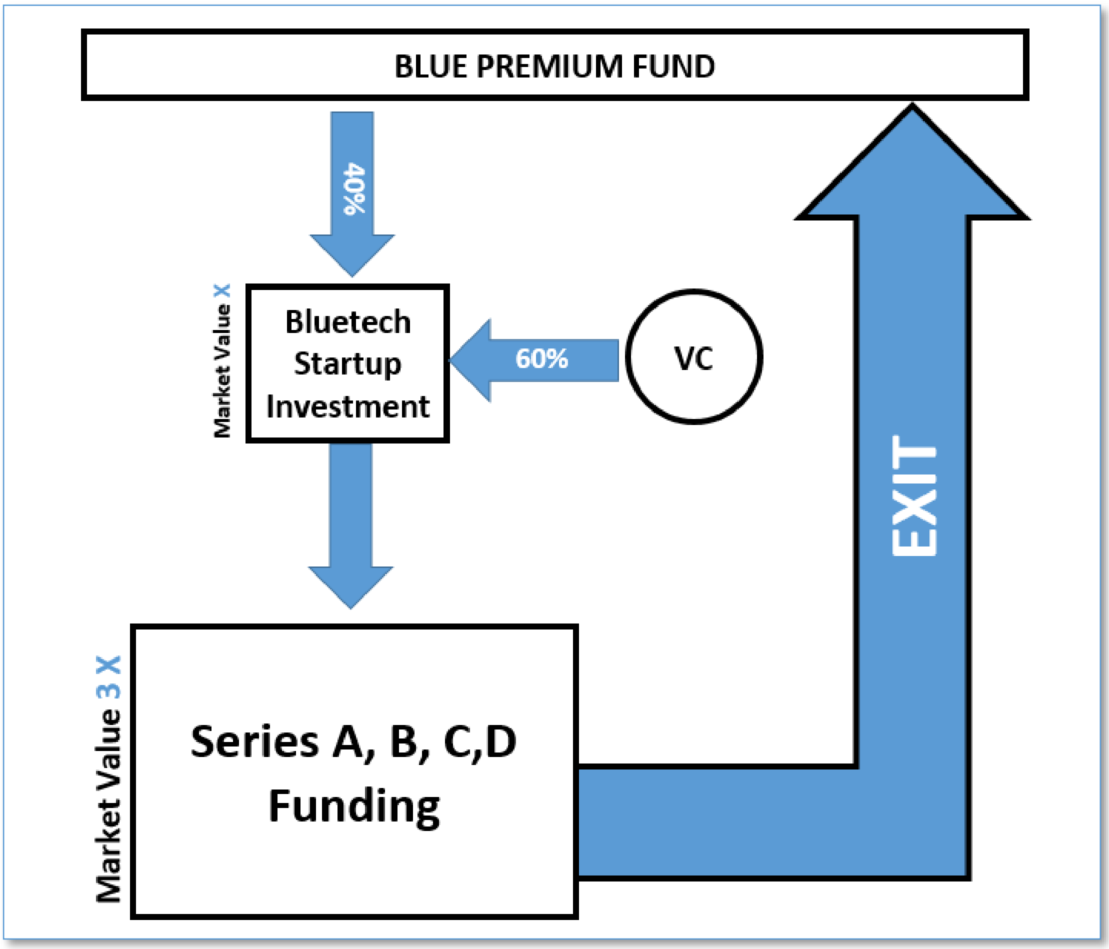


Figure 42 The EU Philanthropic Funds
(Source: Author)

4.2.7 Exits of the Investments

In order to support the blue investor and entrepreneur ecosystem of the Blue Premium Fund, revenue is expected from the exits of the bluetech start up investments that have been successful in the investor rounds that they have been involved in by partnering with the investors with the YOZMA concept (40%). It will continue to fund increasing the efficiency and decarbonization of the maritime sector by improving its R&D and innovation capacity with the revenue generated. An example flow of the investment to the exit stage is shown in Figure 43.



Note: *Triple growth in market value is for illustrative purposes.*

Figure 43 Investment Flow to the Exit
(Source: Author)

4.2.8 ESG Fund Returns

It has been stated in the previous sections that companies with high ESG scores have performed better recently. In particular, the development of blue finance and the shift of investors' interest toward this new investment area cause maritime companies to consider ESG criteria much more than even. Likewise, the maritime industry has the potential as an important investment area for ESG investors due to the sector decarbonization targets. The Blue Premium Fund considers ESG as an investment tool. In particular, it wants to generate income by investing in ESG shipping funds and/or baskets created by EU shipping or fund companies that serve to decarbonize the EU shipping industry. With this investment, it is also planned to increase the performance of EU shipping companies that attempt to fulfil the ESG criteria. Indirectly, it will also serve to reduce the carbon levy that EU maritime companies with a high-ESG score have to pay. Below is Figure 44 describing the mechanism of the investment.

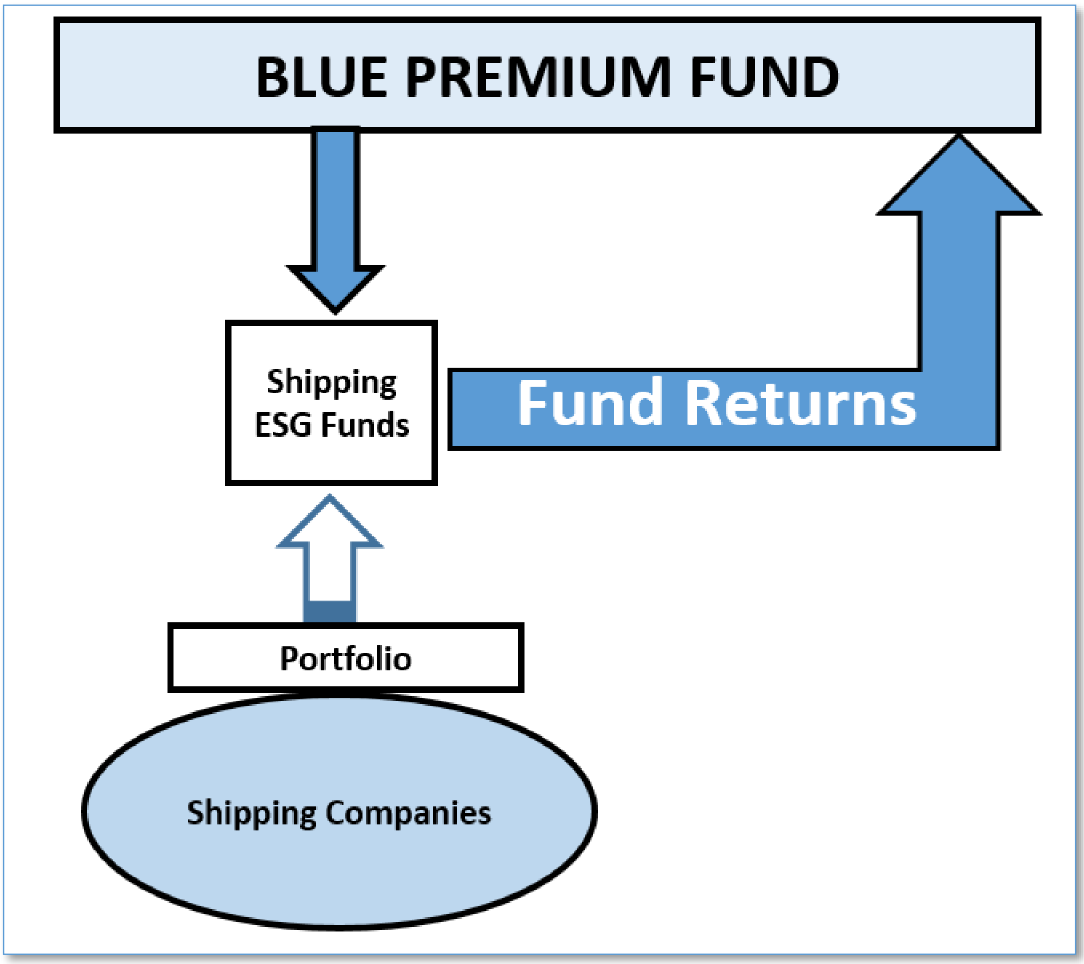


Figure 44 ESG Fund Returns
(Source: Author)

4.3 SUPPORT AREAS OF THE BLUE PREMIUM FUND

The Blue Premium Fund directly benefits many stakeholders of the maritime ecosystem by facilitating the decarbonisation of the European Maritime ecosystem. It provides funds (mostly generated by carbon levy tax) to shipping companies, governments, bluetech start-ups, researchers, universities, research centres and raises funds through partnerships with investors, the EU member states, R&D and innovation funds, investment funds, philanthropists and the biggest shipping companies. How to use the fund is listed below and shown in Figure 45, and in Chapter 6, each application area of the fund will be illustrated with a decarbonization solution (alternative fuel or energy efficiency enhancing technologies) and the working principles of the fund will be explained.

- Funding ship owners’ investments in alternative fuel and energy efficient technologies
- Funding the R&D and innovation activities of universities, research centers, researchers and/or bluetech startups
- Partnering with bluetech startups as an investor
- Funding the corporate R&D activities of shipping companies for capacity building
- Investing in the shipping ESG funds

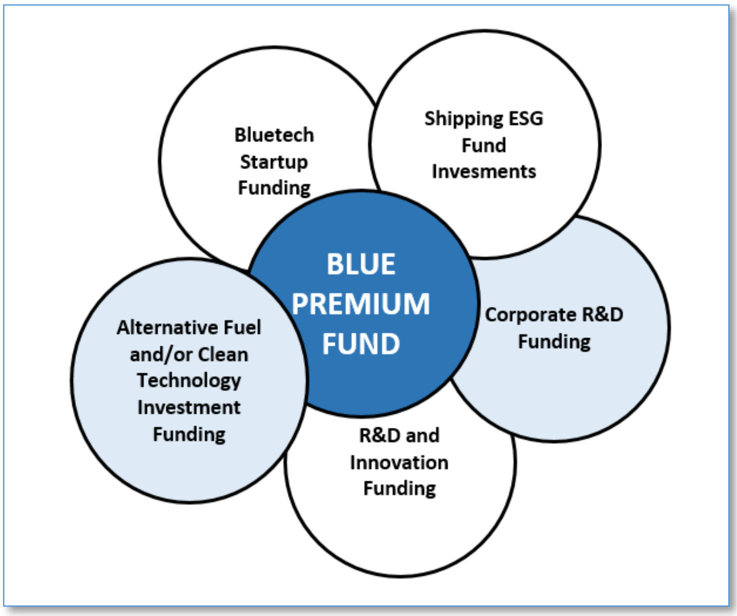


Figure 45 Support Areas of the Fund
(Source: Author)

4.4 GOVERNANCE OF THE BLUE PREMIUM FUND

The competence of the EU in fund management and the fact that it has many fund mechanisms is a great advantage for the Blue Premium Fund. There are many fund support mechanisms such as R&D and Research funds such as Horizon Europe, climate funds such as the EU ETS Innovation Fund, and strategic and resilient recovery investment funds such as InvestEU. The governance is so effective and communication of these support mechanisms with each other is strong. Moreover, the EU's partnership with important VCs such as Breakthrough Energy, which has gathered many VCs to reduce greenhouse gas emissions, is in its strengths. Therefore, the Blue Premium Fund will be managed and governed by keeping in touch with other existing funds of the EU, as shown in Figure 46. It will also be in harmony with the relevant legislation concerning the decarbonization of shipping, within the Fit for 55 package put into effect by the EU under the EU Green Deal.

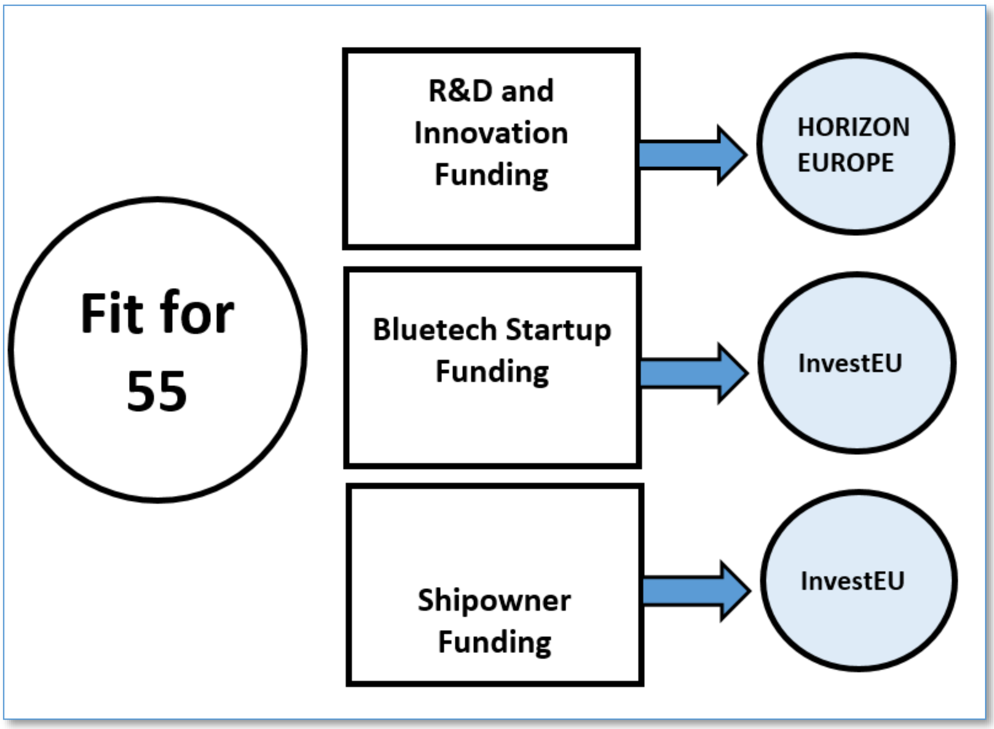


Figure 46 Governance of the Fund
(Source: Author)

Chapter 5

5.0 CASE STUDIES OF THE BLUE PREMIUM FUND

5.1 SHIPOWNERS' INVESTMENTS FUNDING

An area that the Blue Premium Fund will support is the ship owners' investments in alternative fuels and/or new innovative technology to reduce emissions. The aim is to reduce the blue premiums of alternative fuels and/or technologies. In the study, the working principle of the Blue Premium Fund in this case will be explained without making any calculations and considering financial technical details, and how to support ship owners will be explained. The aim of this case study is to explain how this support works with decarbonization solutions.

As described earlier, numerous hydrogen-based technologies and uses cost more than traditional fossil fuels. In order to maximize the market readiness and scale of hydrogen generation, distribution, and end-use technologies, major R&I activities are still needed to increase their efficiency, cost, durability, and manufacturability. The Blue Premium will seek to help ship-owners use hydrogen competitively in terms of price.

5.1.1 Hydrogen-Powered Vessel

In this case study, the Blue Premium Fund will support ship-owners who want to invest in hydrogen-powered ships. The goal is to make the fleet completely zero-emissions. InvestEU and Blue Premium Fund will provide funds if they approve the investment after reviewing and evaluating the investment. The investment amount can be as much as Blue Premium, which is between the conventional fuel-powered and hydrogen-powered ship costs available in similar ship types. The working principle of this fund type is shown in Figure 47.

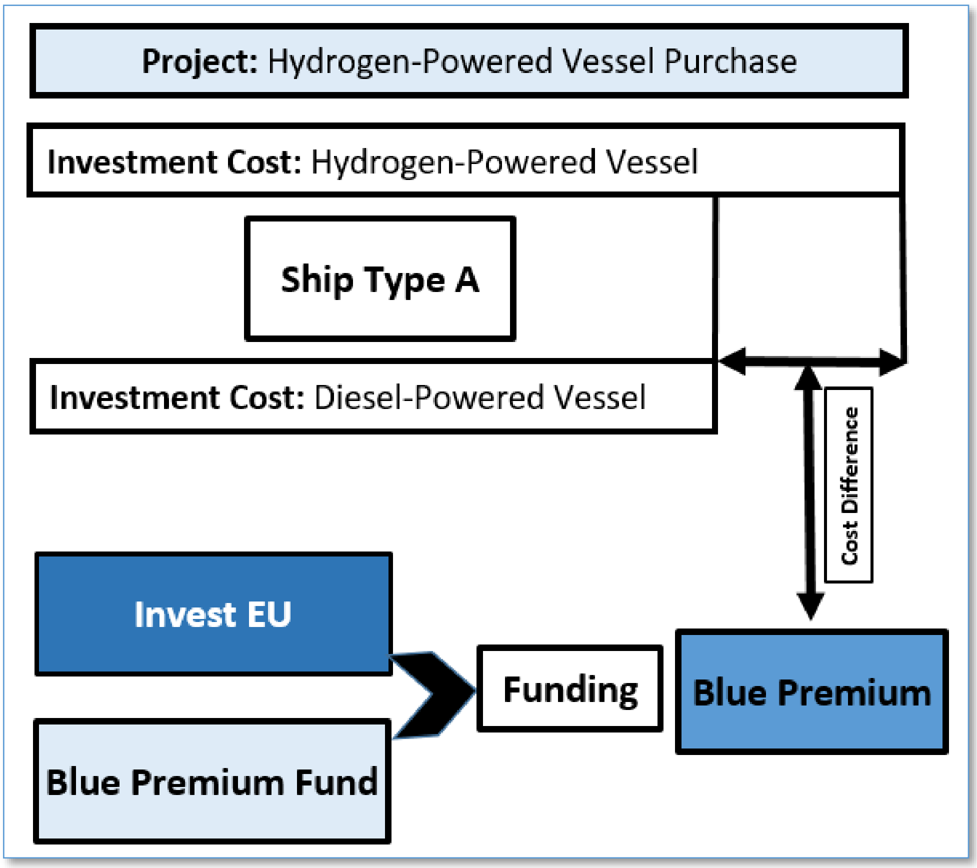


Figure 47 Case Study 1, Hydrogen-Powered Vessel
(Source: Author)

5.2 R&D and INNOVATION FUNDING

R&D and innovation activities are extremely important for the maritime industry to achieve both the IMO and the EU emission targets. There is a need for ground-breaking new innovations in alternative fuels and technologies to be competitive by removing the barriers in front of them. Therefore, R&D activities by universities, research centres, companies, researchers and bluetech start-ups should be supported. The Blue Premium Fund will also fund core R&D and innovation activities.

5.2.1 Wind-Assisted Ship Propulsion

This case study is a R&D project on wind-assisted propulsion systems. The coordinator of the project is a university in this case. The aim of the research project is to develop a wind propulsion system for energy savings of up to 50%. A prerequisite for supporting the research project is that it receives a grant/fund from EU R&D and innovation funds such as Horizon Europe before applying for the Blue Premium Fund. In case the project is financed by one of the EU R&D support programs, as illustrated in Figure 48, the necessary co-financing will be provided by the Blue Premium Fund.

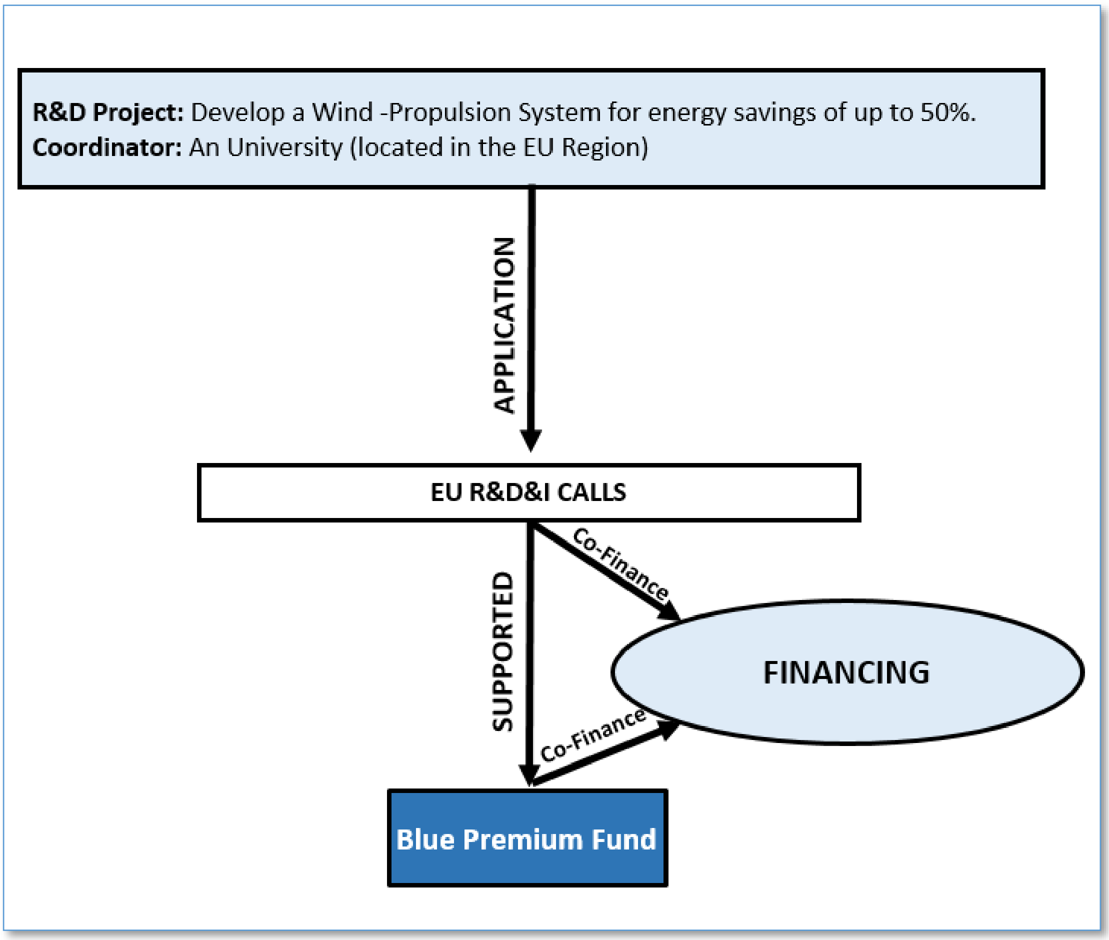


Figure 48 Case Study 2, Wind-Assisted Propulsion
(Source: Author)

5.3 BLUETECH STARTUP FUNDING

One of the most important fund areas of the Blue Premium Fund will be bluetech start-ups. The number of start-ups performing out in the maritime industry is less than in other sectors and there is no unicorn operating in this sector yet. The contribution of bluetech start-ups will be important in innovations that will be developed for the decarbonization of the shipping industry. As stated before, start-up funding will have a funding system similar to the Israeli YOZMA program. The blue entrepreneurship technology ecosystem will be developed by ensuring that private investors and VC companies fund bluetech start-ups. As explained in Chapter 5, any VC who wants to invest in bluetech start-ups will be able to receive funding from the Blue Premium Fund after submitting their project applications to InvestEU and getting their approval.

5.3.1 Air Lubrication Start-up

In the third case study, the Blue Premium Fund will support a bluetech start-up working on air lubrication technology. With an innovative air lubrication technology, it has developed, it has managed to reduce the fuel use of existing ships by up to 20% with a payback period of two to three years.

Here, if start-up manages to receive funding from an investor (for example, a VC) whose venture is a partner of the Blue Premium Fund, the start-up should submit this to InvestEU. In case of approval, the Blue Premium Fund will partner with the investor at a rate of 40 percent, as in the YOZMA Model concept. If this initiative is successful, Blue Premium Fund will exit in the future and create revenue for the fund. There will be no expectation if this attempt fails. The funding of the blue tech start-up is simply explained in Figure 49.

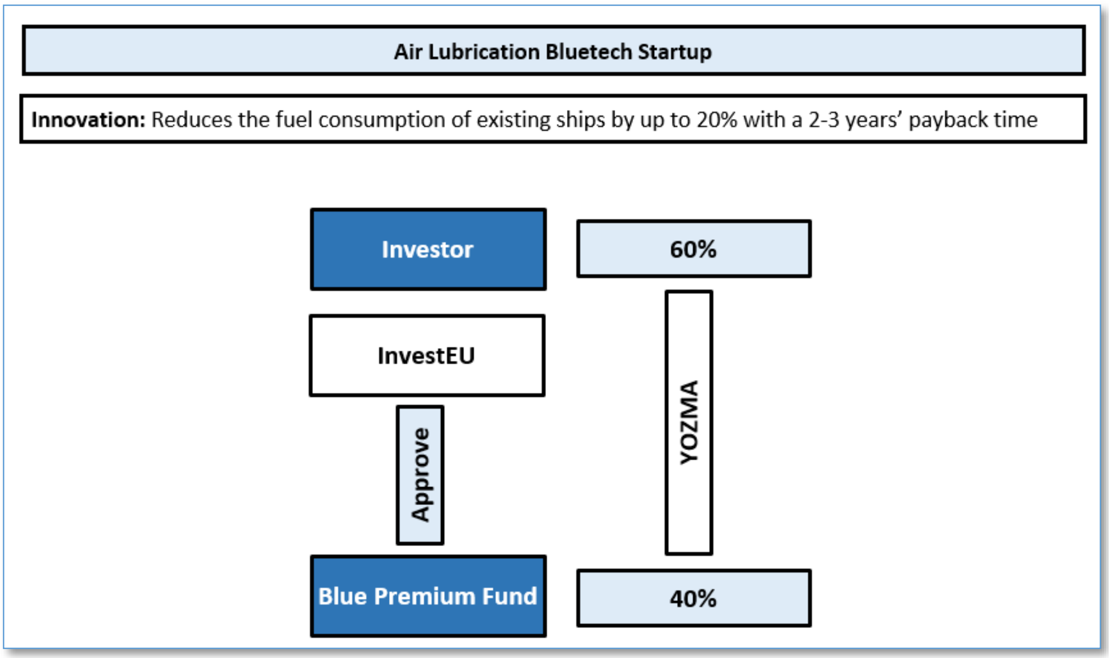


Figure 49 Case Study 3, Air Lubrication
(Source: Author)

5.4 CORPORATE R&D FUNDING

Developing the R&D capacity of the maritime ecosystem is important for emission reduction targets. Compared to other sectors, R&D expenditure is low, and maritime companies should invest more in R&D. Maritime companies can increase their R&D capacity through direct and indirect ways, such as identifying required components or solutions through research, developing new products, services, and software, creating prototypes, and testing both in-house and on-site. solution integration and testing, building R&D departments, and hiring R&D personnel.

The Blue Premium Fund will support the corporate R&D activities of shipping companies, especially the development of intrapreneurship and decarbonization solutions, to increase the competencies of these companies and to become more sustainable companies. The shipping company should continue its R&D activities according to the priorities set in the STRIA.

5.4.1 Biofuels R&D Project

The fourth case study is to accelerate the deployment of the low Life-Cycle Inventory biomethane in shipping, a project the shipping company has undertaken in line with its own in-house zero-emission shipping goal. This research determines whether biomethane has the potential to make a major early-stage contribution to decarbonization in the maritime industry and to identify what strategy and approach it should do so. If the R&D activity agrees with STRI priorities, the shipping company will be able to meet the financing requirements it needs during the project by applying to the Blue Premium Fund. Only shipping companies that pay a carbon levy can receive this support. Working principle of this support is illustrated in Figure 50.

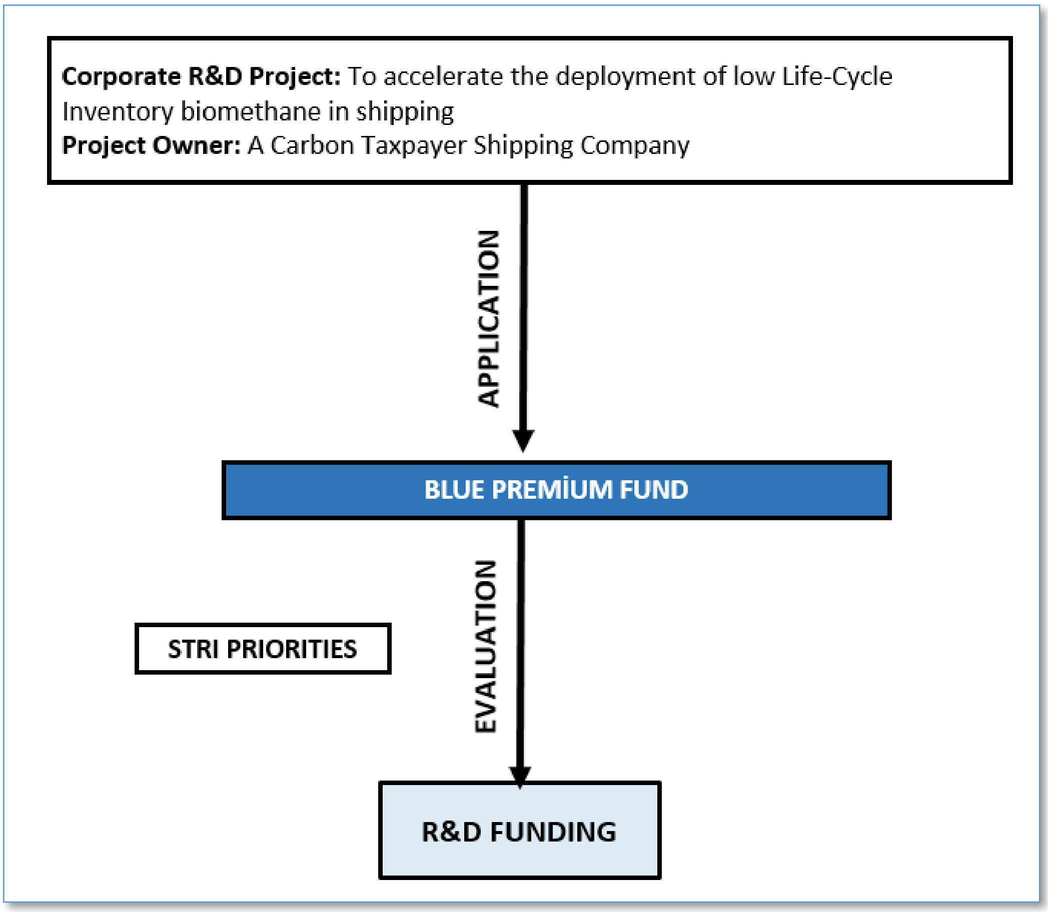


Figure 50 Case Study 4, Biofuels
(Source: Author)

5.5 SHIPPING ESG FUNDING

It has been observed worldwide, especially after the COVID-19 pandemic, that companies have increasingly started to act with ESG responsibility beyond earning returns for shareholders. Investors are increasingly seeing that companies that perform well on the ESG are less risky, better positioned over the long term, and better prepared for uncertainty. The fact that companies with high ESG performance have started to show higher financial performance has increased the importance of ESG scores in many sectors. One of these sectors is the shipping industry. As mentioned before, meeting the ESG criteria for shipping companies to attract more investment has been one of the important agenda of this sector.

The Blue Premium Fund also takes ESG scores into account while charging the carbon tax from the ship owners. The shipping company with a high ESG score will pay less tax. A certain part of the revenues accumulated in the fund will be transferred to the maritime funds in order to generate revenue for the fund and to increase the ESG awareness of maritime companies.

5.5.1 Renewable Methanol

In this case study, the Blue Premium Fund will invest a certain portion of its savings in the ESG Methanol Clean Energies fund. 40 European shipping companies engaged in "clean energy-related businesses, including a broad mix of renewable methanol fuel and clean energy equipment, make up the Maritime Clean Energy Index. In this way, the Blue Premium Fund will support these shipping companies that are trying to contribute to the decarbonization of the maritime industry, and all shipping companies will be encouraged to improve their financial performance by raising their ESG scores. This will help them reduce their carbon levies. The fund work principle is simply shown in Figure 51.

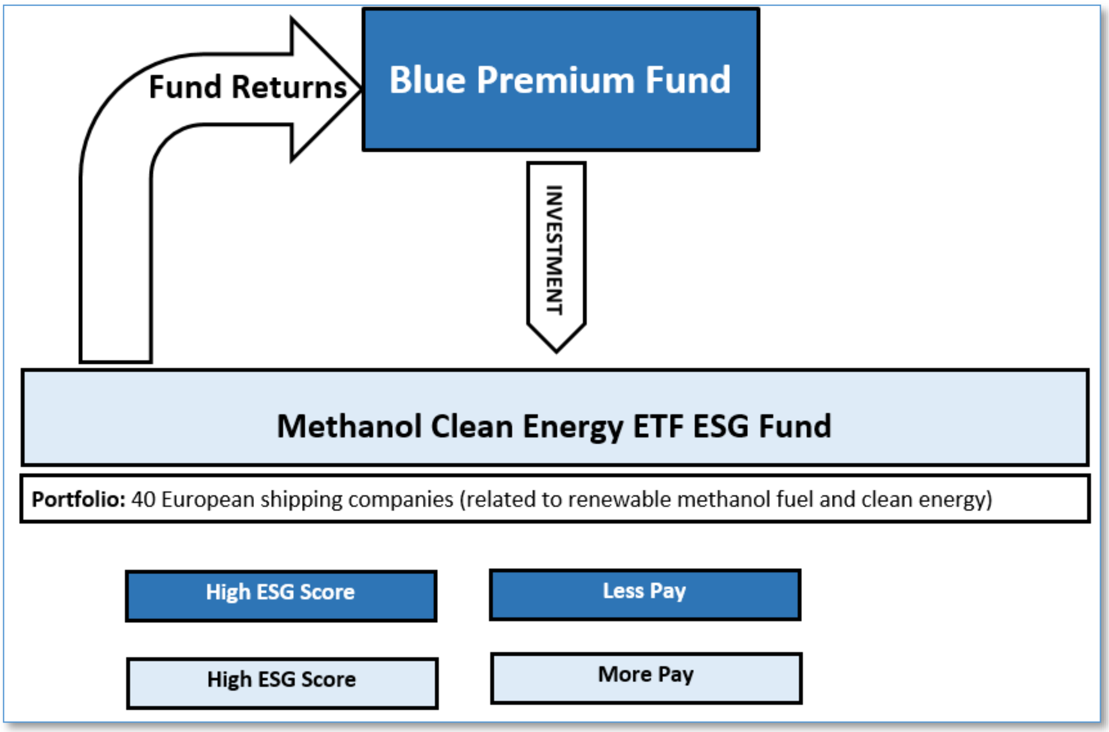


Figure 51 Case Study 5, Methanol
(Source: Author)

5.6 CASH FLOW OF THE FUND

As mentioned earlier, the Blue Premium Fund has some sources of revenue. These sources will be used for the decarbonisation of the EU shipping industry. When a calculation is made with some assumptions, approximately a total revenue of €16 billion is expected during by 2033. At least 80 percent of this revenue will be used for the decarbonisation of the EU shipping industry. Figure 52 shows the expected revenue.

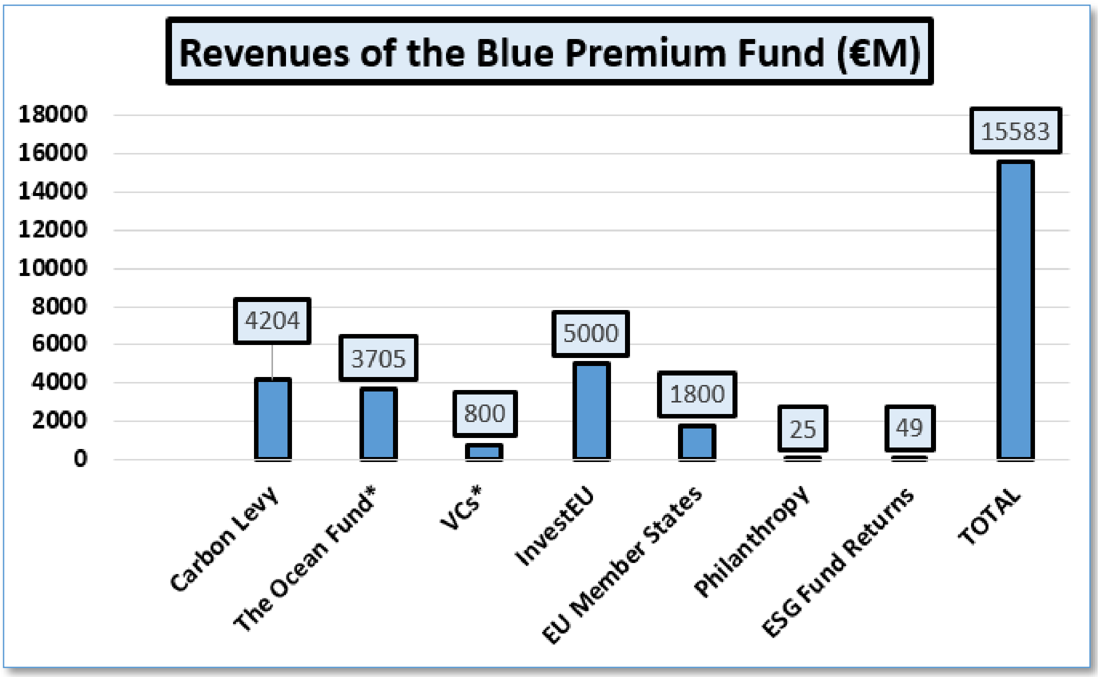


Figure 52 Revenues of the Blue Premium Fund
(Source: Author)

Some assumptions were made while making these calculations. For example, the carbon levy decreases over the years. It is estimated that 50 million tons of marine fuel consumed in the EU will decrease by at least 45 % until 2033, in line with the EU 2030 targets. An assumption was made that the ESG score will also increase at least twice from 0.38 to 0.76. At the end of 10 years, it is expected to generate a total revenue of approximately €4 billion. Figure 53 shows carbon levy revenues.

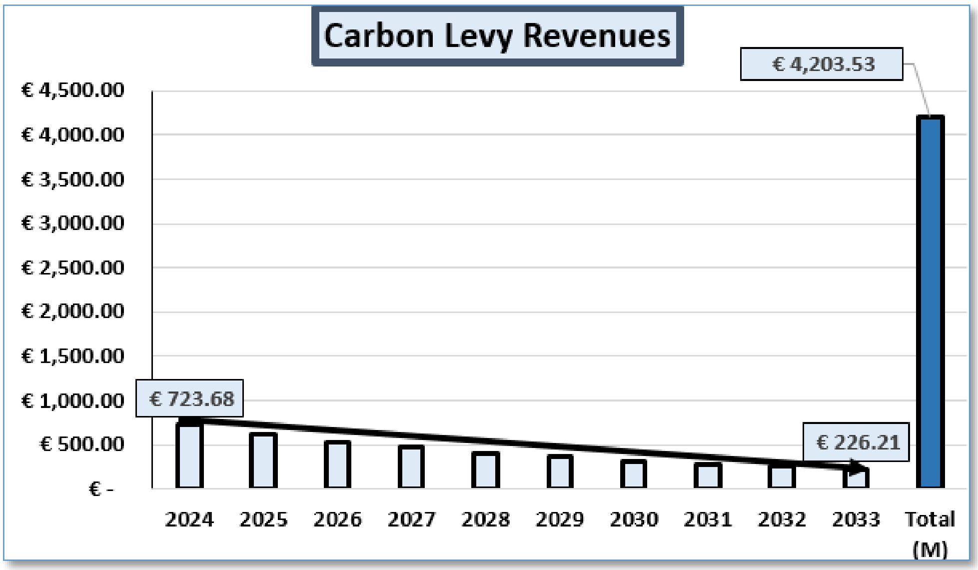


Figure 53 Carbon Levy Revenues
(Source: Author)

Another calculation is the Ocean Fund revenues that are probably established. At least 13% of the €38 billion expected to be created by 2030 in the EU ETS Innovation Fund will come from maritime allowances. 75 percent of this revenue will be transferred to the Ocean Fund. In this study, it is recommended to transfer the revenue accumulated in the Ocean Fund to the Blue Premium Fund. A revenue of approximately $4 billion is expected. Another assumption made is that InvestEU will allocate at least €5 billion euros for the decarbonization of shipping at the end of 10 years. Additionally, in the YOZMA model, it is assumed that there will be a contribution of at least €60 million each year from the private investors and VCs it wants to attract to the fund. Moreover, a contribution to the Blue Premium Fund is also expected from EU member states. Assuming that at least 5 % of the contribution of 23 EU countries to the Green Climate Fund will be made to the Blue Premium Fund, it is estimated that a fund of close to €2 billion will be allocated by 2033. Assuming that the 1.6 billion Euro donations made by philanthropic funds, which is another source, to the EU maritime industry in 2020, continues to increase by at least 10 percent every year, it is estimated that there will be at least €25 million in revenue in 2033.

In addition to these revenues, an assumption is made that if two unicorn companies emerge among the bluetech start-ups, where the Blue Premium Fund will become a 40 percent partner with the YOZMA model within 10 years, it is estimated that it will generate at least €800 million in revenue. Finally, it is assumed that there will be at least 10 percent revenue from the shipping ESG funds, with a total inflow of €50 million by 2033.

An assumption has also been made about how the Blue Premium Fund will use resources for EU shipping decarbonisation, as shown in Figure 54. At least 50 percent of the funds will be used in decarbonisation investments of ship owners, at least 10 percent in R&D activities, at least 10 percent in bluetech start-ups, at least 5 percent in corporate R&D activities of shipping companies and at least 5 percent in shipping ESG fund investments.

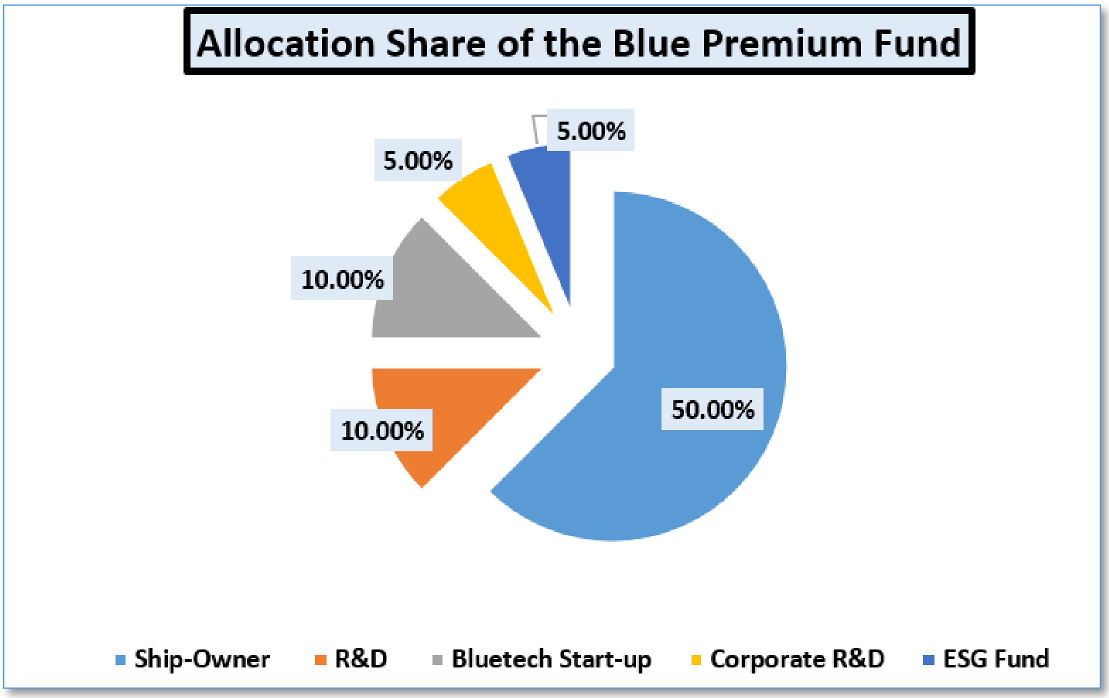


Figure 54 Allocation of the Blue Premium Fund
(Source: Author)

In summary, the Blue Premium Fund will help finance the decarbonisation of the EU shipping industry, generating an annual revenue of at least €1.5 billion with a simple calculation. This will make a significant financial contribution to the annual 4–5billion Euros that the EU should allocate to be net-zero.

Chapter 6

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

There are some solutions put forward for the decarbonization of the EU shipping industry to achieve the IMO and EU 2030 and 2050 targets and to reduce GHG emissions. The most important of these solutions are switching to zero-emission alternative fuels, using renewable energy, adapting to new shipping propulsion systems, transitioning to new technologies that reduce emissions, and improvements to be made in vessel design. It is important to reach the desired targets at the EU level, as it is worldwide, and it is planned that the maritime industry will be a zero-carbon industry with regulations and legislative packages such as Fit for 55. However, there are technical, operational and financial barriers to this transition. The most important of these is that, although there are technologies available and ready in the market, they are more expensive than traditional fuels and new innovative emission reduction technologies due to their investment and operational costs. The key to decarbonization of the shipping industry is therefore financing. In order for alternative fuels and new technologies to be used on ships, they should be brought to competitive prices. In other words, the blue premium, which is the green premium of the maritime industry used for the first time in the literature, should be reduced.

Financing alone is not enough to reduce Blue Premium. In particular, the maritime sector, which spends less on R&D compared to other sectors, should focus on more R&D activities and try to remove the technical and operational barriers in front of alternative solutions. Likewise, start-ups, which have become the most valuable companies in the world by developing disruptive innovations worldwide in the last two decades, should take a much more active role in the decarbonization of shipping. It is critical for the decarbonization of shipping that the bluetech start-ups and investor ecosystems will be developed and the funds will shift to these areas more and that bluetech start-ups will emerge in the coming years. In order to develop this ecosystem, financial instruments should be diversified and navigated in line with the priorities of the sector and the IMO, and the EU targets.

The EU, on the other hand, is more ambitious with the goal of being the first zero-emission continent, as it is far ahead of maritime decarbonization according to the IMO. It is based on climate change and global warming concerns with various R&D, innovation, and investment funds and aims to create a sustainable ecosystem. However, even at the EU level, there is no fund that focuses directly on the decarbonization of shipping. It has only the intention to build up the "Ocean Fund", which is at the proposal stage, where 75% of the EU ETS revenues coming from maritime allowances are planned to be transferred. However, even if this fund is established, it would be insufficient for the investment amount required for full decarbonization of the EU shipping industry. Therefore, it is necessary to establish a new maritime fund that will support the EU's policies and serve to achieve the IMO and EU 2030 and 2050 targets. The Blue Premium Fund is designed for the EU shipping industry to address this need and to close the gap. Based on the principle of levying carbon tax from ship-owners for marine fuel used per ton, such as the maritime R&D fund proposed by the ICS to IMO, EU ship owners will be charged a base value of €5.5 per tonne of marine fuel they use. While calculating carbon tax, unlike ICS, it will take less tax from ship owners with high ESG scores, considering ESG score. In this way, shipping companies will be encouraged to meet the ESG criteria so that they can have resilient and green finance sustainably.

The Blue Premium Fund has some sources other than a carbon tax to ensure its sustainability and raise more funds. It proposes to transfer the revenues accumulated in the Ocean Fund to the Blue Premium Fund, if the Ocean Fund enters into force. In order to attract private investors and VCs to the Fund, it will use the model applied in Israel's YOZMA program in the 1990s. In order to develop the start-up and investor ecosystem with this model, YOZMA fund encouraged investors to invest in start-ups by partnering 40% with each start up. Similarly, 40% of each investment made in bluetech start-ups in the Blue Premium Fund will support the development of the start-up and investment ecosystem. If the joint venture is successful, the revenues from the exits will be transferred to the fund. In case of failure, there will be no expectation. Additionally, the Blue Premium Fund will increase the volume of the fund by raising funds from the InvestEU, EU member states and philanthropic foundations, and the biggest shipping companies, allocating funds for more R&D and innovation activities, investments and bluetech start-ups. The last source of capital flow for the Blue Premium Fund is the returns from shipping ESG funds. By investing in ESG funds, whose portfolios are shipping companies that fulfil the ESG criteria, it helps to increase the financial performance of these companies and to have an encouraging effect on the ESG criteria of other shipping companies.

As a result, the Blue Premium Fund is a new, innovative, and an inclusive funding mechanism proposal fund for the sustainable financing of the decarbonization of the EU shipping industry developed by examining the EU and world R&D and investment funds, and considering the EU's current policies and climate-neutral targets as well as global 2030 and 2050 targets set by the IMO.

6.2 FUTURE RESEARCH

The Blue Premium Fund is to reduce blue premiums and contribute to making new energy-efficient technologies and alternative fuels more competitive. Blue Premium, in this study, is illustrated simply to show the difference between the current market prices of new solutions and conventional emitters (e.g. HFO vs. green hydrogen). However, it did not consider the other effects of GHG emissions on societies, economies, and companies. When the devastating effects of climate change and global warming are considered, a completely different economic picture will emerge. Here, it will be observed that the blue premium reaches zero and below values. Therefore, in future studies, it will be shown that the transition to new alternative fuels and new emission-reducing technologies for the maritime industry is a reasonable and necessary investment by calculating the blue premium (considering its economic, social, and environmental costs) in more detail.

Additionally, a calculation tool that considers fluctuating energy and fuel oil costs and possible decreases in the prices of alternative fuels and technologies should be developed and presented to the maritime industry. In this way, any ship-owner will have a better chance of planning its investment in these alternative fuels or in any emission reduction technology.

Finally, although the Blue Premium Fund is designed for the EU, the decarbonization of shipping is a global need and is addressed at the IMO level. It is also necessary to establish an R&D fund within the IMO. Adapting the Blue Premium Fund and designing a fund for the IMO will be discussed in future studies.

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