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Shipping EU ETS and decarbonization strategies for emission reduction.

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Abstract

It is reported that about 3% of the world's greenhouse gases (GHG) are released by the global shipping market. With rising technological advancements in the shipping industry, it is hoped that as per the IMO's regulation 2050, all the ships should be a carbon free vessel. In accordance with the new regulations, most of the maritime companies started to plan customary practices in order to reduce their vessel's Co2 emissions. With the goal of encouraging sustainable development within the shipping industry, the European Union (EU) has approved the inclusion of shipping in its emissions trading system. The EU-ETS is a 'cap and trade' system acting as a regulatory tool to reduce greenhouse gas emissions in a cost-effective manner, for this the EU sets a yearly cap on the amount of EU Allowances (EUAs) that can be traded on the market in the form of 'Free Allocations and Auctions'. Major reforms evolved in the recent years, particularly the 'Fit-for-55' which was introduced in 2014, aiming to fulfil EU's goal of reducing greenhouse gas emissions by 55% by 2030 compared to 1990 and reaching carbon neutrality/net-zero by 2050. This article addresses the significance of the EU ETS along with the implementation challenges. In order to obtain a general understanding of the system, fifteen participants from four different shipping companies participated in an interview procedure. Their responses made it possible to create codes and labels that were then subjected to thematic analysis. This study provides an overview of the technological measures that ship owners might implement to lessen their carbon footprint and associated barriers by analyzing the answers provided in the interview and the literature review.

Keywords: Green Shipping, EU-ETS regulations, global shipping market, decarbonization, IMO, greenhouse gas emission, Co2 emissions, carbon tax, carbon reduction,

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List of Abbreviations

GHG	-	Greenhouse Gas Emission
CO2	-	Carbon di oxide
EU ETS	-	European Union Emission Trading System
IMO	-	International Maritime Organization
COP21	-	Paris Climate Conference
UN	-	United Nations
EU MRV	-	EU Monitoring, Reporting and Verification
IMO DCS	-	IMO Data Collection System
MBM	-	Market Based Measures
SOLAS	-	International Convention for the Safety of Life at Sea
MARPOL from Ships	-	International Convention for the Prevention of Pollution
HFO	-	Heavy fuel oil
MEPC	-	Marine Environment Protection Committee
EEDI	-	Energy Efficiency Design Index
EEXI	-	Energy Efficiency Existing Ship Index
SEEMP	-	Ship Energy Efficiency Management Plan
CII	-	Carbon Intensity Indicator
CCS	-	Carbon capture and storage
OTC	-	Over the Counter
EEX	-	European Energy Exchange
TNAC	-	Total Number of Allowances in Circulation
N2O	-	Nitrous Oxide
CH4	-	Methyl hydride
PRISMA Meta-Analyses	-	Preferred Reporting Items for Systematic Reviews and
ISM	-	International Safety Management
MICMAC classification	-	Cross-impact matrix multiplication applied to
ICIO	-	Inter-Country Input-Output
EIO	-	European Investigation Order
BWM	-	Ballast Water and Sediments
VDRs	-	Voyage Data Recorders
ECDIS	-	Electronic Chart Display and Information Systems
AIS	-	Automatic Identification Systems

1.Introduction

It's been observed that as industry advances quickly, the environment is being affected more and more. The effects on the environment include burning fossil fuels, air and water pollution, and climate change. But given its worldwide importance and wide-ranging effects, climate change is frequently recognized as having a significant negative influence on the environment. Greenhouse gas accumulation is the primary cause of climate change (GHGs) (Talley, 2003)

This thesis focusses on the Co2 emissions in shipping industry. One of the main components of the EU's initiatives to cut greenhouse gas emissions and move towards a low-carbon economy is the EU ETS, which was established in 2005. Fundamentally, the EU Emissions Trading System (ETS) functions based on the cap-and-trade principle, which establishes a maximum allowable quantity of greenhouse gas emissions from specified sectors while permitting flexibility through the exchange of emissions permits.

A wide number of industries are covered by the EU ETS, including manufacturing, aviation, electricity generation, and other major producers of emissions. On January 1, 2024, the European Union Emissions Trading System (EU ETS) was extended to the shipping industry. The EU's efforts to lower greenhouse gas emissions from maritime transport, a major source of emissions globally, have advanced significantly with this extension. Large shipping corporations began to retrofit their ships with new technologies and alternative fuels in an effort to reduce carbon dioxide emissions (World Bank Group, 2021)

1.1 Research Background

Almost 90% of the goods are carried by sea and the importance of the shipping sector is paramount to running the global economy. Shipping plays a crucial part in forming economies, civilizations, and international trade. The business of shipping is an international commodity in its own right, with a very active world-wide financial exposures connecting various parameters (such as politics, geopolitical tensions, sanctions, war, inflation, regulations and supply and demand elasticities) into consideration for conducting global trade and transactions (Wettestad & Gulbrandsen, 2022). The cyclicality of the industry is very unique with its own booms and busts

and that's what separate the maritime sector from the other transportation industry. Transoceanic shipping is a vital and reasonably priced means of supporting billions of people's livelihoods by facilitating the efficient import and export of goods. Over the next 30 years, the extent of maritime activity may double or even quadruple, assuming a conservative growth rate of roughly 2-3% annually. According to some projections, the amount of maritime trade that occurs globally could rise from 2015 levels by 50% to 250% by 2050.

The challenges arise in parallel with the expansion in demand. It is reported that the Greenhouse gas emission will increase if no proper and prior steps taken. Currently maritime is reporting about 2.5% (as of in 2022) of emissions globally which was aimed to reduce in the upcoming year (Goyal & Llop, 2024). Ships produce Carbon di oxide (Co2), sulfur oxides (Sox) and nitrogen oxides (NOx) which is collectively called as Greenhouse Gas emissions. Human health and the quality of the air are negatively impacted by these GHG. The International Maritime Organization (IMO) was founded in 1987 with the goal of monitoring vessel pollution and maritime safety (Bortuzzo et al., 2023).

Over the years of international voices and environmental safeguarding pressure, the UN in 2015 through conference of parties (COP21) introduced the Paris Agreement on climate change, where countries agreed the target of limiting the rise in global temperatures below 2*C (Bouman et al., 2017). This target is crucial for nations and industries that encompass the global economy, the maritime industry through its UN agency i.e. International Maritime Organization (IMO) takes the target into account and considers its ambition, adequacy, and effectiveness in ensuring a fair contribution to the global green transition and decarbonization efforts. (Bouman et al., 2017)

The decarbonization of the maritime industry has become a core priority due to the slow take-up of the industry's green transition to align with the Paris Agreement goals and efforts, due to this governments have taken national initiatives that compete with the current IMO's decarbonization strategy and efforts, particularly the EU has taken significant steps and has made a high priority on the environmental and political agenda. The EU has proposed set of proposals to making the EU's climate, energy, transport, and taxation policies fit for reducing the net GHG emissions by at least 55% by 2030 compared to 1990 levels under it's so called 'Fit for 55' package. (Wang et al., 2023)

One of the main components of the EU's initiatives within the package to cut greenhouse gas emissions and move towards a low-carbon economy is the EU ETS, which was established in 2005. Fundamentally, the EU Emissions exchange System (ETS) functions based on the cap-and-trade principle, which establishes a maximum allowable quantity of greenhouse gas emissions from specified sectors while permitting flexibility through the exchange of emissions permits. A wide number of industries are covered by the EU ETS, including manufacturing, aviation, electricity generation, and other major producers of emissions. On January 1, 2024, the European Union Emissions Trading System (EU ETS) was extended to the shipping industry. (Bortuzzo et al., 2023)

The inclusion of the shipping industry within the ETS system would make it difficult for the shipping companies to comply with the regulation without the right and approachable strategy, as the regulation in itself is very new to the maritime sector. Although the previous regulations such as the EU MRV and IMO DCS made efforts to making the industry oblige to data collection methodologies for monitoring and accounting vessel specific CO2 emissions, the ETS is a complex mechanism where shipping companies are obligated to comply and enter a new market system i.e. carbon markets (World Bank Group, 2021). This represents number of complications to a traditional industry like shipping, shipping companies must reduce their emission exposure to avoid being in the financial risk for overspending in purchasing carbon allowances for fulfilling their compliance obligations. This makes shipping companies to use the market available methodologies proposed by both IMO and EU to reduce their emissions using operational measures (relating to the way in which a ship is used speed, route etc.) and Market Based Measures (MBMs) as a short-term investment and explore other alternatives available within the maritime market for long-term investments. (Bortuzzo et al., 2023) (Psaraftis et al., 2021)

Ships are given an IMO ship identification number at no cost. IMO establishes International maritime traffic security and safety standards to the industry. Some of the major regulations proposed by IMO includes SOLAS (Safety of Life at Sea), and MARPOL (International convention for the prevention of pollution from ships) regulations. In the ever-changing industry, surviving is the key to success. Thinking ahead with an eye on the environment is always a wise move.

The dynamics of supply and demand, weather, natural disasters, global economic trends, fuel prices, and environmental legislation on decarbonization all have an impact on the expansion of the maritime business. The most frequently utilized fuel source for maritime shipping is Heavy Fuel Oil (HFO), also referred to as bunker fuel. Burning HFO releases a lot of carbon dioxide (CO2) and other harmful emissions into the atmosphere, which are responsible for contributing to climate change. Compared to other fuel spills, Arctic HFO breaches are anticipated to have higher cleaning, socioeconomic, and environmental impacts. This is due to the fact that spilled HFO can emulsify in water and does not evaporate as rapidly or fully as other fuels like distillates or MGO. This produces a combination that is very difficult to fully clean up (Comer et al., 2020).

Burning HFO can also produce black carbon, which is particularly problematic in the Arctic region and has the capacity to absorb more than one million times the solar energy entering the atmosphere as CO2. Among these factors, this thesis paper discusses about the various technical strategies that can be taken by the shipping companies to reduce their emission. Technical strategies includes technologies or methods that can help to reduce the emissions (World Bank Group, 2021).

IMO estimates that by 2050, emissions from international shipping are expected to rise by 90–130 percent. Under the authority of the IMO, environmental matters are handled by the Marine Environment Protection Committee (MEPC). At the Marine Environment Protection Committee (MEPC 80) meeting, member states of the International Maritime Organization (IMO) accepted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships, which includes higher targets to address harmful emissions. (IMO, 2023)

This research study will explore the measures by the IMO and EU in general with a specific focus to the ETS system as the regulations entered into force only this year (1.01.2024). Additionally, shipping companies are facing extreme turbulence in complying with the regulation as this imposes stricter penalties and prohibitive measures for non-compliance. (World Bank Group, 2021)

1.2 Research Questions

The EU ETS is the largest international emissions pricing mechanism, various studies have examined whether the EU ETS has had a negative or negligible influence on different

competitiveness metrics. Multiple research scholars are investigating the importance of EU ETS in maritime and how do they have an impact in the industry.

The part of the thesis deals with the most two relevant research questions aiming to investigate the key tactics and obstacles of the EU ETS and to provide an overview of the technologies that are currently being available to reduce emissions. These study questions aim to find out how prepared the industries are for the decrease in carbon emissions and what kind of strategic approach would be most beneficial to achieve the EU ETS.

Research questions:

1. *What are the technical strategies adopted by the shipping companies to comply with EU ETS?*
2. *What are the barriers in implementing EU ETS in shipping sector?*

1.3 Goal of the thesis

The main objective of the thesis is to present a high level of validity, dependability, and transparency in a qualitative research approach to the thesis issue. The study also aims to comprehend the companies' present understanding of reducing carbon emissions and to make a contribution to the field of research by conducting Interview with the sustainable managers from four different companies.

1.4 Structure of the thesis

Figure1 Structure of the thesis

The introduction to the thesis and its contents is the first section of the structure, which is then followed by background information about the research, Theoretical background section defines the overview of EU ETS and Section 4 discusses literature reviews and considerations, while Section 5 details the data collection and method used to process the data. The responses from the interview process are included in chapter 6's results. Chapter 7 offers a discussion and analysis, while Chapter 8 addresses ideas for the future and conclusion.

2 Theoretical Background

2.1 History of EU ETS

The International Maritime Organization (IMO) which is an intergovernmental organization is in the position of regulating maritime matters, including environmental protection and safety, has provided many operational and technical measures to increase the energy efficiency and to reduce the greenhouse gas emissions across the world's fleet. Among these the Ship Energy Efficiency Management Plan (SEEMP) and the Energy Efficiency Design Index (EEDI), are required for all vessels larger than 400 GT as of January 2013. Since the global data collecting system for shipping CO2 emissions was adopted in 2016, all vessels that are equal to or larger than 5000 GT are also required to track and report data on the quantity of fuel they use and the amount of transport work they perform annually. The latest regulations cover additional technical measures that went into effect on January 1st, 2023, including the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII) (Christodoulou & Cullinane, 2024)

In addition to the various technical and operational measures that have been implemented or scheduled, there has been speculation about the possible implementation of market-based measures (MBMs) in the context of the IMO, the EU, and specific countries like China, Japan, and Australia. In other industrial sectors, MBMs have been successfully and economically applied to reduce greenhouse gas emissions from operations. Frequently talked-about MBMs for possible adoption in the maritime sector are CO2 emissions trading and a worldwide carbon tax (or charge) on fuel consumption. EU ETS is a part of MBM which impose an annual cap on the aggregated greenhouse gas.

2.2 EU ETS (EU Emission Trading System)

Since its founding in 2005, the EU ETS has progressively grown to include a number of industries, including maritime transport. EU ETS has four phases started from 2005 with an ambition towards net-zero emissions in 2050 (Haraldsson & Logren, 2022).

On 14 July 2021, the European Commission adopted a series of legislative proposals setting out how it intends to achieve climate neutrality in the EU by 2050, including the intermediate target of an at least 55% net reduction in greenhouse gas emissions by 2030. The package proposes to revise several pieces of EU climate legislation, including the EU ETS, Effort Sharing Regulation, transport and land use legislation, setting out in real terms the ways in which the Commission intends to reach EU climate targets under the European Green Deal (World Bank Group, 2021) (Haraldsson & Logren, 2022)

Since carbon emissions have become more of a focus in recent years, the shipping industry has come under increasing criticism. This critique is based on the industry's excessive reliance on burning fossil fuels, which contributes to significant carbon dioxide emissions and exacerbates climate change and global warming (Wang et al., 2023). The International Maritime Organization (IMO) provides an insight to this issue by demonstrating the overall CO2 emissions from the maritime shipping climbed from 962 million tons to 1056 million tons between 2012 to 2018. According to this report, it is almost 3% of CO2 emissions released by humans worldwide between 2012 to 2018 (Wang et al., 2023)

In order to support the sustainable growth of the shipping sector, this issue gives way to a number of carbon emission reduction policies, including carbon pricing (carbon taxes and cap-and-trade schemes), Carbon Capture and Storage (CCS), and China's double carbon goals (carbon peaking and carbon neutrality) (Haraldsson & Logren, 2022) (Sikora-Alicka, 2023). These policies are described in the next section.

2.2.1 Phases of EU ETS

There are four phases of EU ETS as described below,

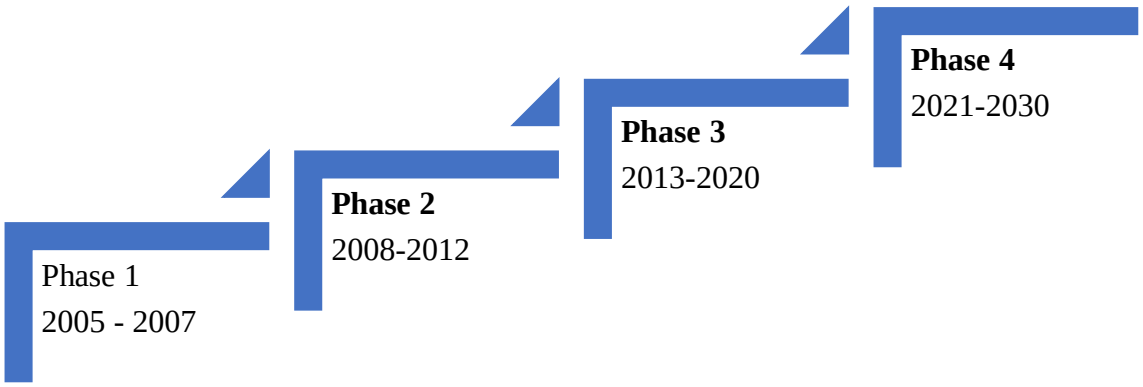

Figure2 Depicts the phases of EU ETS

2.3 Fit-for-55 package

A set of legislative recommendations known as "Fit for 55" was presented by the European Commission in July 2021. The substantial climate ambitions of the European Union, especially the target of lowering greenhouse gas emissions by at least 55% from 1990 levels by 2030, rely heavily on this package. The term "Fit for 55" refers to the aim of these ideas, which are to make sure the EU is prepared to meet its climate targets. (Goyal & Llop, 2024)

2.4 Cap-and-Trade system

The EU ETS works on the **'cap and trade'** principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by the installations covered by the system. The cap is reduced over time so that total emissions fall. Within the cap, installations buy or receive emissions allowances, which they can trade with one another as needed. The limit on the total number of allowances available ensures that they have a value. After each year, an installation must surrender enough allowances to cover fully its emissions, otherwise heavy fines are imposed. If an installation reduces its emissions, it can keep the spare allowances to cover its

future needs or else sell them to another installation that is short of allowances. (World Bank Group, 2021)

The cap-and-trade acts as a key element in reducing the emissions as it provides the flexibility to companies as to where and how emission reduction takes place, a global or regional tax does not guarantee reduction in GHG emissions due to its multi-national system and not all countries would agree in setting or fixing a right price for the carbon due to economic and industrial tensions (Trotignon, 2011)

The cap-and-trade limits the GHG emissions by setting a system cap that is designed to ensure compliance with the relevant commitment, by reducing the cap companies and installations will have the flexibility to reduce the emissions thereby avoiding the carbon price to meet the desired target (Trotignon, 2011)

The most recent version to the EU Green Deal outlines the objective for lowering emissions. The 2030 framework for climate and energy policies was proposed in January 2014 and approved by EU leaders in October 2014, marking a significant turning point in the decarbonization process towards 2050.

The deal foresees the following:

- A reduction of GHG emissions by 40% below the 1990 level by 2030 to be achieved domestically;
- An increase of the EU-wide renewable energy share to at least 27%; and
- Improving energy efficiency by at least 27% by 2030, with 30% by 2030 in mind

The EU ETS legislation creates allowances which are essentially rights to emit GHG emissions equivalent to the global warming potential of 1 tons of CO_2 equivalent (tCO2e). The level of the cap determines the number of allowances available in the whole system. A proportion of the allowances are given to certain participants for free, while the rest are sold through auctions. The participants must return the allowances for every ton of CO2 and if they are short of allowances then it must be bought in the primary (auctions) or secondary markets (OTC – Over the Counter) as traded or from similar participants who are willing to sell their excess allowances. (Trotignon, 2011)

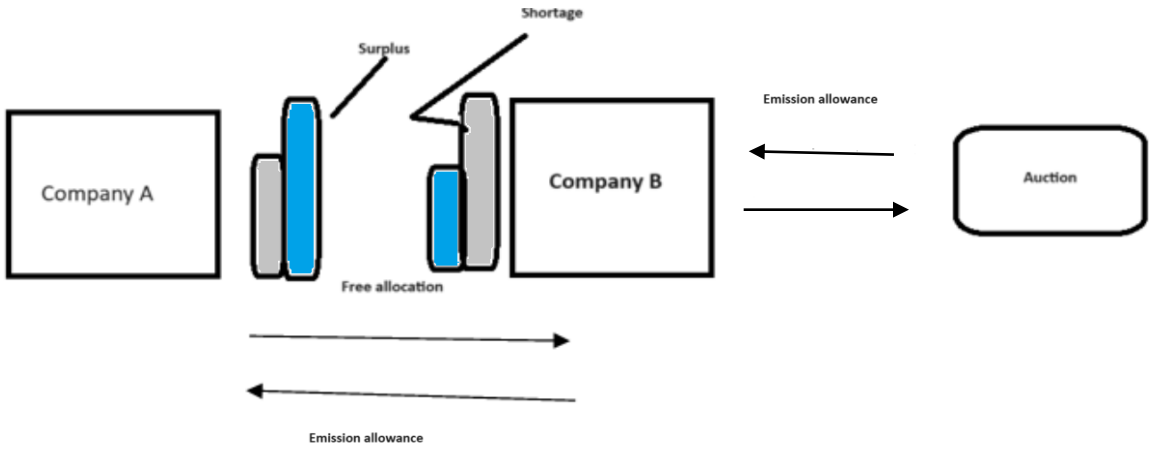

Figure3 Diagram representing the process of EU ETS

Source: EU ETS handbook (World Bank Group, 2021)

The auctioning of allowances is conducted in venues or auction platforms as below

- European Energy Exchange (EEX) and
- ICE Futures Europe (ICE)

2.5 Governing bodies

As a result of its imposition as environmental law, the EU ETS trading system is a product of European power. The European level is where all system decisions are made. The principal role of the system is to authorize the holder of an EU permit (EUA) to emit either One metric tonne of CO2 or a comparable quantity of other strong greenhouse gases, such as nitrous oxide, methane, and perfluorocarbon (Haraldsson & Logren, 2022).

The EU allowance is either supplied to the business operators for free, sold at auction, exchanged over the counter, or at a subsequent market. Shipping industry doesn’t have the free allowance so a phase in period was provided and ship owners are supposed to reduce the emissions within the desired period by acquiring any of the technical strategies to their vessels. Operators are about to submit the overall emission report and this report will be verified by a verifier within the financial year (i.e., March 30th). Once the provided information gets verified the operators can submit the necessary allowances by April 30th of the same year. However, if a business doesn't comply with the current regulations—namely, doesn't buy the necessary amount of emission rights for its emissions and doesn't turn them in by the deadline—it will be fined. This is

equivalent to more than tripling the price at writing, or 100 euros plus the daily cost of emission rights. (Trotignon, 2011)

The revenues generated from the auctioning of allowances are used for funding decarbonization projects across EU for example the German "Energy and Climate Fund" is an example funded by the EU ETS revenues. There are plans by the EU to fund more decarbonization and CCS (Carbon Capture and Storage) projects involving all member states. (World Bank Group, 2021)

2.6 Inclusion of shipping in the EU ETS system

The EU will require owners or International Safety Management (ISM) Companies of ships of 5000gt (regardless of flag State) to pay for the operational emissions from ships calling at EU ports. The EU ETS currently focusing on vessels which exceed GT of 5000 tons which are operating under European union's jurisdiction. Ships operators/owners who have vessels with 5000 tons GT will monitor, document their reports, and timely monitor their vessels emission rate in line with the IMO's guidelines. During the annually emission meeting they need to submit their report of emissions for their vessels. Each vessel will be allowed to have their own allowances which they need to monitor in order not to exceed. If any company needs additional allowance, they are allowed to purchase additional allowances. To guarantee adherence to EU ETS regulations, stringent enforcement methods are implemented. Operators that violate the regulations may be subject to fines and port access suspension. (Ayaz et al., 2023)

Non-EU nations and industry groups are concerned about possible trade consequences and regulatory issues as a result of shipping's membership in the EU ETS. To create a worldwide framework for tackling maritime emissions, discussions are currently taking place on a global scale, especially within the International Maritime Organization (IMO). With this regulation, the focus is on tank-to-wake CO2 emissions only, with the scope of emissions determined by the scope of emissions covered by the EU MRV Regulation. This would mean that initially, only CO2 is being considered for now however this could also include CH4 and N2O in the near future. The impact will be determined by the CO2 price in the EU ETS. ETS is expected to add to voyage costs and sophistication of shipping operations but is not anticipated to generate a carbon price before 2025 which would drive the uptake of zero-GHG energy carriers and power sources (Borghesi et al., 2023)

2.7 Market Stability Reserve in the EU ETS

"Market stability reserve" (MSR) is a term used to describe a mechanism inside the EU ETS (European Union Emissions Trading System) that is intended to rectify imbalances in the supply and demand of emission allowances within the carbon market. The objective of the MSR is to improve the efficacy and stability of the EU ETS by automatically modifying the quantity of permits that are available in accordance with market conditions. During the initial phase of EU ETS, it is noted that over-allocation of allowances was done which leads to reduction in the carbon price. The EU's reorganization of the EU ETS for the fourth trade period (2021–2030) included the introduction of the MSR which was designed in a way that enables it to absorb or release portions of the auction volumes. This MSR mechanism is controlled by Total Number of Allowances in Circulation (TNAC) (European Parliament, 2023).

The TNAC has established ranges, with a higher threshold of 833 million allowances and a lower barrier of 400 million. In the event that TNAC above 833 million, twenty-four percent of TNAC is subtracted and transferred to the MSR. Conversely, if the threshold is lowered, the MSR auctions off 100 million allowances (European Parliament, 2023). This method ensures that the allowances are allocated exactly and without any issues.

3 Literature review

3.1 List of Literature's considered

This paper examines the technology approaches used by the EU ETS system to achieve net zero emissions, as well as the associated challenges. The goal of the EU ETS is to cover 40% of GHG emissions in 2024, 70% in 2025, and 100% in 2026. Methane (CH4), carbon dioxide (CO2), and nitrogen oxide (N2O) are all considered greenhouse gas emissions. At the moment, CO2 is regarded as the most preferred gas. A qualitative research approach is used for this study's initial stages because there is not enough quantitative data to perform a full quantitative analysis since the shipping industry was only included in the ETS system this year.

Scopus and Google Scholar databases are used for literature reviews. A thorough analysis of the literature was conducted, and papers that meet the criteria are given attention. Initially, by using some of the major key words related to the research topic, about 273 files were found in the

Scopus database; additional filtering was carried out by choosing “Articles” and “English” as a primary criterion. To find the qualitative papers that fit the current thesis topic, various search terms were employed. The keywords used for search are “*emission trading, carbon trading, carbon tax, EU ETS, carbon allowance, barrier, and challenge*”. The table below provides an explanation of the keywords utilized and the number of articles obtained.

S.no	Boolean Keywords	No. of articles
1	("emission trading" OR "carbon trading" OR "carbon tax" OR "EU ETS" OR "carbon Allowance*") AND ("shipping" OR "maritime")	273
2	("emission trading" OR "EU ETS" OR "carbon Allowance*" OR Decarbonization) AND ("shipping" OR "maritime") AND ("barrier*" OR "challenge*")	168
3	("emission reduction" OR "EU ETS" OR "carbon Allowance*" OR Decarbonization) AND ("shipping" OR "maritime") AND ("barrier*" OR "challenge*")	145
4	("emission trading" OR "carbon trading" OR "carbon tax" OR "EU ETS" OR "carbon Allowance*") AND ("shipping" OR "maritime") AND ("barrier*" OR "challenge*")	45

Table 1 Keywords used for the Scopus search

Further, the Scopus database recommended 32 documents following the filtering procedure. These 32 documents are given a peer review by understanding the Abstract of the article. Most of the document deals with decarbonization and emission reduction and it is found that only few documents have specific outline about EU ETS which is the major target of this thesis. Among these 32 documents from Scopus, 15 documents found to be relevant to the topic. Few articles from Google scholar were also taken into consideration. Every data has been noted in an excel to easily navigate between the articles. Refining the articles searched from Scopus and Google scholar are analyzed by using excel as below,

S.no	Article title	Authors	Year	Methodology use	Key findings
1	A roadmap to alternative fuels for decarbonising shipping: The case of green ammonia	Balci, G., Phan, T.T.N., Surucu-Balci, E., Iris, Ç.	2024	Interpretive Structural Modelling (ISM)	success factors of the industry-wide adoption of green ammonia
2	Sustainable Maritime Transportation Operations with Emission Trading	Wang, H., Liu, Y., Li, F., Wang, S.	2023	Mathematical model	Outline about EU and emission control over EU
3	Optimization Model for Container Liner Ship Scheduling Considering Disruption Risks and Carbon Emission Reduction	Meng, L., Wang, X., Jin, J., Han, C.	2023	hybrid evolutionary algorithm	impact of port disruptions on route operations, develops a mixed integer nonlinear programming model considering fuel costs, recovery costs, and carbon emissions
4	Mitigation of CO2 Emissions from Commercial Ships: Evaluation of the Technology Readiness Level of Carbon Capture Systems	Bortuzzo, V., Bertagna, S., Bucci, V.	2023		Describes about carbon capture technology

Table2 Showing how the articles are summarized in excel

The document "*Sustainable Maritime Transportation Operations with Emission Trading*" (Wang et al., 2023) provides an overview of the European Union's pollution control policies. In addition to outlining the significance of the EU's emission reduction efforts, this study suggests the lowest speed at which a vessel operating within the EU might cut emissions. A mathematical model is used by (Wang et al., 2023) to analyses the resources. It also discusses the non-EEDI and the Energy Efficiency Design Index (EEDI). Overall, the study makes a substantial contribution to the understanding of how shipping companies might proactively respond to the EU's novel legislative environment by strategically formulating educated decisions. This research provides practical direction for navigating the opportunities and challenges given by the policy by providing the unique solution approaches.

Article "*Carbon Emission Trading Scheme in the shipping sector: Drivers, challenges, and impacts*" (Wu et al., 2022) describes the challenges and impacts of EU ETS using Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA). Authors have overlined

the less usage of EEDI and slow steaming technologies. This article describes about the (1) drivers, (2) Obstacles, and (3) impacts towards ETS. The article concludes by summarizing how challenging it is to create a carbon ETS for the global shipping industry because of the complicated organizational structure, jurisdiction under international law, and scarcity of data on international shipping. Finally, the authors provide some guideline for policy makers, shipping owners, shipping operators, ports and other stakeholders.

Study "*A roadmap to alternative fuels for decarbonizing shipping: The case of green ammonia*" mainly focus on green ammonia by highlighting the success factors of green ammonia using Interpretive Structural Modelling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC). In order to determine the success criteria of early adopters and stakeholders, an ISM survey on green ammonia was conducted with 48 specialists for this study project.

In the paper "*Mitigation of CO2 Emissions from Commercial Ships: Assessment of the Technology Readiness Level of Carbon Capture Systems*" (Bortuzzo et al., 2023)carbon capture is suggested as a quick fix for ship-related CO2 emissions. The opportunities and difficulties associated with carbon capture have been discussed by authors. Conversely, drawbacks include things like storage capacity and a method of disposal that reduces hazards to the environment and public health.

(Ayaz et al., 2023) article explains about implementing EU ETS in port side and their impact. Authors used Complex Adaptive System Approach to identify the obstacles in implementing EU ETS in ports. This study features 14 senior managers. High investment cost and long payback period were the two major limitations addresses during the analysis.

Further to narrow down the search towards the core topic keywords like "*eu AND ets AND ("shipping" OR "maritime"), eu AND ets AND decarbonization AND ("shipping" OR "maritime")* are used and found few additional articles as listed below,

Title	Authors	Year
1. The shipping industry under the EU Green Deal: An Input-Output impact analysis	Goyal, S., Llop, M.	2024
2. The prospects for, and implications of, emissions trading in shipping	Christodoulou, A., Cullinane, K.	2024
3. The methodology for Assessing the Potential to Capture CO2 of the FSRU-Based Vessel	Malūkas, A.	2023
4. Decarbonising Short Sea Shipping Operations: Examining the Efforts and Outcome of a Finnish Shipping Line's Relevant Initiatives	Christodoulou, A., Dalaklis, D., Ölçer, A.I., Masodzadeh, P.G.	2022
5. On the process of including Shipping in EU Emissions Trading: Multi-Level Reinforcement Revisited	Wettestad, J., Gulbrandsen, L.H.	2022

Table 3 List of articles which has EU related topics and contents

Article "*The shipping industry under the EU Green Deal: An Input-Output impact analysis*" (Goyal & Llop, 2024) describes about the "Fit-For-55" policies that are intended to reduce greenhouse gas emissions. Authors used the OECD Inter-Country Input-Output (ICIO) covering 45 sectors, the Leontief price model, and the environmental input-output (EIO) model. (Christodoulou & Cullinane, 2024) study examines the historical evolution of the debates and actions conducted inside the European Union at both the global and regional levels and offers a qualitative assessment of them. Here global level refers to the International Maritime Organization (IMO) and regional level includes the European union countries. Authors used SWOT analysis to find and discuss the green technologies which has more evident of reducing

carbon footprints. Following their investigation, the authors emphasized that investing in alternative fuels and energy sources could yield greater outcomes.

Article *"Decarbonising short sea shipping operations: Examining the efforts and outcome of a finishing shipping line's relevant initiatives"* (Christodoulou et al., 2022) mainly focusses on a Finnish shipping line called "Viking Line". Viking Line's activities and efforts to reduce CO2 emissions have been documented in Author Christodoulou's document. This article discusses how the shipping sector failed to meet emission control goals in 2018 despite having a number of operational and technical solutions in place, such as DCS, SEEMP, and EEDI. Case study methodology is used in this article. A semi-structured interview with the company's sustainability manager was conducted after sustainable reports were gathered. Following the conversations, the author of this article discovered that the company's primary goal was sustainability, and in order to achieve this, the company made modifications in the following sectors,

1. Onshore Power Supply (OPS)
2. Wind power and LNG conversion
3. Construction of new vessels
4. Energy management systems
5. Energy efficiency improvement projects
6. New organization model

Authors have described how the sustainability was maintained in each of the above sectors and they focus only on one company and mentioned very little facts about EU ETS. (Christodoulou et al., 2022)

In addition to the literature review, this thesis also makes use of the following sources.

- CMW_EU_ETS_101_guide
- Emissions Trading and Business (Book)
- Reducing emissions from the shipping sector
- Final Report Emission allowances and associated derivatives

- Maritime transport in EU Emissions Trading System (ETS) by European commissions and more web articles from companies like DNV, Vertis, Synergy and Wartsila have been considered.

4.Data and Methodology

Decarbonisation in the maritime industry in an ongoing trend that has been happening when the EU was lobbying in early 2014 to include shipping within the EU ETS system. Although there are various research methodologies available within the areas of shipping decarbonisation, it appears that only a limited range of methodologies has been applied to the topic of EU ETS for the maritime industry. This is due to the fact the regulation applies to the industry only from this year (i.e. 1.01.2024) as a phase-in period and the full implementation will only occur by 2027.

This is also one of the reasons for choosing qualitative research methodology over quantitative, as the shipping industry seem to be still in the process of digesting the new regulation and there is no extensive research study with the topic. Qualitative tool is an appropriate tool for understanding in-depth subject matter of the ETS system and its applications of impacts within the shipping industry and identify various themes which can later be helpful in conducting a quantitative approach.

The research approach is conducted through interviews with individuals who are key representatives of ship management companies and decarbonisation service providers who are assisting shipowners with the compliance of the regulation, through their market and compliance understanding addressing the impacts and strategies for navigating a complex regulation is seemingly possible, hence a qualitative study with industry experts was chosen for the present study.

4.1 Interview

The interviews with personnel in managerial positions from four different companies are described in this section in order to have a general understanding of company's opinions regarding the EU ETS. Firms include Synergy Groups, Azolla, V. Ships and Great Eastern Shipping. Ten questions that are related to the EU ETS have been prepared and asked during the interview. To retain the quality of the results same questions were used with all the four companies. The total number of participants that were intended was 25, however due to

numerous personal conflicts, only 15 participants from four companies have been interviewed. Consent was obtained and as per their request no recordings have been done. Interviews were in the form of face-to-face and zoom meetings. Meetings have been scheduled on various dates based on their availability. Interviews with three companies' participants were held at their offices or coffee shops, while Zoom was used for the fourth interview.

Every interview was scheduled to last between 45 to 1 hour, with the first few minutes committed to basic demographics questions and the remaining minutes to topic-specific inquiries. The interview was conducted in both the local tongue and English. Answers to interviews came solely from the company's viewpoint; no personal information was provided.

Handwritten notes were taken during the interview and were eventually documented. The primary aim of the interview was to examine the present attitudes of enterprises on the EU ETS and identify potential obstacles and approaches for its implementation.

List of questions targeted were mentioned below,

Interviewed Questions

These questions cover the basic query about the EU ETS,

1. Can you please explain about your company and you’re understanding towards IMO and the EU's GHG emission regulations?
2. Do you undertake IMO DCS, EU MRV, CII and EEXI regulations in your company?
3. What is your understanding towards EU ETS in general?
4. How do you plan to integrate EU ETS in your company for compliance?
5. What are the steps you have taken to comply with the ETS regulation?
6. What is your company's current and future emission exposure within the ETS system?
7. What are your plans and strategies for EUA procurement towards 2025 ETS compliance?
8. How do you see your company's budget efficiency against emission performance?
9. What are your plans for reducing emissions and financial risks in the future?
10. What do you think about the way forward for shipping's green transition?

4.2 Recruitment

The overall interview process targeted professionals who are specialised in the area of maritime decarbonisation from technical, environmental and commercial perspectives. First interview

meeting was held with Synergy's Senior technical specialist. Furthermore, since the participants from the first company has close contact with other companies "Chain-referral sampling" was used and came to know about more participants from the remaining three companies (Platt et al., 2015). The sampling size became expanded in short duration. No financial incentives were provided for the interviewed candidates as they are close connections. The interview was transparent by taking notes of the different questions that were asked to the participants and the information regarding this was informed prior to the interview scheduled which occurred in various environments such as office premises, coffee shops, and zoom. The participants were also informed that there will be no recording and only noted which will be used for research purpose only and verbal consent was obtained before the interview.

4.2.1 Timeline of Interview process

Below timeline refers to the achieved work plan for the interview process from the month of March to April.

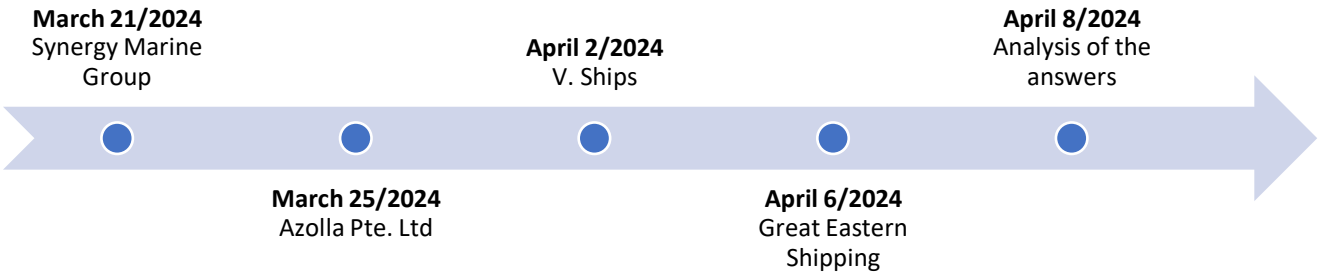

Figure4 Timeline of Interview process

4.3 Approach to analysis

Thematic analysis is a fundamental component of qualitative research methodology, providing a methodical means of identifying patterns, interpretations, and discoveries within qualitative data (Braun & Clarke, 2006). The theme indicates a level of patterned response or meaning within the data set and highlights an essential aspect of the data in respect to the research topic.

All of the interview answers from document have been transcribed using Excel to find the codes or labels. Through a thorough analysis of the material, scholars are able to recognize recurrent patterns, comprehend fundamental ideas, and arrive at insightful conclusions. Thematic analysis

is an insightful and adaptable research approach that may yield a complex yet rich and complete explanation of the data (Braun & Clarke, 2006).

Thematic analysis is generally carried out in 6 phases as below,

- Familiarizing with the collected data
- Produce initial codes
- Find different themes
- Refine the themes
- Defining each theme individually
- Reports/Result

This research paper follows the above phases by collecting the data and organizing the responses in a word document. Each company's answers were documented and transferred to excel sheet after organizing. The present study adheres to the previously mentioned stages of data collection and response organization, starting with transcription. Subsequently, data is entered into an Excel spreadsheet to identify the subject codes or labels. The subject has been refined once the codes and their central idea have been identified. Two processes that are judged to be identical can be combined into a single theme; if two themes are unrelated, they can be eliminated.

Interviewee's	**Question**	**Keywords found**
1	Can you please explain about your company and you're understanding towards IMO and the EU's GHG emission regulations?	AZ1: We use digital arm called "AlphaOri" to maintain the regulation.
		AZ2: provides full technical and commercial ship management services
		AZ3: corporate social responsibility by promoting **sustainable practices**, supporting community initiatives, and contributing to environmental conservation efforts.
		AZ4: We as a company respect and are striving towards the industry needs for **decarbonizing the maritime sector**
2	Do you undertake IMO DCS, EU MRV, CII	AZ1: Yes
		AZ2: Yes

	and EEXI regulations in your company?	AZ3: Yes
		AZ4: Yes
		Every comment seems to be very similar with common word "Yes"
3	What is your understanding towards EU ETS in general?	AZ1: The company invests in **fuel-efficient** technologies
		AZ2: We use **MRV** reporting
		AZ3: Continuous Monitoring and Adaptation
		AZ4: Synergy Maritime Group maintains robust systems, procedures, and documentation to **support compliance efforts and facilitate transparent reporting to relevant authorities.**
4	How do you plan to integrate EU ETS in your company for compliance?	AZ1: **Maritime Operator Holding Account (MOHA)**
		AZ2: We track emission exposure using each ship or fleet's **MRV reports**
		AZ3: We try to understand more about the **Regulatory bodies**
		AZ4: Install and maintain appropriate **equipment, sensors, and software for emissions monitoring, data acquisition, and reporting purposes**.
5	What are the steps you have taken to comply with the ETS regulation?	AZ1: **Data Collection and Reporting**
		AZ2: **Allowance Management**
		AZ3: Regulatory Compliance
		AZ4: Making the ship owners to know about the importance of EU ETS
6	What is your company's current and future emission exposure	AZ1: Between 100,000 – 200,000 EUAs
		AZ2: No exact answer
		AZ3: We only represent the exposure and emission figures to the **owners using MRV data** and the

	within the ETS system?	owners will be the one who would be **responsible for procuring** these EUAs for EU ETS compliance
		AZ4: No answer
7	What are your plans and strategies for EUA procurement towards 2025 ETS compliance?	AZ1: plans to have a one-stop-shop
		AZ2: Depends on the **ship owners' decisions**
		AZ3: Financial exposure of owner plays a major role
		AZ4: To implement more **business strategies** in the near future
8	How do you see your company's budget efficiency against emission performance?	AZ1: We cannot answer this, since it's totally depending on **ship owners financial budgeting**
		AZ2: It's not so easy to say exactly since it may differ according to the **overall profit** of ship owners
		AZ3: No answer
		AZ4: Ship owners' decision
9	What are your plans for reducing emissions and financial risks in the future?	AZ1: To develop more new business models
		AZ2: **Alternative fuels** and lot more
		AZ3: Installation of Energy Efficiency Technologies
		AZ4: EETs and ESDs **retrofit** options can reduce their emissions exposure
10	What do you think about the way forward for shipping's green transition?	AZ1: Ship owners should invest more on new vessel buildings with new technologies
		AZ2: Retrofitting's can be done
		AZ3: Slow Streaming can be followed
		AZ4: Fuel savings and alternative fuel

Table4 Derivation of codes

Above figure shows an example of interview done for one company. During the interview process answers were taken as a note and documented first. Then the data are sorted using the

company name and their respondent numbers. After reading out the answers deeply codes are found and highlighted in the excel, the process was repeated for the other three companies as well. Codes and sub-codes that are discovered from their responses open up to the themes and their in-depth explanation of each theme.

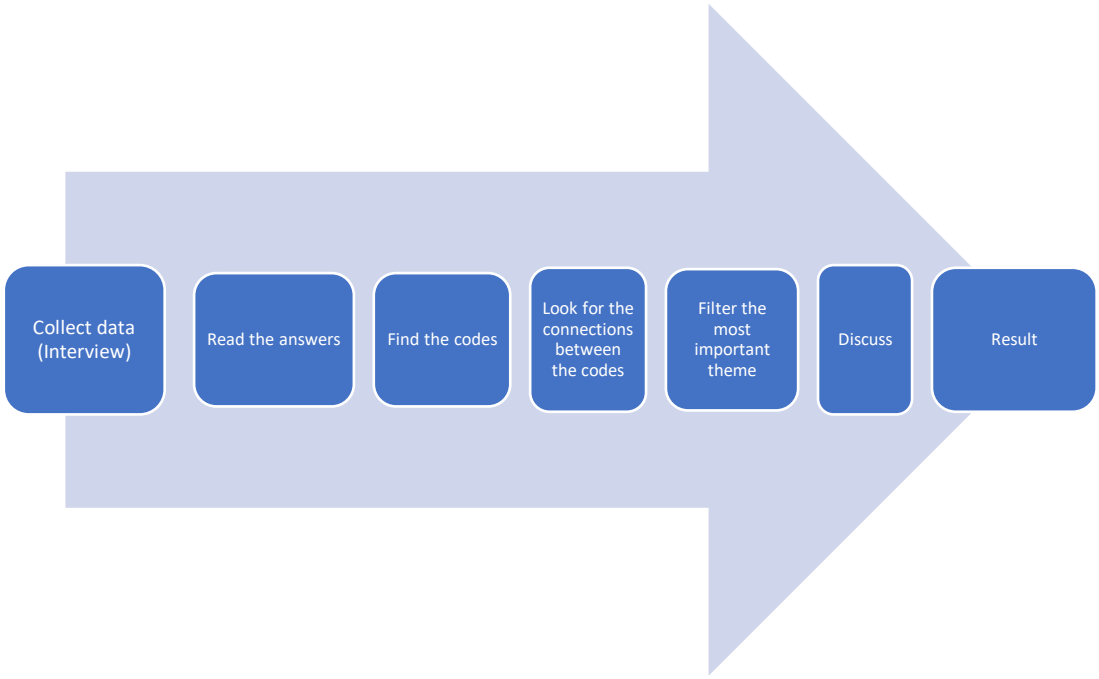

Figure5 Flow of the Data methodology

4.4 Interview characteristics

According to (Baker et al., 2012) six to twelve samples will provide incredibly valuable information for a qualitative study. Selected with four companies and 15 respondents the interview process was held based on their availability. Among the interviewees about 90% has the designation of Specialist including technical and decarbonizing specialist. Each code has been assigned to each individual based on their company name (AZ refers to Azolla Pte.Ltd, SY refers to Synergy Marine Groups, VS refers to V. Ships, GES refers to Great Eastern Shipping). Each participant's answer has been noted by assigning a respondent's name as shown below,

Responds	Gender	Positions
AZ1	M	Manager
AZ2	M	Decarbonization Specialist
AZ3	M	Head of Business
AZ4	M	Senior Engineer -

		Decarbonization
SY1	F	QHSE
SY2	M	ECO
SY3	F	Senior technical specialist - decarbonization
SY4	M	Assistant General Manager
VS1	M	Fleet Manager
GES1	M	HSEQ - Manager
GES2	M	Group Technical Manager
GES3	M	Group Environmental Manager
GES4	M	Environmental and Compliance specialist
VS2	M	Decarbonization Engineer - Technical

Table5 personal traits of the participants

5.Results and analysis

The "inductive or bottom up" method is one of the primary method in which themes or patterns within data can be found in thematic analysis (Braun & Clarke, 2006). Based on the codes derived from Thematic analysis, a thematic structure has been defined and there were five core themes emerged during the analysis. Themes include *Ship owners, Data collection and Compliance, Business models, Decarbonization and Sustainable shipping, and Environmental regulation.*

5.1 Overview of the themes

Since the entire interview process was done with managers and decarbonization specialist, respondents basically had a general subject knowledge about the interview questions and thesis topic. Participants are allowed to give their genuine feedback from companies' perspective, genuine feedback gives us more reliable answers for the interview questions. After the interview process is complete and the codes are prepared, it's time to define each code separately and to discuss about the most crucial theme. From the derived answers deeper analysis was done by comparing with the articles which was found relevant in Literature Review. Since the thematic analysis approach was not previously used, the papers listed in the literature review did not address the subjects covered in this work, so additional articles were referred. The motive of this section is to derive an interlink between the themes and to define them in a bigger perspective.

5.2 Thematic analysis diagram

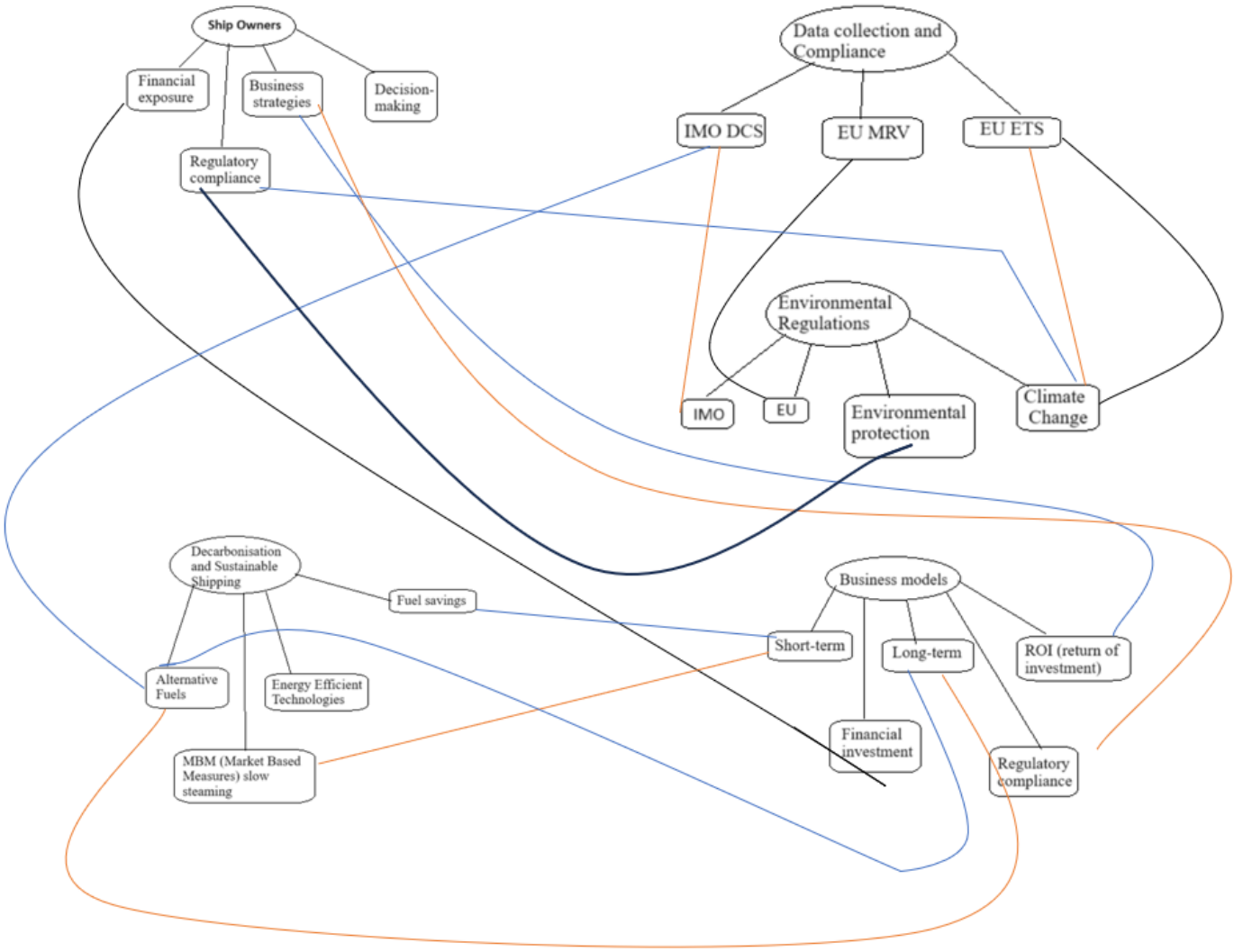

Figure6 Thematic analysis diagram defining the five codes

5.2.1 Ship Owners

Being the primary organizations in charge of the ownership, management, and operation of ships, ship owners are vital to the marine sector. These people or businesses spend a lot of money on buying boats, which can range in size from tiny recreational vessels to enormous cargo or luxury ships. Owners of ships have obligations that go beyond simple ownership. They are in charge of the business activities, insurance, staffing, and preservation of their vessels. Ensuring adherence to marine legislation, overseeing financial matters such as budgets and income

streams, and preserving connections with diverse stakeholders such as charterers, port authorities, and regulatory organizations are all part of this.

A complicated web of regulations must be complied with, effective business plans must be developed, financial exposure must be carefully considered, and ship owners must make well-informed judgements as they navigate the volatile waters of the maritime industry. Ship owners worry a lot about their financial risk since they have to deal with unstable markets, shifting freight rates, and rising operational expenses. Due to the capital-intensive nature of ship ownership, it is necessary to use risk mitigation techniques, smart financial management, and backup plans in order to weather economic downturns and preserve profitability (SCARSI, 2007)
From the conducted interview it shows that the ship owners create strategic efforts to improve fleet performance, strengthen market positioning, and seize new possibilities in response to market dynamics and competition constraints. Expanding the fleet, diversifying into new markets or vessel categories, forming strategic alliances, investing in technical advancements and environmental projects are some examples of business strategy followed by the companies. Ship owners make strategic decisions and adjust to changing industry trends by using advanced market analysis, risk assessment, and scenario planning approaches.
From (Psaraftis et al., 2021) article, in order to accomplish a business goals, ship owners have to balance a multitude of operational, commercial, and regulatory complications. Evaluating investment prospects, buying or selling vessels, financing choices, chartering agreements, and regulatory compliance issues are some examples of decision-making processes. The financial sustainability, regulatory compliance, and fleet performance are all significantly impacted by the decisions taken by ship owners
For ship owners, regulatory compliance adds still another level of complication to the process of making strategic decisions. Vigilant monitoring, record-keeping, and reporting are necessary to assure adherence to international, regional, and national legislation controlling vessel operations, safety standards, environmental protection, and crew welfare. The ship owners are considered to be an important key driver in the maritime field since they need to concentrate on strong safety management systems, pollution control strategies, crew training programs, to comply with laws like SOLAS, MARPOL, and the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). It is crucial to be aware of regulatory

requirements and to take proactive measures to comply with them. Noncompliance can lead to financial penalties, harm to one's reputation, and disruptions in operations.

5.2.2 Data collection and compliance

Data collection and compliance are crucial elements in the shipping sector that guarantee the Environmental sustainability, safety and efficiency of maritime operations. The process of collecting data includes obtaining information from a variety of sources while a ship is at sea, in a port, and via satellite systems. Position, course, speed, weather, load information, usage of fuel, engine performance, and other details may be included in this data. The ongoing collection of this data is made easier by cutting-edge technologies like Voyage Data Recorders (VDRs), Electronic Chart Display and Information Systems (ECDIS), and Automatic Identification Systems (AIS).

In the marine sector, data collecting is essential to regulatory compliance. International agreements and rules, including the MARPOL Convention of the International Maritime Organization (IMO), provide strict guidelines for safety procedures, ballast water management, and emissions from ships. To prove compliance with these requirements, maintain environmental stewardship, and ensure that vessels operate within the law, accurate data collecting is necessary. Each company differs in their data collection methods. From the interview, shipping firms monitor, analyze, and optimize vessel operations, fuel consumption, emissions, and environmental performance in order to support their decarbonization efforts. They do this by using a variety of data collection tools and technologies. These resources offer insightful information about fuel economy, opportunities for reducing emissions, and regulatory compliance. Interviewed companies use IMO DCS, EU MRV, and EU ETS as major monitoring systems. All the participants accepted the importance of collecting the data and shared how they ensure the data collection is done. From the thematic diagram (Figure6), the IMO DCS is directly linked with the IMO regulations and compliances, EU MRV is connected with the European regulations and EU ETS will be about climate change. From (Bui & Perera, 2019), The data collection and compliance seem to be grown more when there is new technology and digitalization.

Apart from adhering to regulations and managing risks, gathering data has enormous potential to promote efficiency and innovation in the maritime sector. Stakeholders can gain important insights to enhance logistics operations, route planning, and vessel performance by utilizing big data analytics and artificial intelligence. Data-driven optimization techniques can reduce environmental impact and result in significant economic savings, from cutting fuel use to shortening travel times.

5.2.3 Environmental regulations

In order to ensure sustainable practices in the shipping industry and to reduce the carbon footprint of maritime activities, environmental rules must be an essential measure. The main goals of these rules are to avoid ship-related marine pollution, restrict greenhouse gas emissions, and lessen pollution in the air and water. One of the most significant global agreements concerning environmental regulations in shipping is the International Maritime Organization (IMO). The IMO establishes international guidelines and standards for the sector that address issues like pollution, managing ballast water, and managing hazardous goods. Some of the important regulation rules emerged from IMO are MARPOL and its annex VI, Ballast water management, Energy Efficiency Regulations etc., These rules seek to lessen the effect of shipping operations on climate change, preserve marine habitats, and encourage sustainable practices in the shipping sector. In order to guarantee ecologically responsible operations and promote a cleaner and healthier maritime environment, shipowners, operators, and other stakeholders must abide by these standards.

Global climate change due to CO2 emissions is a trend that the world discovered a few decades ago. Ships emissions were aroused to be a great concern regarding their impacts on climate change and global warming, so several countries are developing technologies and drafting Laws and regulations for mitigating this problem. By referring to various articles listed in Literature review and additional documents this part of the paper discusses the importance of Environmental Regulations in shipping industry.

The reduction of CO2 from ships is of greater interest because of its global impacts and shown to be significant enough to motivate action plans "Around 6% of the global CO2 emissions are emitted from ships" (Goldsworthy,2010). CO2 is a direct access to climate forcing's which leads the world to dangerous conditions like the melting of ice caps in the arctic. The results of ice melting paves ways to several other impacts such as rising sea levels, threatening low lying areas, influencing food production, all results at the end as a crisis on human survival.

The IMO plays a major role in the formulation and implementation of the global shipping regulations in general but recently there were concerns that IMO is not aligned with the goals of the Paris Agreement and national institutions like the EU has stepped up to incorporating their own national specific regulations such as European Green Deal and the recent implementation of the EU Fit-for-55 package that was introduced in 2014. This has grown to introducing various maritime specific regulations such as the EU ETS, FuelEU Maritime, AFIR (Alternative Fuel Infrastructure Regulation) & RED (Renewable Energy Directive). IMO feeling pressured on the other hand has introduced various decarbonization measures particularly incorporating new measures to Marpol Annex VI by introducing SEEMP (Ship Energy Efficient Management Plan), thereby introducing market-based measures for reducing GHG emissions from ships which includes CII, EEXI and EEDI (Hasanspahic et al., 2021)

As the competition between the two major organizations evolves, shipping companies are facing complex issues in incorporating the introduced regulatory mechanisms within their organization, although IMO is said to only introduce a carbon tax starting 2027, EU ETS has gained major momentum within the industry for its incorporation within the EU's climate package. The EU ETS has entered into force starting this year for the maritime sector as a phase-in period, i.e. only 40% of the emissions are covered for this year's compliance cycle which makes the companies to surrender EUAs (European Union Allowances) so called carbon allowances before September 2025. This will gradually increase where shipping companies will be required to surrender their allowances 100% by 2027.

The base criteria or analysis of the emissions a shipping company needs to surrender depends on the fuel type they use and the data collected for calculating the accumulated emissions, for this there are specific guidelines introduced by the EU under the data collection methodology called EU MRV (European Union Monitoring Reporting and Verification), this methodology allows the shipping company to gather and collect the released CO2 emissions per voyage simultaneously

accumulating the whole data for a year. This accumulated data will have to surrendered to an EU platform called ‘Thetis MRV’ where the total emissions that has occurred within the European voyages are published annually and are accessible by public and NGO entities. (Hasanspahic et al., 2021)

The shipping companies then using this methodology and attaining a complete overview to their emission exposure will be required to buy the EUAs or carbon allowances from various sources such as EU auctions and OTC (Over-The-Counter) platforms based on their emission exposure for the periodical year, once the required amount of EUAs are bought they have to be surrendered before the EU ETS compliance deadline to the respective administrative authorities that are specified within the EU ETS regulatory systems.

By doing this shipping companies are subjective to reducing their emissions in order to avoid their financial exposure to the EU ETS system buying carbon allowances. Shipping companies can reduce their emissions through various solutions recommended by both IMO and EU, some of the commonly used methods for reducing fuel thereby reducing CO2 emissions as per the Interview answers are

1. Slow Steaming, weather routing, trim optimization etc.
2. Retrofitting of energy efficient technologies such as pre and post swirl devices, propellor polishing, bulbous bow etc.
3. Use of alternative fuels like biofuel, ammonia, LNG and methanol etc.

Detailed description about these topics will be covered in the next sections.

5.2.4 Decarbonization and sustainable shipping

The marine industry is adopting a multimodal strategy that includes fuel savings, alternative fuels, energy efficiency technologies, Market-Based Measures (MBM), and slow steaming tactics in order to achieve decarbonization and sustainable shipping. Shipowners, operators, and regulators are placing a higher priority on programs to cut greenhouse gas emissions, increase fuel economy, and shift to greener and more sustainable marine practices as worries about climate change and its effects on the environment continue to mount (Christodoulou et al., 2022). As a practical means of lowering the shipping industry's carbon footprint and dependency on traditional marine fuels, alternative fuels are becoming more and more popular. LNG (liquefied natural gas), ammonia, hydrogen, and biofuels are a few of the alternative fuels that are being

investigated as possible substitutes for conventional bunker fuels. These fuels are viable choices for reaching emissions reductions and regulatory compliance since they have lower emissions profiles, less air pollution, and are compatible with the infrastructure already in place aboard vessels (Christodoulou et al., 2022)

Energy-efficient solutions are essential for improving ship performance and cutting fuel usage. Technological solutions such as advanced propulsion systems, waste heat recovery systems, hybrid propulsion, and smart energy management systems are being implemented to maximize energy efficiency, reduce energy loss, and enhance overall vessel performance. With the help of these technologies, shipowners may comply with regulations while achieving notable fuel savings, operational cost savings, and environmental benefits.

Market-Based Measures (MBM) are becoming more popular as a tool for policymakers to encourage sustainable shipping practices and reduce emissions. The objective of mechanisms like carbon pricing, emission trading systems, and carbon offset programs is to promote investment in low-carbon technology and practices while internalizing the environmental costs of shipping. MBMs encourage innovation, cooperation, and industry-wide dedication to decarbonization objectives while offering financial incentives for emissions reductions.

In the maritime sector, slow steaming has become more popular as an economical way to cut emissions and fuel use. Shipowners can extend vessel range, save fuel, and lessen environmental effect by running their vessels at speeds below maximum capability. Additional advantages of slow steaming include increased safety margins, less engine wear and tear, and more flexibility in trip planning (Christodoulou et al., 2022)

5.2.5 Business Models

Business models in the shipping industry comprise a broad spectrum of tactics and techniques used by organizations and individuals engaged in marine trade. The mentioned models determine the configuration, functioning, and economic aspects of shipping services, taking into account the distinct requirements and goals of various industry participants. From conventional ship ownership to cutting-edge online resources. Business models in shipping includes Chartering, Shipping and Logistics, Port operations, Ship brokering, Ship Finance, Green shipping etc.,

Shipowners and operators negotiate a variety of business models in the ever-changing maritime industry, each one designed to meet specific short-term goals while coordinating with long-term sustainability and profitability objectives. In order to take advantage of market possibilities and minimize risks in the short term, short-term business models priorities quick financial advantages and operational efficiencies. They frequently concentrate on cost optimization, revenue maximization, and nimble decision-making. These methods could include spot market trading, short-term rental agreements, or shrewd investments in ships or routes that yield good returns in a short amount of time (Bortuzzo et al., 2023).

On the other hand, long-term business models take a strategic stance, prioritizing resilience, value generation, and sustainable growth over a longer time frame. Long-term plans priorities investments in capabilities, infrastructure, and assets that create long-term value, cultivate customer loyalty, and position the business for long-term success in the changing maritime industry. This is exhibited by shipowners and operators. Long-term business strategies can include buying more ships, diversifying the market, growing the fleet, or forming strategic partnerships with the goal of gaining market share, realizing economies of scale, and strengthening competitive advantage.

Overall, the above-mentioned codes are thought to be major forces in the shipping industry, and this section provides some insight into the initial portion of the research question. These regulations are just one of the strategic approaches that must be closely watched in order to implement the EU ETS and other emission-reducing technologies.

5.2.6 Barriers

This section tries to identify the second portion of the study topic “Barriers”. There are few barriers considered with the inclusion of shipping in the EU ETS system such as pricing, risks and possible infrastructure to support the regulation, the below table is put on the understanding what could be the possible implication to the maritime industry. (DNV, 2023)

Pricing	Regulation	Risks	Infrastructure
Carbon price volatility. Uncertainty on total free allowance. Expected reduction on free allowances by 2030.	Risk of undermining IMO negotiations. Administrative burden due to inconsistency between IMO and EU regulations.	Country-specific penalties and enforcement. Risk of trade diversion given the reduced competitiveness of European goods. Diverting efficiency improvement investments to purchase of allowances.	Availability of bunkering stations (Alternative Fuels). LNG bunkering infrastructure most advanced.

Table6 List of Barriers

Taking one example from the above table i.e. the price of the allowances, as the shipping industry does not receive any free allowances and is given a phase-in period, shipping companies need to buy EUA's from either the primary or the secondary market. The price of carbon allowances follows various fundamentals which are listed below and these fundamentals makes the carbon price more volatile which makes it difficult for shipping companies buy allowances at the right time or when the price is low to benefit their exposure to CO2 towards their fleet size.

- Legislative changes
- Energy mix and production
- Economic and Financial markets
- News and speculative activities

Company failing to comply may have the below consequences:

1. ***Bad Publicity***

   A list of shipping company in breach will be published

2. ***Penalty***

   Excess emission penalty (EEP). The EEP will levy against shipping companies that do not surrender sufficient allowances by the 30th of September for the prior calendar year.

3. ***Amount***

   The EEP is currently set around €100/tco2, emissions that have not been covered by an EUA and the payment of the penalty will not liberate the shipping company from the obligation to surrender the corresponding allowances of the previous year.

4. ***Amount increase***

   The penalty amount will be revised annually in accordance with the EU CPI.

5. ***Expulsion***

   Shipping companies that fail to comply with their ETS surrender requirements for two or more consecutive reporting periods may be issued with expulsions orders.

6. ***Effects***

   One result could be that the ship under the expelled shipping company can be detained by the flag member state, or denied entry to port under the jurisdiction of a member state.

These are some of the barriers which needs to be taken into serious considerations when implementing EU ETS and technologies.

6.Discussions and Research Analysis

6.1 Factual context

The interview was first scheduled to target two to three participants from each of the ten companies. But only 4 companies were able to go through because of different scheduling and personal difficulties. The number of participants from each organization was increased to 4–5 in order to obtain a trustworthy outcome. Ultimately, 15 individuals representing 4 companies were selected to assess the outcome. This would probably give 23% acceptance rate. Following data collection and code analysis, the data are cross-checked against the research question to provide a result graph that is based on the data that was gathered.

Below table describes the basic information about each company,

Company name	Interview mode	Revenue	General description about the company
Synergy Marine Group	Face-to-Face	$78 million	Synergy marine groups handling about 600+ vessels under technical management which includes VLCC's, Suezmax, Aframax, Container ships (from 2,000 to 20,000 TEU), LR2, LR1 and MR tankers, LPG carriers, etc.
Azolla Pte. Ltd	Face-to-Face	$5-7 million	Azolla Pte Ltd is an advisory firm which helps owners and charterers with their decarbonization process. Successfully executed 50+ EET installations,17+ propeller installations, and 50+ BWTS installations.
V.Ships	Face-to-Face	$25 million	V.Ships provide financial, procurement, risk management, and ship technical services to the tanker, bulker, container, offshore, and leisure industries.
Great Eastern Shipping	Zoom meeting	$75 million	The two primary business segments of GE Shipping are offshore and shipping. The delivery of dry bulk goods, liquified petrol, petroleum products and crude oil is the focus of the shipping industry. The company provides offshore production and exploration services as part of its offshore operations.

Table7 Describing the companies involved in the interview process

6.2 Synergy Marine Group

Being a top ship manager, Synergy Group offers comprehensive marine solutions with precisely and skillfully customized services. Strong technical proficiency and a wide range of products combine to produce the best possible efficiency, productivity, and customer experience. Synergy groups have already taken multiple steps to reduce their overall annual emissions by introducing several technological advancements. While answering the interview questions it is noted that the participants share about the technology which they used to reduce the emission and the profit they have turned. To ease their work, synergy is using 'AlphaOri' technologies to manage their vessel data. Synergy makes sure that the ship owners are in line with the regulatory compliance in both segments i.e., IMO and EU. Some of the technologies used by the company are explained in the upcoming section.

6.2.1 Slow steaming

Slow steaming process is coded under Digitalization and sustainable shipping which is also interlinked with the Business models short term goals. Slow steaming is the process of maintaining the vessel under minimal speed in order to save the fuel. This technique is followed by many ship owners and they seem to get beneficial. But slow steaming also has some negative feedback includes duration of voyage increases, unfavorable climatic challenges, and maintenance challenges. Even though slow steaming is a cost saving technique, this cannot be done for a long run (Halff, n.d.)

6.2.2 Trim Optimization

Trim and draft optimization is applicable for all vessel types and vessel ages. Some vessels have less flexibility regarding trim as, for example, cruise vessels which are designed for passenger comfort and facilities for the passengers. Further, full-body ships where resistance from viscous friction is higher than wave friction (e.g. tankers and bulk carriers) will have a less reduction by optimizing the trim and draft and similarly for ships with limited ballast flexibility.

In order to be able to optimize the trim and draft additional equipment is required such as a better loading computer or a dedicated trim optimizer. In addition, the crew need training in the use of such equipment. Achieving best fuel consumption requires giving the vessel crew the

information and tools needed to optimize trim and draft for a given voyage to achieve the lowest fuel consumption. Commercial tools are available to provide crew and cargo planners a means of optimizing trim and draft. Better trim and draft will reduce the resistance and therefore less engine power is required which leads to lower fuel consumption. The overall savings varies from 0.5-5% depend on the vessel type and trade. Trim optimization needs a better knowledgeable crew members to handle the pressure, which is not suited for long run.

6.2.3 Retrofitting

Adding new systems or components to an already existing machinery or infrastructure to improve the performance, efficiency, functionality or compliance with new standards or laws is called as Retrofitting. Retrofitting is a popular practice in many industries to improve reliability, security, sustainability, and energy consumption without having to replace all of the current assets (Kolios, 2024).

In technical point of view integrating a new technology into existing structure needs thorough investigation. Before fitting compatibility, operational efficiency, and security must be considered. If any of the thing goes wrong the vessel's performance, safety, and durability may be in question. The viability of retrofitting projects hinges on cost effectiveness and return on investment considerations. Space limitations, regulatory compliance, cost, Return on Investment (ROI), technical complexity are some of the drawbacks which needs to be taken into serious considerations before heading up. (Kolios, 2024)

6.2.4 Propellor polishing

In the shipping industry, propeller polishing is a maintenance process used to maximize a ship's propeller's hydrodynamic performance. Marine fouling, which includes algae, barnacles, and other creatures, can build up on the propeller blade surfaces over time and degrade propulsion efficiency by increasing hydrodynamic drag.

To restore the smoothness and streamline shape of the propeller, fouling and rust must be mechanically removed from its surface through propeller polishing. Polishing aids in reducing resistance as the propeller rotates through the water by removing roughness and imperfections

from the blades. This enhances maneuverability, maximizes fuel efficiency, and improves overall vessel performance.

Since the cost of propeller polishing is on the order of $10k US and the reductions in fuel consumption can be up to 4% following a polishing of a heavily fouled propeller, it is good practice to regularly polish the propeller. **Cost**: $10k. **Savings**: 1-4% (Zinati et al., 2023)

6.2.5 Weather Routing

The planning and optimization of vessel routes based on weather forecasts, marine data, and other environmental conditions to ensure safe, efficient, and economical passage is known as weather routing in the shipping industry. Weather routing seeks to maximize crew comfort and safety, minimize the effects of unfavorable weather on vessel operations, and minimize fuel usage.

6.2.6 Digital decarbonization services

In the shipping sector, digital decarbonization services usually entail the use of digital platforms, advanced analytics, and data-driven technology to monitor fuel use, optimize vessel efficiency, and pinpoint areas where emissions can be reduced. These services may include a range of topics related to vessel operations, such as compliance management, fuel efficiency monitoring, emissions tracking, and route optimization (Psaraftis et al., 2021).

6.3 Azolla

Azolla Pte Ltd is an advisory firm which helps owners and charterers with their decarbonization process. Successfully executed 50+ EET installations,17+ propeller installations, and 50+ BWTS installations. Azolla is sister company of Synergy Marine groups. Azolla and Vertis Environmental Finance teamed up to start a cooperation for decarbonization and EU ETS services. Through this strategic partnership, Vertis and Azolla will pool their resources in carbon trading and emission analytics through CASPER (Carbon Accounting Software for Periodic Emission Reporting), enabling them to offer comprehensive, superior, economical, and customized marine decarbonization services and knowledge to clients across the globe (*Vertis*

Environmental Finance and Azolla Launch an Exclusive Partnership for EU ETS Services & Decarbonization Offering, n.d.)

Azolla uses Retrofitting, Digital services which includes voyage and weather routing, carbon trading and LED lights as major technologies for better tomorrow. Topics which have not covered before are explained below.

6.3.1 Voyage optimization

Voyage planning has always been an integral part of marine operations. Traditional voyage planning involves plotting a vessel's intended route on paper or electronic charts, shown as a series of course headings and waypoints. A voyage optimization system can provide an optimized ship route for an expected time of arrival (ETA) with well-planned waypoints and sailing speeds for a specific voyage, minimizing fuel consumption and structural damage due to vibrations.

Over the years, voyage planning has evolved into a detailed risk management process considering numerous factors such as safety and storm avoidance, Just in Time arrival, vessel and cargo conditions (draft, trim, etc.), fuel consumption, fuel management, vessel speed, etc.

Voyage planning is often about strategic, business, and logistics planning (Sung et al., 2022). Modern tools for this purpose include:

- Shore-based active weather routing services and their associated suite of software tools (similar to above).
- Proprietary spreadsheet/modelling tools.
- Proprietary software programs.
- Voyage/fuel optimization services and software.
- Systematic processes for data collection and continuous performance improvement.

6.4 V. Ships

Leading independent ship management firm in the world, V. Ships is a global leader in technology, innovation, and services for ship owners all over the world holding 60 offices across 30 countries.

V. Ships, which has over 35 years of experience managing ships in the shipping, cruise, and energy industries, is dedicated to delivering safe and legal operations via openness, initiative, and solid alliances. V. Ships offers ship owners and operators all over the world a comprehensive variety of ship management and marine support services, as well as the flexibility to combine those services in novel ways to satisfy particular client requirements. V. Ships have the capacity to establish, monitor, and fulfil the highest industry requirements in terms of service quality, safety, compliance, and environmental preservation. They exhibit the expertise, dedication, and passion to assist each and every one of our clients in reaching their objectives through asset management that is affordable, secure, and improves performance – wherever and whenever it is required. They use Slow steaming, weather routing and propellor polishing as a major technique to reduce their carbon footprints.

6.5 Great Eastern Shipping

GE shipping is an Indian shipping firm, whose primary business products are bulk liquid, gas and solid products. The company began its existence by supporting sea logistics before branching out into tramp shipping and offshore oil field services. This was done in defiance of industry norms, and the result was that the company frequently swam against the tide and successfully turned the tide in its favor, paving the way for others to follow. From the interview, participants shared that the company is using Slow streaming, Retrofitting, Engine Optimization, and Weather routing to reduce the emission rate.

6.6 Analysis

The paper conducted research analysis over the various decarbonization technologies based on the conducted interviews and referring the answers with the articles from Literature review. All 4 companies had different strategical approach limited to short- and medium-term strategies and applications to its current fleet, for example Synergy Marine answers were keen on using slow steaming, weather routing, propellor polishing and retrofitting, all the options were in one form or other a trusted methodology for other three companies which are very much aligned to short- & medium-term approach for compliance and reducing emissions. However, long-term approach or strategy is underway in all 4 interviewed companies where all the company's mentioned in the

interview that the ideal long-term approach would be the use of alternative fuels. Article *"A roadmap to alternative fuels for decarbonizing shipping: The case of green ammonia"* (Balci et al., 2024) describes the importance of using Ammonia as an alternative fuel for long term strategy. The use of alternative fuels depends on various factors such as production, availability, scalability and access to the maritime sector at least within various bunkering regions globally, this transition also comes with barriers in using fuels like biofuel, methanol, LNG, ammonia etc., which is clearly highlighted on a high-level in the above discussion highlighting the characteristics and shortcomings to use the various alternative fuel options.

Article *"Decarbonizing short sea shipping operations: examine the efforts and outcomes of a Finnish shipping line's relevant initiatives"* (Christodoulou et al., 2022) briefly examined Finnish shipping line's successful alternative technologies used in order to reduce their emission. This article includes techniques like building a new vessel, retrofitting's, slow streaming, OPS, etc., which explains that retrofitting's can be done even for older vessels by proving "Viking Gabriela" as an example.

Below figure describes the top techniques mentioned in the literature review articles and as well from the Interview answers.

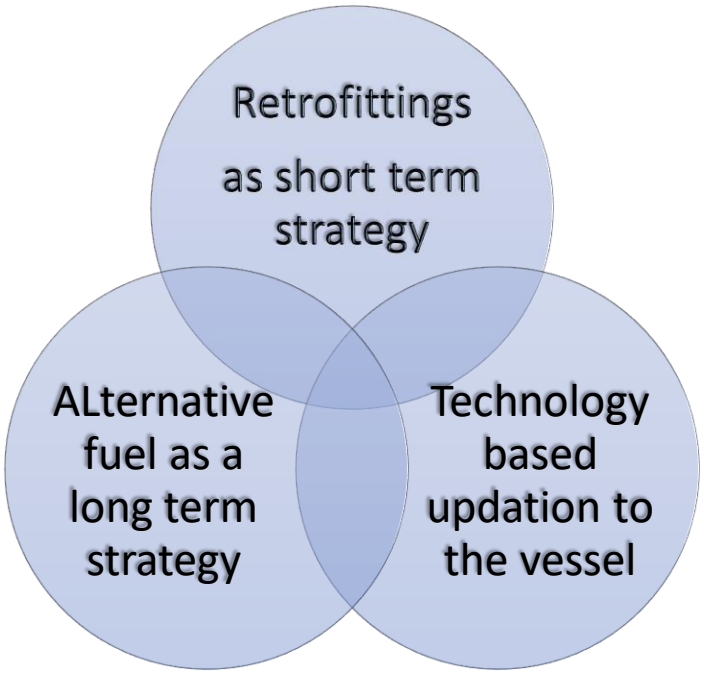

Figure7 Chart describing the technical strategies from Literature review and Interview.

Technology based updating refers to using any technical applications like “Hull and voyage optimization, Energy management systems, Emissions Control Technologies, etc.” which have been covered in the previous chapters.

Based on the conducted research analysis and interview themes, the approach for a company to a long-term strategy towards the ongoing transition requires a company specific ‘decarbonization plan’ which could possibly tailor the fleet and vessel specific characteristics of the ship within the company to conducting a detailed analysis of the efficiency of the ship and which technologies or alternative fuel types would be an ideal option for developing long-term asset evaluation and a ‘decarbonization model’ for the ships within the fleet. Both the decarbonization plan and model requires quantitative data from the interviewed shipping companies for a detailed research analysis to narrow down a methodology as a proposal which the shipping companies can evaluate to identify and validate options to the different technology and fuel type that can be optimal for the ship thereby extending the approach to the entire fleet.

As the paper attempted a qualitative approach to identifying the ongoing decarbonization trends and compliance of the maritime industry in particular EU ETS, further study is required as a quantitative approach to evaluate the available emission reduction options for the interviewed shipping companies. This approach would derive a decarbonization plan and model for decision-making method for a company to choose the right technology and alternative fuel for reducing emissions, this would help in furthering EU ETS and other regulatory compliance for the company and narrow downs the options for a sustainable transition aligning with the various regulatory requirements.

7.Future work

A quantitative methodological approach to a decision-making structure for decarbonization investments in the maritime industry.

This paper currently focusses on the qualitative method which gives an idea about the short-, medium- and long-term techniques to reduce the emissions by conducting interviews. May be in the future, a quantitative methodology to get a long-term solution would be necessary for making decision-based investment in the maritime industry. For the purpose of simulating the long-term implications of investments in decarbonization, quantitative modelling tools are essential. Decision-makers can evaluate the trade-offs between various plans by using scenario analysis and optimization algorithms, taking into account elements like cost-effectiveness, technological feasibility, and regulatory compliance. Through the process of calculating the possible hazards and benefits linked with every alternative, interested parties can order investments in a way that maximizes environmental efficiency while minimizing expenses.

8.Conclusion

Based on the conducted interviews and articles referring to the Literature review, it is understandable that environmental regulations by both the IMO and EU are driving factor for reducing emissions from the maritime industry. The EU is aggressive with their EU green deal by including shipping within their EU ETS system, this puts shipping companies to either comply with the regulation by procuring EUAs and surrendering them for compliance with the regulation to avoid any huge penalties and maintaining the organisation's reputation within the market for business opportunities. Shipping companies with the understanding of maintaining compliance with the complex regulation are planning to implement various emission reduction strategies to their business by incorporating methods that are suggested by the IMO and the EU where the ultimate aim for implementing various environmental regulations is to drive change within the maritime industry and align the segment to the Paris Agreement climate change goals.

The way forward for shipping companies is to reduce their GHG emissions particularly CO2 through various options highlighted in the above discussion where market-based measures such

as slow steaming and retrofitting of energy efficient technologies are considered as short-term options and switching to alternative fuel usage is highly considered as the long-term agenda based on the interview answers. The implementation of the mid and long-term strategy for a shipping company is based on their fleet size, financial details and risk management which accounts on the business opportunities and different strategies that can be applied for an environmental regulatory compliance and a sustainable transition.

The qualitative approach of the paper gave an overview to the applicable regulatory requirements in particular EU ETS and how shipping companies are facing difficulty in reducing their emissions, the conducted interviews presented an overview to the available options within the maritime industry on the various energy saving devices and alternative fuels that are considered by companies for reducing their emissions profile, narrowing down the approach presented the commonality in the technologies used by shipping companies that are used to reduce emissions such as slow steaming, weather routing and retrofitting which are considered as short and medium term approach for reducing emissions and complying with the regulatory requirements.
Long term approach based on the interviews are conclusive towards the use of alternative fuels such as LNG, methanol, ammonia, however the availability and scalability of the fuel comes with certain barriers which the industry is pushing through policy and infrastructural development efforts to make the fuel transition accessible to the maritime industry. By comparing the answers from the interview and the articles from literature review, the findings are more or less same. Almost all the findings end with short/medium- and long-term strategies. Finally, further discussion to the topic is proposed in the form of quantitative analysis where more detailed information from the companies are required to derive a decarbonisation methodology for decision-making structure to analyse and implement the suitable technology and alternative fuel type that should be an option for a ship and consecutive fleet, this would provide a structural decarbonising approach for a sustainable transition for a company to reduce their emission exposure and align with the various regulatory requirements by both the IMO and the EU.

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