Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Department of Ocean Operations and Civil Engineering

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Increasing Ship Energy Efficiency with Technical Retrofits

What Key Drivers Encourage Shipowners' Investments?

Bachelor's thesis in Shipping Management
Supervisor: Jan Emblemsvåg
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Preface

This research paper is a part of my completion of a Bachelor of Science degree in Shipping Management at the Norwegian University of Science and Technology. The thesis was written during my fifth semester as a part of an internship at Becker Marine Systems in Hamburg, Germany. It examines shipowners' investment decisions behavior for deciding to retrofit their vessels with energy efficiency technologies. The research topic was chosen and formulated after various considerations. These involve a personal interest in the subject, the needs of the internship host, and the aim to contribute to filling a research gap.

The project provided me with the opportunity to apply theoretical aspects I have learned during my studies in real-life situations. Personally, this is the most comprehensive academic task I have ever undertaken. The work has been demanding and challenging, but at the same time, it has felt exciting, educational, and meaningful. I have gained invaluable knowledge and experiences that I will carry with me into my professional life.

I would like to express my gratitude to everyone in the sales department at Becker Marine Systems. I did not expect it was going to be easy moving alone to another country for the first time. However, all of you welcomed me very warmly and supported me every step of the way. A special thanks to Mr. Jan Peter Folsland and Mr. Henning Steffen for the exceptional opportunity and mentorship, alongside the guidance of Mr. Alessandro Castagna and Mr. Sören Hildebrandt. Finally, I would like to thank Prof. Jan Emblemsvåg, my research supervisor, for providing valuable insights and feedback during writing of the report.

Hamburg, 12.12.2023

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Abstract

Shipowners' limited retrofitting with energy efficiency technologies (EETs) has become a barrier to reaching the International Maritime Organization's goal of net-zero GHG emissions from shipping by 2050. A primary explanation for shipowners' reluctance to invest in EET retrofits, is a lack of knowledge about the commercial advantages and benefits the technologies can provide. Having insufficient knowledge about the achievable pros, makes it difficult, from a cost-perspective, to evaluate if the investments will be of value. To contribute to overcoming the knowledge barrier, the thesis empirically studies drivers that encourage shipowners' investments.

With basis in previous research on ship energy efficiency investments in general and across industries, qualitative interviews with ten deep-sea shipowning companies that frequently retrofit with EETs have been conducted. This interview sample was selected with the purpose of investigating what drove their decisions to invest in EET retrofits and uncovering their experiences with the technologies following these investments.

The findings suggest that compliance with the Energy Efficiency Existing Ship Index and the Carbon Intensity Indicator, fuel-cost savings, increased market competitiveness, the potential to charge higher charter rates, and principal-agent problems, are key drivers for shipowners' EET retrofit investments.

The study holds both academic and professional transfer value. It contributes to filling a research gap within the field of energy efficiency in shipping and establishes new knowledge in its sub-division of EET retrofitting. Additionally, it is particularly relevant for EET suppliers and authoritative bodies promoting energy efficiency enhancement in the shipping industry.

Content

List of illustrations

Abbreviations

CAPEX	**Cap**ital **Ex**penditure
C/P	**C**harter **P**arty
CII	**C**arbon **I**ntensity **I**ndicator
CO_2	Carbon Dioxide
CSR	**C**orporate **S**ocial **R**esponsibility
EE	**E**nergy **E**fficiency
EPL	**E**ngine **P**ower **L**imitation
EET	**E**nergy **E**fficiency **T**echnology
EEXI	**E**nergy **E**fficiency E**x**isting Ship **I**ndex
EU ETS	**E**uropean **U**nion **E**missions **T**rading **S**ystem
GHG	**G**reen**h**ouse **G**as
IMO	**I**nternational **M**aritime **O**rganization
MEPC	**M**arine **E**nvironmental **P**rotection **C**ommittee
OPEX	**Op**erating **Ex**penses
ROI	**R**eturn **o**n **I**nvestment
SEEMP	**S**hip **E**nergy **E**fficiency **M**anagement **P**lan
TC	**T**ime **C**harter
VC	**V**oyage **C**harter

1.0 Introduction

Each year the world merchant fleet transports around 11 billion tons of goods around the globe from port to port (UNCTAD, 2022). This number corresponds to 90% of world trade, making the shipping industry a fundamental part of the world economy. Despite being the most efficient method of transport per ton transported, shipping is annually responsible for 1 076 million tons of CO_2 and 2.9% of total greenhouse gas (GHG) emissions in the world (European Commission, 2023). A study by the International Maritime Organization (IMO) (2020) revealed that GHG emissions from shipping could in 2050 be upwards of 130% of the 2008 emissions, if no action is taken. To contribute to achieving the universal targets of the Paris Agreement, the IMO puts pressure on stakeholders in the shipping industry by having set a target of net-zero GHG emissions by or close to 2050. This target is supported by two intermediate checkpoints; to reduce total GHG emissions from international shipping by at least 20% by 2030 and at least 70% by 2040, compared to the 2008 levels (IMO, 2023).

Vessels burning heavy fossil fuels are the main contributors to GHG emissions in shipping (IMO, 2021). A rapid decarbonization of these vessels is necessary, and there is a consensus between its stakeholders to look for solutions to achieve a “greener” fleet. Due to speculation and a not yet fully transition to low to zero emission fuels like methanol, hydrogen, ammonia etc., the IMO’s strategy for short-term, until 2030, GHG emissions reduction, involves implementation of energy efficiency (EE) measures on vessels (see Figure 1) (IMO, 2018). Among these, retrofitting vessels with energy efficiency technology (EET) plays a vital role in reducing GHG emissions and working towards achieving the short-term target of 20% GHG emissions reduction by 2030 (IMO, 2018). EETs increases EE, which is a reduction in the amount of energy needed to perform a given amount of work – in regard to shipping, this means less fuel consumption (Holsvik & Williksen, 2020). Retrofitting in this context involves installing fuel-saving technology on existing vessels to increase their EE, which will therefore result in reduced GHG emissions.

1.1 Purpose and research question

The purpose of this thesis is to illuminate and examine a research gap that has been identified regarding the decision-making process of shipowners for retrofitting with EETs. Previous studies show that EETs have experienced limited retrofitting from shipowners despite their significant fuel-saving potential. Of almost 80 000 vessels worldwide, only around 5 000 vessels have installed any form of EET (Clarksons Research, 2023). As in consensus with the IMO's (2023) short-term GHG emissions reduction strategy, these numbers must increase considerably in order to reach the short-term target by 2030.

Besides reduced emissions, EET retrofit investments are influenced by several other drivers, or i.e. advantages and benefits shipowners can achieve. The researcher has identified that a main barrier for EET retrofit investments, is a lack of knowledge about these commercial advantages and benefits. Therefore, adopting well-known operational EE measures, such as slower sailing speed, is often a more favorable approach. Shipowners are reluctant to do EET retrofitting as they have a hard time considering the cost-benefit aspect of it. They see it as a very resource-consuming burden, but do not know if the pros outweigh the cons – which makes investments risky. One example of this is that there is a big focus on technical brochures about how specific technology works and general emissions reduction charts etc. However, there is insufficient information on how shipowners can benefit from installing the technology seen from a pure business perspective.

As the knowledge barrier is a significant hinder to EET retrofitting, empirically studying drivers that encourage investments is necessary to overcome it. The researcher has not been able to identify any previous research conducted to examining and comparing the advantages and disadvantages of retrofitting with EETs. To add effort to solving the problem of limited EET retrofitting, the research question is formulated as the following:

What Key Drivers Encourage Shipowners' EET Retrofit Investments?

By answering the research question, the researcher aims to provide shipowners with a factual basis of what is possible to achieve from investing in EET retrofits. The idea behind this approach is to contribute to stimulate the growth of vessels being retrofitted with EETs – which will increase the world merchant fleet's overall EE, ultimately contributing to reaching the IMO's short-term GHG emissions reduction target.

1.2 Thesis structure

To answer the research question, an understanding of the topic and background for the research problem is first presented in chapter 2. Further, existing literature relevant to the research problem is reviewed in chapter 3. Chapter 4 discusses the methodology of the research, and why particular research methods are utilized as opposed to others. Chapter 5 presents the qualitative study's empirical findings. In chapter 6, by interpreting the findings and discussing them together with the literature review, the research question is answered. In chapter 7, potential limitations of the research are clarified and criticized, and further research is proposed. Finally, in chapter 8, a conclusion is drawn.

1.2.1 Refinements and assumptions

For practical and professional reasons, it has been necessary to make some refinements and assumptions to better understand the scope of the thesis.

Firstly, there is a sole focus on the shipowners' perspective, as they are the customers of EETs. With that being said, charterers, suppliers, and other stakeholders will still be discussed in the thesis, but they will not be empirically studied. Secondly, the scope of the thesis only applies to EETs for retrofitting on existing ships, so newbuildings will not be assessed. Further, the thesis will not debate which EE measures is the better choice, as it is the combination of them that is necessary to reach the short-term emissions reduction target (IMO, 2021). The thesis will instead solely focus on the problem of the low retrofitting rate of EETs. Finally, and very importantly, the thesis is carried out from a commercial perspective. Drivers discussed do not refer to technical aspects from a naval architect's or engineer's perspective, but instead from a pure business perspective.

In regard to the study's short time frame and the researcher available resources, interviews have only been conducted with Norwegian and German shipowners. Limiting the thesis can still be seen as an advantage, as the task becomes more manageable and precise for the specific objectives studied. It is assumed that what findings apply to the Norwegian and German shipowners, also applies to the deep-sea world fleet. This "generalization" is based on the fact that the shipowners interviewed all directly operate within deep-sea shipping (intercontinental). Additionally, together, the shipowners represent all freight market segments (oil, gas, chemicals, dry bulk, containers, cars, cruises, research etc.). Flag states and domestic headquarter locations should not have any impact on the results of the study. With that in mind, domestic and governmental factors will also not be addressed, as the deep-sea world fleet is the focus of the thesis.

2.0 Background

Due to EET retrofitting's technical and niche nature, it is necessary to first provide a comprehension of the topic and background for the research gap in order to understand the literature review. Section 2.1 provides an overall understanding of EE measures and further elaborates specifically on what EET retrofitting involves. Section 2.2 explains why lack of knowledge is a main barrier for EET retrofit investments.

2.1 Energy efficiency measures

EE measures is a widely used term across many industries and can generally be defined as: "Any machine, software, system, practice, or retrofit that leads to a general reduction in energy usage without significantly impacting level-of-service..." (OrbitsHub, 2022). In regards of shipping, this refers to actions to significantly reduce vessels' fuel consumption (Holsvik & Williksen, 2020). The IMO's Global MTCC Network (2018) published estimates that show potential upwards of 75% reductions in vessels' energy usage and carbon dioxide (CO_2) emissions from implementing EE measures.

The shipping-term is firstly split into either measures for newbuildings and measures for existing vessels. For newbuildings, measures involve building environmentally friendly vessels, or more commonly known as "eco-ships". Eco-ships are being built with the purpose of emitting as little as realistically possible and at the same time being efficient in operations (Psaraftis, 2019). They are often characterized by alternative fuel propulsion (commonly liquefied natural gas) and built-in EETs (Seddiek & Elgohary, 2014).

For the existing fleet, which this thesis is focused on, the average vessel's age is 12.3 years (Clarksons Research, 2023). This means that most vessels do not possess the technology and environmentally friendly characteristics as newly built eco-ships. To compensate for the way more polluting operations of existing vessels, implementing EE measures is necessary. For existing vessels, as seen in Figure 1, EE improvement can be achieved through two main measures: operational measures and technical measures

(EET retrofitting) (IMO, 2021). Operational measures refer to practices and strategies that are implemented to optimize a vessel's day-to-day operations. Reduced sailing speed and improved voyage planning (selecting routes based on weather conditions, just-in-time arrival, etc.), are common examples of operational measures (Plomaritou & Papadopoulos, 2018). Technical measures involve implementing EETs on existing vessels (retrofitting). This includes several various already available devices, systems, equipment, actions for optimization of components, and other very soon available novel technologies (Psaraftis, 2019).

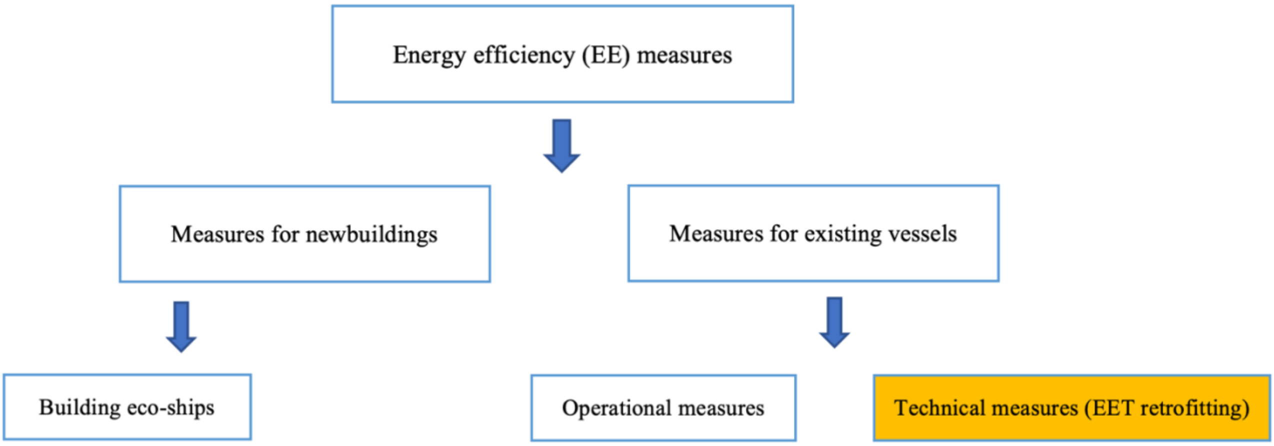


Figure 1: Scope of the thesis (Own elaboration on the IMO (2021) & Gao (2022))

2.1.1 Energy efficiency technologies for retrofitting

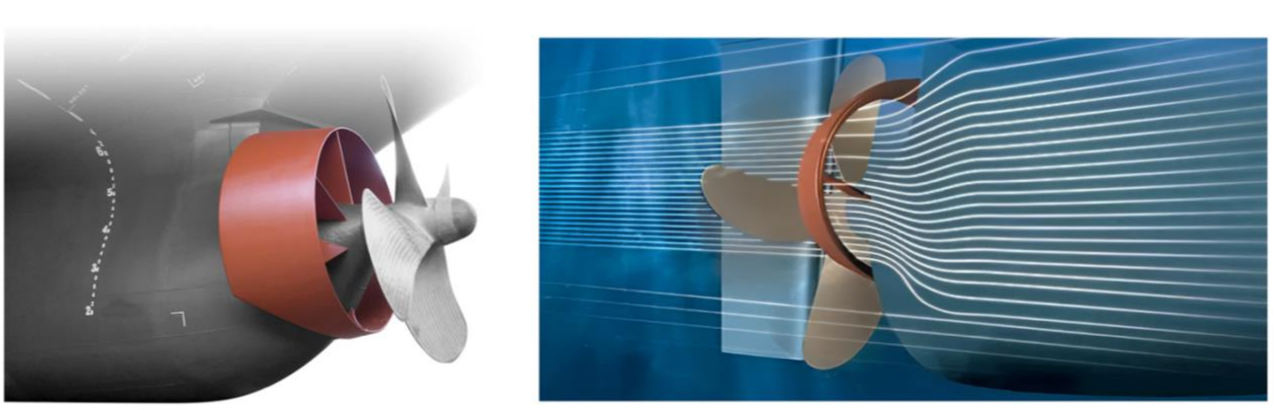
There are four main equipment groups of EETs; engine room, propeller, deck equipment, and hull (Clarksons Research, 2020). As seen in Table 1, there are several various technologies available for significant fuel-savings, whereas propeller and engine room enhancements are most common.

Table 1: Energy efficiency technologies (Clarksons Research, 2020)

Equipment group	Technology	Example project	Fuel-savings (Marketing claim)	No. vessels equipped (Per Aug 2020)
Engine room	Waste Heat Recovery System	ABB	3-8%	>38
	Exhaust Gas Economiser	Kangrim	4-6%	>1515
Propeller	Propeller Duct	Becker Mewis Duct	3-8%	>1161
	Pre-Swirl Stator	DSME Pre-Swirl	4-6%	>8
	Rudder Bulb	Wärtsilä Energopac	3-5%	>268
Deck equipment	Flettner Rotors	Anemoi Wind Engine	7-10%	>8
	Rigid Sails	DSIC	8-30%	>2
	Wind Kite	Airseas Seawing	Up to 20%	>0
	Solar Sail	Eco Marine EnergySail	Up to 20%	>0
Hull	Air Lubrication System	Mitsubishi MALS	5-10%	>71
	Bow Enhancement	Kawasaki SEA-Arrow	4-10%	>252

The term retrofitting is defined as “when equipment is modified to bring a vessel in line with the latest rules, regulations and standards” (Bureau Veritas, n.d.). Modification of equipment involves switching components with substitutes or implementing extra technologies, which is more energy efficient than the vessel’s standards. Retrofitting in this context is also done "by the shipowner’s interest to upgrade to higher operational standards” (European Commission, 2015) – which is driven by other possible advantages and benefits one can achieve. As per the world fleet’s average age of 12.3 years, retrofitting with EETs is highly relevant to the majority of today's existing vessels (Clarksons Research, 2023).

Picture 1 demonstrates a popular EET, the Becker Mewis Duct. “The Becker Mewis Duct consists of two strong fixed elements mounted on the vessel: a duct positioned in front of the propeller along with an integrated fin system. The duct straightens and accelerates the hull wake into the propeller and also produces a net forward thrust. The fin system provides a pre-swirl to the vessel wake which reduces losses in the propeller slipstream, resulting in an increase in propeller thrust at a given propulsive power” (Becker Marine Systems, 2023). As with any other EET, the purpose is to increase EE.



Picture 1: The Becker Mewis Duct (Becker Marine Systems, 2023)

2.2 Lack of knowledge as a main barrier for EET retrofitting

Latest updates on EET investments occur in a report by Clarksons Research (2023), revealing that only 5 775 vessels globally have been equipped with any variant of EET. As this number includes newbuildings (eco-ships) as well, the statistic for EET retrofitting is arguably even lower. Compared to the world merchant fleet consisting of over 74 000 vessels per 2021 (BIMCO, 2021), the level of investments is not satisfactory.

Faber *et al*. (2010), Smith *et al*. (2013), and Rehmatulla & Smith (2015) found that operational measures are more frequently implemented than EETs. These claims are still supported by more recent research by Erginer & Kaya (2021), which is years after the IMO published its short-term GHG emissions reduction strategy in 2018, highlighting the importance of retrofitting with EETs. The study by Erginer & Kaya (2021) was conducted with questionnaire surveys on 23 deep-sea shipowners about which EE measures they think are most preferable to implement, concluding with a ranking system showing that most various operational measures outperform EETs from their perspective.

The inconsistency between optimal and actual implementation of EET retrofits has basis in theory on the "energy efficiency gap". The energy efficiency gap theory is widely used in different academic fields covering different industries, and is explained by the existence of barriers for implementation. The barriers have basis in different disciplines, e.g., organizational, economic, behavioral sciences etc. (Jafarzadeh & Utne, 2014). It has been observed that Erginer & Kaya (2021) and several other of the most prominent researchers in this field (Acciaro *et al*., 2013, Armstrong & Banks, 2015, Poulsen & Sornn-Friese, 2015, Poulsen & Johnson, 2016), have conducted studies to examine these barriers in terms of shipping. Additionally, they examined barriers specifically for EET retrofitting and why operational measures are more often implemented instead. They could all conclude that lack of knowledge about EETs, more specifically, lack of information about commercial advantages and benefits of installing them, is a main barrier for investments. With that in mind, it is not necessary that implementing operational measures is a better approach than EET retrofitting, but a standard business principle is that one naturally associates lack of knowledge about investments with higher risk. Erginer & Kaya (2021) found that shipowners want to avoid this risk as much as possible. When it comes to the cost-benefit aspect of EET retrofitting, shipowners therefore often only consider the resource consumption of the investment, such as investment and maintenance costs, the lengthy planning stage, the installation process etc., rather than also evaluating the advantages and benefits one can achieve – which ultimately is most likely worth the "trouble". But as mentioned, the lack of knowledge about these pros makes it difficult to evaluate if investments are worth it.

According to Sales Manager, Alessandro Castagna, at Becker Marine Systems, information through e.g. brochures and websites of EET suppliers consists mostly of very technical specifications about how the technology works in practice [1]. What is missing is information concerning the value EET retrofitting can create for shipowners. It may therefore be difficult convincing decision-makers with commercial backgrounds to submit an offer request due to their limited knowledge about how EET retrofit investments can benefit their companies from a business perspective.

[1] (Personal communication, September 5th, 2023)

3.0 Literature review

This chapter presents the literature necessary to discuss the problem the study aims to solve. The purpose of the literature review is to validate data collected in the qualitative research.

The literature discussed is a combination of previous research studies, academic books, and official sources. The research has been retrieved from the online academic databases ScienceDirect, ResearchGate, Google Scholar, MDPI, and additionally university databases. The academic books are written by reputable experts such as Dr. Martin Stopford and Dr. Harilaos N. Psaraftis. The official sources include authoritative bodies such as the IMO, EU, and DNV.

As per the research gap, the researcher acknowledges that there have been difficulties finding scientific literature on EET retrofitting. The literature is therefore primarily concentrated on influencing factors for EE investments in general and across industries, creating assumptions for what may apply to EET retrofitting – which will be examined and explored in the qualitative study.

3.1 Influencing factors for considering energy efficiency measures

According to Armstrong & Banks (2015), there have been several studies on EE for shipping in general, and across industries, identifying three reoccurring influencing groups for considering implementing EE measures; compliance, economy, and clients. Erginer & Kaya (2021) stated that the studies addressing these groups referred to compliance as compliance with regulations and rules, economy as reducing expenses and maximizing profit, and clients as requirements and expectations from clients in terms of sustainability and corporate social responsibility (CSR).

3.2 Compliance

During the Marine Environmental Protection Committee's (MEPC) 76th session held in June 2021, regulations to reach the IMO's short-term (2030) emissions reduction target was introduced. For the existing fleet, this involves the Energy Efficiency Existing Ship Index (EEXI), and the Carbon Intensity Indicator (CII). Vessels must comply once with the EEXI, and with CII, continuously improve every year. For EEXI, shipowners must prove high enough technical EE in order to have permission to commercially sail and operate (Demetrios, 2023). For CII, there are no consequences announced yet by the IMO, but are expected in the upcoming years (DNV, 2022). The EEXI and the CII were put into force in January 2023, and are both some of the biggest topics discussed these days, as they force shipowners to make changes to the majority of the world's vessels. As these regulations target the existing fleet, it can be expected that shipowners must invest in EET retrofits, even though it may not always be economically feasible.

3.2.1 Energy Efficiency Existing Ship Index

The EEXI measures CO_2 emissions per transport work (per cargo ton and mile), only considering a vessel's technical EE. This involves a determination of CO_2 emissions in regard to a vessel's engine power, capacity for transport, and sailing speed. Therefore, no on-board operational measurements are evaluated and values from previous years are irrelevant, as the index only considers the vessel's technical design. EEXI approval must be achieved for all existing vessels of 400 gross tonnage and above. To be approved, a vessel's calculated attained EEXI must be below its required EEXI value. The required value for approval is determined by a relative baseline for the specific vessel type, capacity, and principle of propulsion (IMO, 2022, DNV, 2022).

$$EEXI = \frac{CO_2\ \text{emissions}}{\text{Transportation work}}$$

$$EEXI = \frac{\text{Main engine emissions + Auxiliary engine emissions + (PTI - Innovative electrical energy technologies) — Innovative propulsion energy technologies}}{\text{Capacity * Reference speed * Reduction factors}}$$

$$EEXI = \frac{(\prod_{j=1}^{n} f_j)(\sum_{i=1}^{nME} P_{ME(i)} C_{ME(i)} SFC_{ME(i)}) + (P_{AE} C_{AE} SFC_{AE}) + ((\prod_{j=1}^{n} f_j \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} P_{AEeff(i)}) C_{FAE} SFC_{AE}) - (\sum_{i=1}^{neff} f_{eff(i)} P_{eff(i)} C_{FME} SFC_{ME})}{Capacity\, V_{ref} f_i f_c f_l f_w f_m}$$

Figure 2: Energy Efficiency Existing Ship Index calculation formula (Navalista, n.d.)

The easiest way for a vessel to comply with the EEXI is to install an engine power limitation (EPL) system or by early retirement (Clarksons Research, 2023). Regarding an EPL system, it sets a limitation to the maximum power of the vessel's main engine. Thus, resulting in slower sailing speed, which reduces fuel consumption and emissions. The pro of this approach is that it requires minimal changes to the vessel and does not alter engine performance. However, a large con of early retirement and EPL is that they significantly reduce shipping supply capacity by having to scrap vessels more frequently, and by slower sailing speed, spending more time carrying the same amount of cargo. Shipowners might therefore be forced to expand their fleet by ordering new vessels or expanding their existing vessels' size to fill the supply gap/ carrying capacity lost. (Comer *et al*., 2020). In the bigger picture of reducing global GHG emissions, as the purpose of the EEXI, not only does these solutions potentially nullify the savings or increase overall CO_2 emissions, but also result in a substantial increase in capital expenditure (CAPEX) and operating expenses (OPEX) (Castagna, 2023). Comparing the increased resource consumption and environmental impact of implementing EPLs and retiring vessels early with the investment costs of EET retrofitting, it can be assumed that the EEXI significantly encourages EET retrofit investments.

3.2.2 Carbon Intensity Indicator

The CII is a measure of a vessel's transport efficiency and is calculated in grams of CO_2 emitted per cargo-carrying capacity and nautical mile. All commercial vessels of 5 000 gross tonnage and above trading internationally are required to report their calculated CII. In 2024, these vessels will against a set reference line of CO_2 emissions, receive a rating (A, B, C, D, or E – where A is the best) based on their performance in 2023 (IMO, 2021). This process will be repeated annually, but the rating thresholds will simultaneously towards 2030 become increasingly stringent to ensure reaching the IMO's short-term target. Vessels rated D for three consecutive years, or E once, must update their Ship Energy Efficiency Management Plan (SEEMP) demonstrating how the minimum required rating of C (or above) will be achieved by the next rating (DNV, 2022).

$$\text{CII (gCO2/t} - \text{nm)} = \frac{\text{Annual fuel consumption x CO2 emission factor}}{\text{Annual distance sailed x Deaweight or GT (depending on vessel type)}}$$

Figure 3: Carbon Intensity Indicator calculation formula (GARD, 2022)

As opposed to the EEXI as a one-time certification purely covering **technical** design aspects of vessels, the achieved CII rating is based on the **operational** EE (see Figure 1) IMO, 2021). Clarksons Research (2023) estimated that 40% of today's existing fleet will be rated D or E by 2026 if they do not improve their operational EE. Kenneth Tveter, head of Green Transition in Clarksons, further argue that the most effective operational measure, speed reduction, is grossly overestimated and will not necessarily improve CII-ratings alone. Although Tveter can be considered a reliable source, there is insufficient research conducted to further support his claim – as we have not entered 2024 yet. However, his expert opinion indicates that investing in EET retrofits may be necessary for the majority of the world fleet in order to continuously comply with the CII. If proven correct, it can possibly be expected a considerable increase in EET retrofitting from the CII as a driver alone.

3.2.3 Future outlook: Carbon Emissions Trading

Similar to the IMO regulations is carbon emissions trading. Carbon emissions trading is a type of emissions trading system that is globally used across several industries to reduce CO_2 emissions. The system has variations to it and is usually implemented on a domestic or continental level. The main function is a "cap and trade" principle, where it is set a maximum limit (cap) of a total amount of CO_2 allowed by all participants to emit. The cap decreases over time to put pressure on the participants to increase their EE. CO_2 "allowances" are allocated or bought by the participants based on the current cap and is later possible to trade among the participants (European Commission, 2023). E.g. if a participant exceeds his allowed emissions, he must buy more CO_2 allowances from others to not face penalties. Carbon emissions trading encourages participants to reduce their emissions to profit economically by selling their unused CO_2 allowances (Psaraftis, 2019). It can therefore be assumed that shipowners may profit from EET retrofit investments if emissions reductions are great enough to sell significant amounts of CO_2 allowances.

Starting in 2024, through the European Union Emissions Trading System (EU ETS), carbon emissions trading will be required for all vessels above 5 000 gross tonnage transporting cargo or passengers for commercial purposes in the EU (DNV, 2023). Recent estimates from DNV suggests that a container vessel sailing between Europe and Asia may face allowances charges of about EUR 810 000 (Bloomberg, 2023). Even though the EU ETS does not concern the whole world fleet, it is still highly relevant to discuss as previous research predicts a future international outlook for carbon emissions trading in shipping. The EU ETS has received massive criticism from the academic community (Halim *et al.*, 2018, Ge *et al.*, 2018, Holsvik & Williksen, 2020). The main argument identified from the researchers is that the shipping industry only operates efficiently if regulations, such as carbon emissions trading, are practiced internationally. The studies indicate that the EU ETS as a continental regulation may decrease the efficiency of deep-sea trade and even increase GHG emissions. This is because vessels would likely sail longer detours to avoid entering EU territorial waters (Psaraftis, 2019). This is supported by previous experience with failed carbon emissions trading within the aviation industry, due to it being quickly discovered that regional regulations cannot sufficiently regulate international sectors (Lagouvardou *et al.*, 2020). However, discussions of an international IMO regulated establishment of a maritime carbon emissions trading system have received positive feedback from the academic community (Halim *et al*., 2018, Ge *et al*., 2018, Holsvik & Williksen, 2020).

3.3 Economy

Economy is considered an essential influencing factor when considering EE investments for shipping in general and across industries. E.g., Gao (2022) found similarities and no significant disagreements for consideration factors of EE investment when comparing studies on shipping and residential housing. For shipping, considering volatility of charter rates (vessel rental/hire fees), demand for shipping, and fuel-prices, achieving economic voyages is driven by bottom line profit margins (Drakou *et al*., 2014). Minimizing OPEX and maximizing revenue depends heavily on the right vessel conditions and services operated (Stopford, 2008, Poulsen & Johnsen, 2016). With this in mind, it indicates that the cost-benefit aspect of EET retrofitting, i.e. how shipowners can recover and profit from investments, is a topic worth studying. This is additionally supported by Rehmatulla (2012), who identified that lack of reliable cost- and savings information was a major barrier for implementing EE measures.

3.3.1 Cost aspects

EET retrofit investment-costs include purchase prices of the technology, operational and maintenance expenses, and resource consumption of planning, procurement and installation processes (Erginer & Kaya, 2021, Gao, 2022). Planning and procurement of equipment have order and shipping time that should correspond with planned operations. Installation and maintenance expenses can involve several off-hire periods for the vessels, which often require dry-docking (Armstrong & Banks, 2015). In off-hire, i.e. unproductive days, the shipowner will not be paid, and may experience a poorer reputation with the charterers (Stopford, 2008). Additionally, different EETs need different installment and maintenance periods at the yard, which makes a technical approach for achieving EE very resource consuming. Shipowners may therefore immediately see this as a burden or an economic risk. As mentioned before, avoiding economic risks is a natural business principle and a hinder for investments (Erginer & Kaya, 2021, Mosgaard & Kerndrup, 2016).

3.3.2 Benefit aspects

According to Longarela-Ares *et al*. (2020), the payback period of recovering an investment and further achieving return on investment (ROI), have been confirmed by several researchers to be a determining factor when considering implementing EE measures in general. For shipping, fuel-costs account for 60-70% of vessels' OPEX, and reducing fuel consumption by just 1% can annually save a large container vessel USD 300.000 (Ang *et al*., 2017). In that context, although EE measures can create these immediate high cost-savings, the studies show that there must be a forecast of long-term viability performance in order to actually benefit from that. In regard to the shipping industry, it has been identified two significant criteria for attempting to forecast if EE investments from a cost-perspective are recommended; right vessel conditions and services operated (Poulsen & Johnsen, 2016, Longarela-Ares *et al*., 2020).

Firstly, right vessel conditions refer to a vessel's optimal age and size for investments. As vessels have a limited service life, averaging 25-30 years, investments in older existing vessels can result in economic losses as the payback periods are longer than the remaining lifetimes of the vessels (Maddox, 2012). To avoid economic risk and increase the probability of profiting, shipowners would much rather prioritize EE measures in their relatively new vessels when attempting to increase their fleet's overall EE (Rehmatulla & Smith, 2020). Vessel size can also impact investment decisions as larger vessels consume greater amounts of fuel. Focusing on increasing EE in the fleet's main tonnage will have larger impact on overall OPEX-reductions (Longarela-Ares *et al*., 2020).

Secondly, services operated refer to a vessel's shipping operations. Longarela-Ares *et al*. (2020) found that implementing EE measures may not always be economically beneficial depending on how often a vessel operates. Similar to vessel size, a higher rate of activity per year, i.e. days at sea and distance travelled, results in increased OPEX. Prioritizing EE investments in these vessels have a greater potential for overall EE improvement of the fleet and therefore increase fuel-cost savings.

3.4 Clients

Clients have been identified as the third and final influencing group for considering implementing EE measures. Clients in the context of shipowners refer to their main clients, the charterers. The charterers are the shipping companies that rent or hire the shipowners' vessels to transport cargo. Payment is settled with charter rates, or i.e., fees/prices of renting or hiring the vessels. The contract between the shipowner and the charterer is called a charter party (C/P). A C/P is commonly either a time charter (TC) or a voyage charter (VC). TC involves the charterer renting the vessel for longer time-period, whilst VC entails hiring the vessel for a single specific journey. A main difference between TCs and VCs is that the shipowner has the operational control of the vessel during VCs, whilst during TCs, the charterer has it. This means that the shipowner is only responsible for fuel-costs during VCs. (Marine Insight, 2021).

Armstrong & Banks (2015) stated that; "Major organizations, i.e. those mostly listed in stock exchanges, promote the requirement for vessels chartered by them to carry their cargo, to follow sustainability initiatives and practices as part of their commitment to CSR". The study further reveals that these initiatives and practices are directly related to efforts on increasing EE in shipping operations. Additionally, from the shipowners' perspective, Longarela-Ares *et al.* (2020) could confirm that charterers' requirements was identified as a crucial factor when considering implementing EE measures. Shipowners experience requirements from charterers such as pledged fuel consumption, and requirements to have implemented specific types of EE measures. Previous research suggests that EE measures can have both positive and negative impact on shipowners' market competitiveness and charter rates (Erginer & Kaya, 2021, Gao, 2022). Simultaneously, principal-agent problems can arise depending on different C/P (Holsvik & Williksen, 2020, Longarela-Ares *et al.*, 2020).

3.4.1 Market competitiveness and charter rates

Gao (2022) suggests through a quantitative study that EET retrofitting can have a negative impact on shipowners' market competitiveness. In terms of an economic point of view, EET retrofitting is often not favored due to its significant resource consumption and disruption of shipping operations. Gao (2022) stated that: "Competitors get more profits when vessels from a shipowner's own company are being retrofitted with EETs. Therefore, higher market competitiveness is not evident from this perspective". In contrast, Erginer & Kaya (2021) found that vessels with high EE have the advantage of being chosen when competing for C/Ps, and sometimes even at a higher charter rate than less energy efficient vessels. This is due to the fuel-cost savings possible from a highly energy efficient vessel is often greater than the immediate cost-savings from acquiring a lower charter rate. It can therefore be assumed that retrofitting with EETs to achieve higher EE can be a tool for eliminating competing shipowners and even score higher charter rates.

3.4.2 Principal-agent problems

Charterers' requirements to shipowners to have implemented EE measures can create principal-agent problems between the shipowner and the charterer. A principal-agent problem is simply a conflict in priorities between the owner (the shipowner) of an asset (the vessel) and the one (the charterer) who have been delegated to control the asset. The researcher has not identified any specific research to this in regard of EET retrofitting, but an assumption is that EET retrofit investments would be more strategic on vessels that operate mostly under VCs, as high obtained EE in this context is in favor of the shipowner (he pays the fuel). This assumption can be interesting to study, as it is arguably supported indirectly by Holsvik & Williksen's (2020) study addressing operational measures' role in C/Ps. The study found that vessels that mostly operate under TCs (where the charterer pays the fuel), are more likely to implement operational measures rather than EETs, as it is cheaper for the shipowner to take operational actions instead of investing in "expensive" EETs. This is furthermore supported by Faber *et al.* (2010), Smith *et al.* (2013), and Rehmatulla & Smith (2015), who all could conclude that various operational measures have a higher implementation rate in TCs than in VCs. The findings suggest that this is also due to the charterer having the operational control of the vessel in TCs and their own encouragement to reduce fuel consumption.

Regarding principal-agent problems, in a T/C, the shipowner (principal providing the service), determines the level of EE, while the charterer (agent demanding the service) bears the costs associated with that level of EE. If the charterer is not satisfied with the current level of EE offered by the shipowner, he may require the shipowner to implement more or specific EE measures. The «problems» arise when the shipowner, even though it is not economically feasible, must comply with the charterers requirements to be awarded the T/C. (Agnolucci *et al*., 2014). Compared to the research on operational measures in this context (Holsvik & Williksen, 2020), also investigating this theory in the case of EET retrofitting would be interesting. An assumption is that shipowners may experience the benefit of eliminating less energy efficient competitors and charge higher charter rates, but will not necessarily profit directly economically from the investments due to the high investment costs.

3.5 Key points in chapter 3

This section is dedicated to shortly summarize the most important key points retrieved from the literature review.

3.5.1 Key points of "Compliance"

Compliance involves complying with regulations in order to reach the IMO's short-term emissions reduction target. For the EEXI, vessels must comply once to have permission to sail, and it purely considers technical EE. Solutions for compliance are engine power limitation (EPL), early retirement, and EET retrofitting. As EPL and early retirement reduces shipping supply capacity, shipowners may expect increased OPEX, CAPEX, and environmental impact, by having to potentially order new or expand their existing vessels.

For the CII, shipowners must comply and continuously improve every year. There are currently no IMO driven consequences announced yet, but they are expected in the upcoming years. CII-ratings are mainly driven by operational EE, but experts are claiming that operational measures are not sufficient.

Carbon emissions trading involves trading CO_2 allowances, and is characterized by high EE being rewarded, whilst low EE being punished. The EU ETS starting in 2024 will cover carbon emissions trading in EU territorial waters, but have received massive criticism from the academic community. There are currently ongoing academic discussions of an international IMO regulated establishment for carbon emissions trading.

3.5.2 Key points of "Economy"

Economy is about minimizing OPEX and maximizing revenue by reducing fuel-costs. This involves how shipowners can recover and profit from EE investments. The cost aspects of EET retrofitting are characterized by being very resource consuming and poses economic risks that the shipowners want to avoid. Expenses include purchase prices, operational and maintenance costs, and planning, procurement and installation costs. Order and shipping time should also correspond with planned operations, but uncertainty and unexpected events can result in off-hire periods (dry-dockings) where the shipowner will not be paid. In contrast, the benefit aspects are about having forecasted long-term viability performances of the vessels. The right vessel conditions, vessel-age and vessel size, and services operated, level of activity, are significant criteria to consider. Vessels cannot be too old to recover investments, and the more fuel consumed with large sized vessels and high annual activity, the more effective are EE measures.

3.5.3 Key points of "Clients"

Clients refer to requirements from the charterers with basis in improving their sustainability and CSR. Charterers may have requirements to pledged fuel consumption and/or specific EE measures implemented. EE measures may have both positive and negative impact on a shipowner's market competitiveness. Shipowners with a high level of EE may experience the advantage of being chosen amongst other shipowners and sometimes even at a higher charter rate. But simultaneously, implementing EE measures can create significant resource consumption and disrupt shipping operations (off-hire/ dry-dockings). Principal-agent problems may also arise. Implementing EE measures in TCs may be required by the charterer even though it is not economically feasible for the shipowner.

4.0 Methodology

This chapter elaborates on the study's methodological structure. The methodological theory utilized takes basis in Ann Kristin Larsen's (2017) seven phases for a qualitative research process, and elements from Aksel Tjora's (2018) theory on practical qualitative research methods and Tor Busch's (2021) theory on academic writing. Each phase is presented theoretically, before the researcher's own methodological work and decisions are explained. Note that phase 7 will not be addressed as this chapter solely aims to uncover the characteristics of the research process itself, not the report in its entirety.

Table 2: The seven phases of a qualitative research process (Larsen, 2017)

Phase	Key steps
1. Formulation of problem statement	Identifying and explaining the issue to be studied Formulating a research question
2. Selection of units and variables	Units = those the study is about (e.g., interview informants) Variables = characteristics or attributes of the units (e.g., interview questions)
3. Data collection	Primary data = collected by the researcher (e.g., through interviews) Secondary data = collected from previous literature (e.g., through existing research)
4. Data processing	Transcribing the primary data (e.g., from audio recording to text) Simplifying and removing redundant information
5. Data analysis	Coding = compressing, systemizing and organizing the data Searching for patterns, differences and unique reflections
6. Data interpretation	Making sense of the findings Comparing findings with secondary data Establishing new knowledge
7. Reporting	Writing and publishing the final report

4.1 Validity and reliability

Methodological theory aims to clarify the choice of research methods that genuinely align with the research objectives, while maintaining a high level of academic and ethical integrity through the entirety of the project. The purpose of this is to ensure that the data collected and the process of collecting and handling it, is characterized by high validity and reliability. To ensure these criteria are met in this project, the researcher will discuss why particular scientific approaches throughout the research process were made as opposed to others.

Validity refers to the research showing *verifiability* and *credibility*, and having *transfer value*. Verifiability is about the relevance of the study, assessing whether it effectively investigates what it is supposed to investigate. The data we collect must be relevant to the research question, so that the conclusion we draw is valid. Secondly, credibility is about how one interprets what is being studied, and that these interpretations are valid for the reality being studied. The researcher must avoid own personal opinions impacting the units and variables studied. Lastly, having transfer value means that the study's outcome does not only apply to the sample of units studied, but also to similar entities outside of the selection. For this project, the sample consists of a handful selected deep-sea shipowning companies, but still aims to apply to the world's deep-sea fleet. (Larsen, 2017, Tjora, 2021).

Reliability refers to whether the study can be considered trustworthy. I.e. how accurate the empirical findings presented are, which is dependent on how well the data material it is based on reflects actual circumstances. Like validity, this involves that the data material should not be influenced by the researcher's subjective judgment or become a result of random circumstances. Additionally, the research process must be done systematically and in line with scientific requirements to be executed correctly. For others to be able to evaluate the reliability, transparency in demonstrating how one utilized the research process, such as the purpose of this chapter, and why specific choices were made, is important. (Larsen, 2017, Tjora, 2021).

4.1.1 Choosing the right research method

Research projects require an overall predetermined scientific method. The function of a research method is to clarify the process of collecting, processing, analyzing and interpreting data, in order to correctly generate new knowledge within a field of study. Choosing the right approach is critical for the quality of the study, as the chosen method will significantly impact the research process and the resulting outcomes.

One distinguishes between two primary methodological approaches, quantitative and qualitative. The main difference between them is that quantitative data produces measurable results that can be given value, whilst qualitative data describes qualities and characteristics that cannot be expressed with value. I.e. quantitative data is all about "how much" or "how many", whilst qualitative data is about "what", "why" and "how" something is. There are pros and cons of both methods, but the chosen method should reflect the purpose of the project and what data is needed to collect. (Larsen, 2017).

Quantitative research is often conducted through surveys with pre-determined questions and answers. The advantage of this is that you can reach out to a large crowd and be able to generalize the findings. The con is that you will not be able to really explore the reasoning behind the opinions of the contestants. Qualitative research solves this problem as you will instead be able to get a deep understanding of an informant's personal thoughts and experiences about a subject. The data is usually collected through comprehensive interviews, but due to this process being very time-consuming, one can only have a handful of participants and the results can therefore rarely be generalized. One can utilize both methods' true potential and eliminate each other's weaknesses through "Mixed Methods Research", but as all projects have limited resources, especially considering the time aspect, choosing the most suitable method is often necessary. (Larsen 2017, Busch 2021).

The researcher determined that a qualitative study on the topic of drivers that encourage EET retrofit investments was the right choice. As a result of the literature review, the reasoning for this is that when comparing the previous quantitative research on influencing factors for EE investments in general and across industries, the three main groups (compliance, economy, and clients) were already proven to be general for this field of study. The sub-categories within these were also identified for general EE in shipping and specifically for operational measures. Data collected through a quantitative survey on EET retrofit drivers would therefore most likely not differ much from the previous findings. Studying these factors in-depth through qualitative research would allow the researcher to not only find out what the specific drivers are, but also why they are drivers and how they impact the shipowners. Tjora (2021) mentioned that the fundament of qualitative research is that one is looking for "... the world seen from the informant's perspective". As stated in the introduction, this study aims to provide shipowners with a factual basis of what is possible to achieve from investing in EET retrofits. We must uncover how and why exactly EET retrofitting can be beneficial for them. The findings must reflect the actual reality of shipowners who have already been convinced of investing, through collecting data about their personal thoughts and experiences with EET retrofitting. This would not be possible through a quantitative study that only provides general unreasoned findings.

4.2 Phase 1: Formulation of problem statement

A problem statement in a research project serves the main purpose of identifying and explaining the issue that needs to be studied. I.e. it identifies the gap between the current issue and potential solutions to it. A research question is then formulated to provide correct guidance for the process of finding the solutions to the issue. As the main goal is to answer the research question, it must work as a logical thread through the entirety of the project. This involves collecting the theoretical framework and choosing research methods after what is most suitable for trying to answer the research question. (Busch, 2021).

There are general characteristics that define a good research question. First and foremost, it should be an original idea that sparks curiosity and is meaningful for both the researcher and the academic community. It should have a strong theoretical and practical foundation to enable collection of relevant literature and own empirical data. It should additionally be clearly formulated and narrowed down to be solvable with the researcher's available resources. (Busch, 2021).

The first step of formulating a problem statement is to clarify the project's overall topic. The researcher established early contact, approx. 9 months before enrollment, with the internship host. The topic of EET was early proposed by the host due to it being a main area of their business. The host further specified that they had a need to expand their commercial knowledge within the field of the EEXI and the CII, targeting decision-makers in the shipping industry. During literature review on the EEXI and the CII, the research gap of limited EET retrofitting was identified. Therefore, in addition to compliance, it was proposed to also study economy and client-related drivers. Attending the EE conferences Nor-Shipping and Schiffbautechnische Gesellschaft, listening to panel discussions and presenting the proposed research gap to decision-makers, the researcher quickly noticed a high interest from the community.

The next step was to define and specify a strong research question. There are multiple ways to approach the problem depending on what one wants to find out. A simple example may be which decision-maker's perspective to investigate the problem from; the charterer, the shipowner, regulatory authorities, suppliers etc. As the researcher was enrolled at an EET supplier, it was a natural choice wanting to uncover findings that could enhance suppliers' knowledge of their market. The purpose of this is to improve the exchange of factual up-to-date information from suppliers to customers (shipowners). Collecting the data from customers of EET suppliers also made sense as they have done their own research on why they decided to make investments in the first instance.

4.3 Phase 2: Selection of units and variables

Phase 2 of research projects involves selecting the units and variables to be studied. Units refer to those the study is about (those one is trying to say something about), and variables are the specific characteristics or attributes of the units that one is interested in studying or describing.

For this qualitative study, the units are the individuals to be interviewed, whilst the variables are the general interview questions that were asked. A main difference in this phase compared to a quantitative study, is that a quantitative study aims to generalize its findings by having as many units as practically possible. In qualitative studies, the researcher can instead choose informants based on those who are thought best suited to answer the research question. This is called judgmental non-probability sampling and is advantageous when seeking in-depth knowledge about a specific subject. This is paramount when selecting the variables, as in contrast to quantitative research, the variables cannot be “measured”. The aim is to collect and compare data in order to achieve an in-depth comprehension of the subject. (Larsen, 2017).

Selecting units was not a hard task for this project. The internship host has strong connections to numerous shipowners, and helped the researcher establish contact with the right informants. It was concluded that selecting informants with both a strong technical and commercial background was necessary in order to ensure the most reflective answers to the interview questions. The informants also have expertise in the different areas that was needed to answer the research question and they were therefore strategically selected with the purpose of ensuring some variety. The sample of the units was first set to be six informants, but after discussion with the researcher's professor about the relatively large scope of the project, the aim was increased to ten informants. This size was considered sufficient for enough data collection to answer the research question, while still possible within the project's short time frame of four months. As seen in Table 3, the final sample consisted of ten decision-makers from different deep-sea shipowning companies that frequently retrofit with EETs, covering all freight market segments of medium to large sized fleets. Five informants are referred to as O6 to O10 to uphold their anonymity, as consent of exposure was not granted.

Table 3: Overview of informants

Informant	Position	Company	Market segment	C/Ps
Mr. Petter Lalic	Chief Technical Officer	2020 Bulkers	Dry-bulkers	TCs
Mr. Marius Aasen	Head of Decarbonization	Frontline Management	All segments	Mix of TCs and VCs
Mr. Jan A. Berntzen	Senior Vice President – Technical and Projects	Kristian Gerhard Jebsen Skipsrederi	Product-tankers (LR2) and dry-bulkers	50/50 TCs and VCs
Mr. Helge Moeller	Newbuilding Manager	Reederei Nord	Containers, dry- and wet bulkers, tankers	Mainly TCs, a few VCs
Mr. Jan A. Opedal	Manager Projects	Odfjell SE	Chemical tankers	50/50 TCs and VCs
O6	Managing Director	-	Containers	TCs
O7	Fleet Director	-	Gas carriers	TCs
O8	Technical Manager	-	Containers	TCs
O9	Fleet Manager	-	Feeders (containers)	TCs
O10	Manager Projects	-	RoRo (cars)	TCs

The project's variables were selected based on the research question and the existing literature reviewed. The research question made it possible to make open-ended assumptions during the literature review on what may apply to EET retrofit investments. It also made the researcher aware of what was also completely missing from existing literature to contribute to fill the research gap. The variables to be studied were then expressed as questions through an interview guide and covered all the necessary to thoroughly answer the research question (see I. Interview guide)

4.4 Phase 3: Data collection

The primary data in qualitative research is mostly collected through interviews and observations of environments. The data is usually recorded with audio or video, or directly transcribed as text. There are several ways to collect the primary data based on what is most suitable for the project and they all have their pros and cons. Briefly explained, the methods include varieties of how structured the data collection should be and the degree of involvement from the researcher. The secondary data is collected through others' primary data, such as this project's literature review on previous studies. One usually first collects secondary data to gain an understanding of what current research has already been conducted on the same topic and what is missing or needs more investigation (research gap). The primary data is then collected to fill the gap. (Larsen, 2017).

For this project, semi-structured interviews were conducted for collecting the primary data. This involved interviewing with a flexible interview guide with some pre-determined questions. The interview guide was divided into five parts; general, compliance, economy, clients, and closing. "General" and "closing" ensured a smooth start and finish, allowing exceptionally for very open-ended reflections, whilst the three main groups were a direct result of the secondary data (literature review) collected. However, although the questions in the three main groups were made with basis in the literature review, they are still formulated relatively open to allow for unique reflections. This is to ensure the informant's answers reflect what applies exceptionally for them and not feel pressured to go in a specific direction. Depending on what they answered would determine the next question of the guide and sometimes relevant follow-up questions not in the guide. This method was utilized to ensure that the researcher's predicted needs to answer the research question were taken care of, but also to encourage the informants to address own topics which they might think are relevant to the project. Pilot-tests were conducted on three non-participating colleagues of the internship host to review the guide's quality. The researcher concluded that conducting semi-structured interviews was the most suitable approach as the main influencing groups of EE investments (compliance, economy, and clients) were already identified. Therefore, some assumptions and ideas about what were needed to be studied was made, but it was still unknown what to exactly look for. An unstructured interview without a guide, with just a basis in the general topic of EET retrofit investments, would probably result in too vague answers. Additionally, in contrast, a very structured interview would most likely disrupt the flow of the conversations, affect how reflective the informants could answer, and make it difficult for them to address own important topics. (Larsen, 2017).

Contact with the informants was mainly established through phone calls, but also for some, face-to-face during the EE conference, Schiffbautechnische Gesellschaft in September. Furthermore, the interview guide was forwarded in advance to the participants by e-mail correspondence. For ethical purposes, the participants were also required to sign a consent form prepared out from standards set by Sikt – Norwegian Agency for Shared Services in Education and Research, after the researcher received an official approval to carry out the project (see II. Consent form). The consent form contained information about the aim of the project, what a participation entails for the informant, and ethical considerations in terms of rights and personal privacy. This is highly important due to transparency of how the informants' personal data will be collected, stored, and used.

The interviews were carried out face-to-face in the offices of the shipowners and online through Microsoft Teams video-calls. Most of the interviews were conducted over Teams due to practicality and large geographic distances. For informants available near the researcher, the preferred interview-method was face-to-face as it is considered easier to establish trust and openness. However, no challenges or suspicion of video-calls affecting the informants' answers negatively were experienced. Sixty minutes was allocated to each interview, and the average time turned out to be around fifty minutes. The interviews were recorded electronically with audio. The advantage of this is that it provides a sense of security for the interviewer to focus on the interview and flow of conversation, as it allows for transcription to be postponed. (Tjora, 2021).

The researcher acknowledges a challenging process of planning the interviews with the informants. The set duration of conducting all the interviews was during a 14-day period. Several reschedules and cancellations were experienced. Identified main reasons were participants' unexpected increased workloads and holidays affecting their availability. The initial set period turned out to be doubled, and some informants needed to be replaced by new ones. Despite the researcher's increased workload and time pressure, the data collection phase was for the most part successful and straightforward.

4.5 Phase 4: Data processing

Data processing involves preparing the collected data for the next phase, data analysis. In qualitative studies, the researcher aims to simplify and reduce the amount of data to only what is needed for the project. This involves avoiding redundant information collected through small talk or other irrelevant topics the informant might have elaborated on. Right data processing is highly important to ensure that the findings have a solid empirical foundation for further analysis and interpretation. (Larsen, 2017).

As mentioned, audio recordings were conducted during the primary data collection of this project. Processing the data was done through transcribing the audio to text. It was expected that this would be significantly time-consuming, and the assumption turned out to be true as each interview transcription took around two hours to finish. A common challenge with data processing is transcribing from informants' different languages and dialects. Some words and expressions cannot always be translated. However, the language barrier was not relevant for this study as the interviews were carried out on English. Another challenge is that visual observations and body language will often be lost during transcription. The researcher does not consider this affecting this project's data processing significantly, due to the study is mostly trying to understand company behavior, not just the individual interviewed. Additionally, the interviews were characterized by mutual positivity and the informants' own wish to contribute to the project to the greatest extent. (Tjora, 2021).

4.6 Phase 5: Data analysis

Before attempting to interpret the processed data, it is first important to further compress it, systemize it and organize it. Data analysis is about empirically coding and categorizing the processed data, in order to make it ready to search for meaningful patterns, differences and unique reflections. What is identified is then next assessed in relation to existing research and theory (the literature review), and transferable knowledge is established in the form of the final report. This approach is referred to as content analysis and forms the foundation for this project. (Larsen, 2017).

Coding involves highlighting text extracts of relevance to the research question, from the transcribed data material. This can e.g., be important or reoccurring topics and characteristics identified. Similar or related text extracts are then categorized under different "codes", consisting of simple words or symbols to make them easily recognizable. (Larsen, 2017). For this project's data analysis (see Table 4), all relevant findings were first categorized after the structure of the interview guide – which again reflects the literature review. This involves the three main groups: compliance, economy, and clients. The groups did then receive different codes reflecting sub-categories of relevant topics and findings identified in the interviews. In practice, for each code/ sub-category, the researcher identified all statements and opinions from the informants that were considered relevant, and cut and pasted them under the heading of the code. Coding the data material in this way gave a great overview for comparing what the informants had said about the same topics and questions. The advantage of this was a reduced workload when looking for contexts and connections between the different interviews.

4.7 Phase 6: Data interpretation

Interpreting the analyzed data is the last step prior to finalizing the report. While analysis is about discovering findings, interpretation is about making sense of them. I.e. how the patterns, differences and unique reflections should be understood. Simultaneously, the interpretation should also be influenced by the secondary data. Thus, the process is conducted both by the impressions the researcher has gained from the primary data collected through the interviews, and by the theoretical perspectives collected from the literature review. Interpretation can therefore be said to be the process of placing the phenomena being studied in a larger context and introducing something new to the field of study. (Larsen, 2017).

Before starting the interpretation, due to large amounts of data presented in both the literature review and the data analysis, summaries of key findings in both chapters were needed to keep an overview and not lose track. This simplified this phase of the process for the researcher, and also benefits the reader as the most important and valuable information to remember is repeated.

Data interpretation in this project involved discussing the findings from the analysis of the primary data and comparing it with the secondary data collected. The researcher compared what the different informants had said, what the same informants had said about similar things at different parts of the interview, and what had been said about different things. The findings of the interpreted interview data were then compared with the existing research and theory collected through the literature review. The comparison of primary data with secondary data revealed similarities, differences, and attempted to confirm or disprove assumptions, which ultimately was used to contributing to filling the research gap and answering the research question.

5.0 Results

This chapter is dedicated to analyzing the project's primary data and presenting its results. As shown in section 5.1 Coding of the primary data, the interviews' most important findings have been uncovered through empirical coding. Reflecting the structure of the literature review and interview guide, these findings are further elaborated on divided into sections 5.2 Findings regarding compliance, 5.3 Findings regarding economy, and 5.4 Findings regarding clients (see Table 4). The key findings are summarized in section 5.5 Summary of key findings.

Consent of citation has been granted by five informants. These are Mr. Petter Lalic, Chief Technical Officer at 2020 Bulkers, Mr. Marius Aasen, Head of Decarbonization at Frontline Management, Mr. Jan Anders Berntzen, Senior Vice President at Kristian Gerhard Jebsen Skipsrederi (KGJS), Mr. Helge Moeller, Newbuilding Manager at Reederei Nord, and Mr. Jan Arne Opedal, Manager Projects at Odfjell SE. Remaining informants are referred to as O6 to O10 to uphold their anonymity (see Table 3).

5.1 Coding of the primary data

This section show the empirical coding of the most important findings uncovered from the interviews.

Table 4: The most important findings generated by empirical coding

5.2 Compliance	5.3 Economy	5.4 Clients
5.2.1 EEXI **A1** Compliance is driven by EET retrofits	**B1** The resource consumption of EET retrofitting is overexaggerated	**C1** EET retrofits have highly positive impact on shipowners' market competitiveness
A2 EET retrofits are necessary to operate safely and maintain sufficient sailing speed	**B2** Vessel-age is important when considering EET retrofit investments	**C2** EET retrofits allow shipowners to charge higher charter rates
A3 Early retirement should always be avoided	**B3** Vessel sizes and activity levels are not prioritized factors when considering EET retrofit investments	**C3** Enhanced CSR/ "green" appearance from investing in EET retrofits is a powerful outcome
5.2.2 CII **A4** EET retrofits are necessary for compliance and improvement of ratings	**B4** Future-fuels prices will drastically increase demand for EET retrofits after 2030	**C4** Principal-agent problems from charterers' EE requirements are very common
A5 CII-ratings will have significant impact on charter parties		
5.2.3 Future outlook: Carbon Emissions Trading **A6** EET retrofits' impact on CO_2 allowances trading is highly dependent on charter parties and freight routes		

5.2 Findings regarding compliance

This section elaborates on the findings related to **A1** to **A6**, the codes regarding compliance with EE regulations.

5.2.1 Energy Efficiency Existing Ship Index

In this section, the EEXI related codes **A1** to **A3** are elaborated.

A1 Compliance is driven by EET retrofits

All shipowners have either complied with the EEXI already or are in the final stages of doing so. It was discovered that complying was a relatively easy task for the majority of the shipowners and not nearly as dramatic as it first seemed when it was introduced by the IMO. When asked about the reasoning behind this, it was a unanimous agreement between most shipowners that EET retrofitting they had done previous years, had provided their vessels with sufficient technical EE to comply. Their decisions for previously investing in EET retrofits were made prior to the announcement of the EEXI, and instead driven by possibilities for OPEX-reductions and marketing of cost-efficient shipping operations (economy). The remaining shipowners needed to invest in EET retrofits, and everyone could agree that EET retrofitting is a necessity in order to comply with the EEXI. For Mr. Opedal, Manager Projects at Odfjell SE, Mr. Aasen, Head of Decarbonization at Frontline Management, O6, and O9, doing EPLs in addition to EET retrofitting were necessary on some older and worse performing vessels. Early retirements were neither done by any of the shipowners.

A2 EET retrofits are necessary to operate safely and maintain sufficient sailing speed

As mentioned, for four shipowners, doing EPLs were necessary on some of their older vessels, as these generally perform worse and emit significantly more than newer ones. When comparing the specific vessels, the researcher identified that they had an average age of around 20 years, which is only a few years away from normal retirement age. The shipowners stated that the EPLs made additional EET retrofit investments even more important. According to Mr. Opedal, EPLs decreases their vessels' motor power levels so much that they are unsafe to operate. O10 also mentioned this problem and referred to the MEPC.1-CIRC.850-Rev.2, stating that a vessel must not reduce its engine power below the minimum propulsion power guidelines set by the IMO. Increasing EE by simultaneously having equipped EETs will apparently compensate for the decreased motor power level, allowing the vessel to safely operate and not violate the guidelines.

Decreased motor power level from an EPL naturally also reduces sailing speed. O9, Mr. Aasen, and Mr. Berntzen, Senior Vice President at KGJS, said that EET retrofits have made a difference in how fast their vessels with EPL can sail and still comply with the EEXI. Mr. Aasen claimed that from considering just one of their commonly implemented EET retrofits, the Becker Mewis Duct, a theoretical 6-7% power enhancement is achieved, which provides significant increases sailing speed. The shipowners concluded that maintaining sufficient sailing speeds is important to keep up with charterers' requirements. Mr. Aasen mentioned that this is due to charterers' supply and demand capacity – the faster one sails, the more one can transport.

A3 Early retirement should always be avoided

Retiring vessels early to comply with the EEXI was not done by any shipowners. Everyone could agree that one should always aim to keep the vessels alive for as long as maintenance wise feasible. O7 mentioned that vessels start to profit after operating for 12-15 years, and that retiring vessels at this age would therefore not make sense. Additionally, the high investment costs and loss of money during off-hire, by expanding existing vessels or ordering new ones to compensate, would not have been recovered. According to Mr. Moeller, Newbuilding Manager at Reederei Nord, if the ultimatum of an early retirement was to be considered necessary, which is very rare, the vessel would be attempted sold instead.

5.2.2 Carbon Intensity Indicator

In this section, the CII-related codes **A4** and **A5** are elaborated.

A4 EET retrofits are necessary for compliance and improvement

When asked about their calculated CII ratings, the shipowners had varying answers. Most shipowners have vessels in the C-range, which is the current minimum required rating. Half of the shipowners also have some vessels in the unacceptable D-range. Mr. Aasen and Mr. Berntzen said they have only calculated A- and B-ratings, but this is also justified as they have mostly new high performing vessels and a fifty-fifty mix of VCs and TCs, instead of only TCs like most other shipowners.

Regarding charter parties (C/Ps), the shipowners were asked about their opinion on what EE measures are needed for CII-compliance and maintaining good ratings, and the answers were mutual; Theoretically, operational measures can and should have the most influence, but realistically, EET retrofits are often just as important. The CII is considered more favorable towards vessels operating mostly under VCs, as the shipowner has the operational control over the vessel and therefore an own encouragement to improve operational EE by e.g. sailing slower. In contrast, in TCs, where the charterer has the operational control, and which also covers the majority of deep-sea C/Ps, sailing slower means less earnings. Especially for O8, their vessels are chartered out on very long-term TCs, where fixed 10+ year C/Ps were signed long before the CII was even announced. These C/Ps do not contain any CII-related clauses that can e.g., force the charterer to sail slower (operational measure). To achieve good or at least sufficient ratings on TC-vessels, the shipowners said it is necessary to improve EE with EET retrofits to compensate for the charterers negative impact.

According to Mr. Opedal, EPLs have a negative impact on CII-ratings as well; "Increasing technical EE is a key component for us in order to comply with the CII. We have a system monitoring our vessels from day to day and have noticed that vessels we have installed EPLs on will have a hard time complying. We are therefore in the process of making a plan for which EET retrofits to invest in to solve these problems – which allows us to both comply and still sail at required speeds".

A5 CII-ratings will have significant impact on charter parties

Despite no announced consequences of insufficient CII-ratings from the IMO yet, the regulation will still have significant impact on C/Ps until then. Several shipowners said that charterers specifically avoid vessels with bad RightShip GHG-ratings and forecast that this will be the exact same case for CII-ratings as well. RightShip GHG-rating is briefly explained a tool that calculates vessels' GHG emissions considering EE – very similar to CII. As RightShip is a privately owned consulting company and not affiliated with any authorities, there are no legal requirements to have a good rating, but charterers worldwide, use it as a main tool to locate green and highly energy efficient vessels. According to the shipowners interviewed, the CII can be viewed as a required continuation of the RightShip GHG-rating due to its similar calculation and rating system. (RightShip, n.d).

Mr. Aasen mentioned that large shipping companies (charterers), especially in Australia and Brazil, refuse to charter vessels with a RightShip GHG-rating below C. Supportively, O10 highlights that certain ports around the world refuse to accept vessels with a bad RightShip GHG-rating, which can therefore make some voyages impossible to complete. O10 further states that the IMO encourages port authorities and charterers to provide incentives to vessels rated as A or B, and surely believes that this will be experienced with CII-ratings as well. As the RightShip GHG-rating has such significant influence today on how selective charterers are choosing vessels, it is natural to believe this will also apply to the CII-ratings when required in 2024. According to O9, they have since the CII was announced earlier this year, already experienced that bad calculated CII-ratings are already hinders to getting certain C/Ps and have been told by the charterers that they have to retrofit with EETs to stay competitive. O6 have a somewhat conflicting opinion. O6 believes that we are currently entering a period of very high demand for shipping in general and that few vessels will be available at any time for chartering. Therefore, charterers may be forced to operate badly rated vessels anyway. However, O6 believes that, for the shipowners, less favorable C/P conditions, clauses and charter rates will still be a consequence of bad CII-ratings on these particular vessels.

All shipowners could conclude that when the IMO finally announces the CII-consequences, it will naturally put even more pressure on the charterers to require high EE and good ratings from the shipowners.

5.2.3 Future outlook: Carbon Emissions Trading

In this section, the carbon emissions trading related code **A6** is elaborated.

A6 EET retrofits' impact on CO_2 allowances trading is dependent on charter parties and freight routes

The shipowners were somewhat reluctant to answer questions regarding the EU ETS. As the system is starting in 2024, they do not have any experience with it yet and are uncertain how significantly it will impact them. Two reoccurring findings were still identified; C/Ps and freight routes.

O7, O10 and Mr. Moeller, mentioned that EET retrofits will not help them directly in any way solely regarding the EU ETS, as they only have TCs. The operator burning the fuel, which in these cases is their charterers, will be responsible for trading the CO_2 allowances. For Mr. Berntzen and Mr. Opedal, who are operating with VCs, the system directly involves their operations. Both said that increased EE from their EET retrofits will provide sufficient energy savings having to purchase less amounts of CO_2 allowances. When asked if these energy savings will be significant enough to also involve potential to sell CO_2 allowances, both answered that they do not have an active strategy for this, as it likely will not be a main business area for them. Mr. Opedal further explained that only 25% of their fuel is consumed within the EU, so it will not have a as significant impact as it theoretically sounds like. It depends on the vessels' future freight routes, and how often and how long they sail in the EU, which is hard to predict – the shipowners must wait and see. The thought of a global IMO regulated system instead of the EU ETS was supported, as it would reward highly energy efficient VC-owners' and unlock their full carbon emissions trading potential. For TC-owners, O10 highlights that this would drastically drive charterers to put more pressure on shipowners to invest in EET retrofits, to stay competitive.

5.3 Findings regarding economy

This section elaborates on the findings related to **B1** to **B4**, the codes regarding economy – which is about minimizing OPEX and maximizing revenue by reducing fuel-costs.

B1 The resource consumption of EET retrofitting is overexaggerated

Regarding the investment costs of EET retrofitting, most shipowners mention the dry-docking phase as the most resource consuming. As the shipowners are not paid during off-hire, they aim to make this process as efficient as possible. Mr. Lalic, Chief Technical Officer at 2020 Bulkers, Mr. Moeller, and O7, said that this process is always well planned and a long time in advance. The shipowners said they only do EET retrofitting every 5 years when the vessels are required dry-docking and will never take them out of water if it is not necessary by class. During the 5-year-interval, the shipowners have had sufficient time to establish contact with all suppliers, shipyards, and others involved, to ensure the process goes smoothly. O7 refers to the dry-docking phase as just a "Formula 1 pitstop". Operational and maintenance expenses are very low for most EETs and should not be considered as a negative, according to the shipowners. Mr. Lalic highlights that unexpected dry-dockings due to maintenance have, but rarely, occurred. However, these are usually completed rather fast and do not matter as the benefits of EETs largely outweigh these minor inconveniences.

The second significant cost aspect identified is the purchase prices of the EETs. Even though the EETs generate fuel-cost savings over time, their immediate purchase prices are not cheap. Mr. Berntzen said that, on TCs, if the shipowner provides higher EE than normal as a result of EETs, the shipowner will receive compensation on his charter rates. Instead of solely benefiting the charterer, the fuel-cost savings will be shared through a premium of a usual 60/40 split (shipowner/ charterer). According to Mr. Aasen, O8 and O9, cost-sharing purchase prices of investments are also experienced. Mr. Aasen further said that the cost is normally split 50/50, but on very long TCs, the charterers usually even do the EET retrofitting all by themselves. O9 additionally mentioned that another advantage of the charterers' involvement for them in this context, especially the larger Danish and French ones, is that they have tight connections with different favored EET suppliers. If a supplier normally is on the expensive side, the charterer can instead approach them and they might get competitive, offering discounted prices.

B2 Vessel-age is important when considering EET retrofit investments

The vast majority of the shipowners interviewed have or are planning to retrofit their entire fleets with EETs. They have the common opinion that all existing vessels require EET retrofitting, but they are still very selective about when this should take place. The main rule in this context, is that vessels should only be retrofitted if they are young enough to be able to recover and profit from the investments.

Vessel-age 5 was identified as the most preferable age, as this is the first required dry-docking since delivery of the vessel. The earlier one retrofit, the longer is the potential for pay-back and ROI, said Mr. Berntzen. Vessel-age 10 is considered the maximum age for EET retrofitting to still recover the investments and receive ROI. Experienced different pay-back periods of EET retrofit investment have varied from 0.5 years to 4 years, according to all shipowners. Mr. Aasen states that vessels are normally sold around the 15-year-mark and the EET retrofits should therefore have been in operation for a few years to be considered economically profitable investments. In addition, O10 mentioned that it is important to keep in mind that as EETs allow for faster sailing speeds, there is an increase in asset value, which means a lot more than just OPEX-reductions from fuel-savings. Mr. Berntzen supported this statement by saying that one is able to more easily and more expensively sell a highly EET retrofitted vessel. The highly energy efficient vessels are the most popular in the sale- and purchase market by far. O8 and O9 have been required to retrofit some 20-year-old vessels due to other driving factors, but the message remains the same, one must be sure that one is going to keep the vessels until the investments are recovered. In these particular cases, it naturally was until scrapping.

B3 Vessel sizes and activity levels are not prioritized factors when considering EET retrofit investments

The shipowners mention hypothetical theories that the largest sized vessels or those with the highest activity levels can be more beneficial to invest in, due to more fuel consumption. O6 also presented a conflicting thought that it would be more beneficial to invest in smaller vessels, as these would likely have a harder time complying with the CII due to more protocols, shorter voyages, and rules for deadweight. One single shipowner out of the sample, O9, is very selective considering their EET retrofit investments in general. O9 has currently/ planned to only retrofit 20% of their fleet as opposed to the other shipowners. O9 creates an operational profile of each vessel, comparing percentage of sailing time at sea, anchorage, waiting time at ports, and speed and draught, to find the most suitable vessels to prioritize EET retrofit investments in.

But, as previously mentioned, almost all the shipowners (except O9) share the same opinion that their entire fleet will benefit from being retrofitted with EETs regardless of these factors. Therefore, theoretically favorable vessel sizes and activity levels are not prioritized criteria or weighed anywhere near the same as the vessel-age requirement when considering EET retrofit investments.

B4 Future fuels' prices will drastically increase demand for EET retrofits after 2030

The shipowners were asked how they foresee the demand for EET retrofits post-2030 and the reasons behind their expectations. Everyone expressed that they believe the industry will experience a drastic increase in demand, mainly due to very high predicted prices of future fuels. During Schiffbautechnische Gesellschaft, the EE conference the researcher attended during the internship, the majority of a sample of one-hundred international maritime experts voted that they predict a 4x cost-increase for future fuels compared to today's traditional heavy fuel oil prices. Mr. Opedal even suggested upwards of a 6x cost-increase considering how much energy must be stored. Mr. Opedal further states: "Our analysis indicate that it will to the highest degree be important to invest as much as possible in increasing EE. The upcoming energy prices will give highly EET retrofitted vessels an enormous competitive advantage as charterers will solely search for this".

The researcher further asked if the shipowners could provide an estimate of the total fuel-savings they typically achieve per vessel, only considering their EET retrofits. It was then uncovered that most shipowners have on average retrofitted their vessels with three different EETs, which achieve fuel-savings between 20-25% compared to before retrofitting. O8 and O9 have achieved highly energy efficient vessels, averaging around 30% in fuel-savings solely from EET retrofitting. According to Mr. Berntzen, only considering the Becker Mewis Duct retrofit, which on their particular product-tankers and dry-bulkers provide around 6% in fuel-savings, an average of over USD 500.000 in fuel-cost savings is achieved annually per vessel. "As we operate with VCs, economy is the biggest driver for us. We want to reduce expenses and achieve a larger profit margin. Priority one in the future is to make vessels as energy efficient as possible", Mr. Berntzen concludes.

5.4 Findings regarding clients

This section elaborates on the findings related to **C1** to **C4**, the codes regarding charterers' requirements and expectations.

C1 EET retrofits have highly positive impact on shipowners' market competitiveness

According to O6, it will always make sense to modify vessels to best fit the market. Shipowners should strive to do everything to make their vessels as attractive as possible, especially if one wants to close a new charterer. O6 defines the word "attractive" in this context as low fuel consumption and environmental impact. Mr. Lalic said that highly energy efficient vessels are something charterers are explicitly searching for from shipowners today and work as a main competitive driver. Mr. Moeller highlights that it is easier to get C/Ps when offering highly EET equipped vessels, as most charterers have a criterion for this. He further states that the focus of EET retrofit investments should not be on the ROI, but the marketing of the vessel. Offering a fully upgraded vessel helps significantly build relationships with the charterers, which will be beneficial for both parts in the long run. For O9, charterers give great feedback and show appreciation of the shipowner being so open to retrofit with EETs. A direct effect of this is often extensions of their C/Ps, as the charterer favors the shipowner and wants to continue the collaboration. Mr. Opedal mentioned that for VCs, as EETs allow them to reduce fuel-costs, their competitiveness also increases by being able to operate cheaper and have a larger margin compared to less energy efficient competitors.

C2 EET retrofits allow shipowners to charge higher charter rates

Reflecting the increased competitiveness in regard to closing charterers, most shipowners said that they can also use their EET retrofits as an argument to negotiate higher charter rates. According to Mr. Aasen, a good RightShip GHG-rating is amongst other things dependent on having installed EETs. He continued to say that the better rating a vessel has, the higher charter rate can usually be charged. O8 argues that a low energy efficient vessel often has less favorable C/P conditions, involving charter rates in the lower range, and it therefore makes sense to retrofit with EETs to change this. O6 supports this and said that if the market is bad and the rates are low, shipowners should retrofit with EETs to be able to raise their rates. Mr. Berntzen said that even though EET retrofit arguments for higher charter rates mainly apply to TCs, KGJS will regardless achieve increased net profit on their VCs due to the fuel-cost savings. EET retrofits are therefore beneficial in this context either way.

C3 Enhanced CSR/ "green" appearance from investing in EET retrofits is a powerful outcome

Five out of the ten shipowners emphasized how EET retrofit investments enhances their CSR. According to Mr. Aasen, Mr. Berntzen, and Mr. Opedal, building up a "green" profile/ appearance, by showing stakeholders, especially charterers, that they invest in environmentally friendly solutions, works as a powerful marketing tool. In practice, the shipowners dedicate own chapters in their annual reports, describing their specific EET retrofit investments and the positive outcomes these create for the company and environment. The report is reviewed by charterers, banks, financial institutions, investors, and other important stakeholders, who all favor sustainable companies. Mr. Aasen also highlights the importance of continuously improving CSR by arguing that maybe the biggest driver for most companies today, especially the major energy companies such as Equinor and BP, is their goal to become sustainable. Therefore, they strive to achieve sustainability in the whole supply chain, whereas shipping operations play a significant role.

C4 Principal-agent problems from charterers' EE requirements are very common

The majority of the shipowners experience principal-agent problems from charterers' EE requirements. These shipowners have the opinion that it is theoretically more economically beneficial to prioritize EET retrofit investments in VCs, and for TCs, prioritize operational measures. But at the same time, this is unrealistic due to the charterers' requirements and reluctance. The most common requirement the interviewed shipowners experience is pledged fuel consumption, and their level of compliance is dependent on how energy efficient their vessels are. O8 and O10 further state that charterers do not always care about how shipowners obtain the pledged fuel consumption, but having EETs are regardless always necessary to successfully achieve it.

Some of the shipowners also experience requirements to having implemented specific EETs in order to be awarded C/Ps. Mr. Berntzen said that this is most often the case with very long TCs. Mr. Opedal has not experienced charterers' specific EET requirements, mainly due to operating mostly with VCs, but still believes that they will become more and more common in the upcoming years as IMO regulations get stricter. Additionally, to the physically installed EETs, O6 highlights that charterers have sometimes implemented clauses that the shipowner must e.g. hull clean every year, or that every time the vessel is dry-docked, silicon painting must be done. As mentioned before, some kind of cost-sharing, increased charter rate, or C/P extension are sometimes done to compensate the shipowner – as the EETs in TCs solely economically favors the charterer.

According to O6 and O9, unfortunately for the shipowners, not all charterers are equally open to financially contribute to their required EET retrofit investments. O6 said that it is a "power game" between the shipowner and the charterers, as some charterers say it is the shipowner's responsibility to comply with their preferences regardless, if they want them as clients. O9 have experienced that for certain C/Ps, although they have retrofitted significantly to achieve high EE, the charterer's requirements are still not fulfilled as they demand specific EETs or suppliers. The shipowner said they in these situations either have to lose the client or evaluate if their requirements can be achiveved without creating huge disadvantages.

5.5 Summary of key findings

This section is dedicated to a very brief and concrete summary of the most important findings retrieved from the primary data.

5.5.1 Key findings of "Compliance"

For the EEXI, the key findings suggest that EET retrofitting is the main solution for compliance. If additional EPLs are necessary, EETs are still important to avoid unsafe motor power levels, guideline violations, and to maintain sufficient sailing speeds. Early retirement should always be avoided, because it is a severe loss of money as new CAPEX-related investments will not be recovered.

For the CII, the key findings suggest that EET retrofitting is often necessary for compliance and improvement of ratings. In TCs, shipowners cannot rely on operational EE, as most C/Ps do not yet contain clauses that can force operational measures upon the charterer. Retrofitting with EETs is necessary to compensate for the negative effect caused by the charterer being reluctant to e.g. sail slower. Another key finding is that charterers will actively choose vessels based on good CII-ratings, even though there are no IMO consequences announced yet. This is due to previous experience with RightShip GHG-ratings.

For the EU ETS, a shipowner's involvement is dependent on their C/Ps and their freight routes. Regarding C/Ps, the system only applies to VC-owners, as only the operator will be responsible for CO_2 allowance trading. Per today, the VC-owners interviewed consume 25% of their fuel in the EU. Increased EE from EET retrofits will provide sufficient energy savings to impact their CO_2 allowances trading, but how significant is uncertain yet. The discussion of a global system was supported, as it would unlock the operators' full carbon emissions trading potential.

5.5.2 Key findings of "Economy"

The resource consumption of EET retrofitting is overexaggerated. Shipowners aim to make the dry-docking phase as efficient as possible by planning everything a long time in advance. EET purchase prices are not cheap, but shipowners often receive financial contributions from the charterers.

Vessel-age is important when considering EET retrofit investments. The main rule is that vessels should only be retrofitted if they are young enough to recover and profit from the investments. The optimal age is 5 years (first required dry-docking), and maximum age is 10 years (second required dry-docking), unless you are planning on keeping the vessel for a very long time. Vessel sizes and activity levels are not prioritized factors when considering EET retrofit investments. Most of the shipowners share the same opinion that their entire fleets will benefit from being retrofitted with EETs regardless of these factors.

Very high predicted future fuels' prices will probably drastically increase demand for EET retrofits after 2030. The shipowners indicate a 4-6x cost increase compared to today's prices and saving OPEX on fuel-cost reduction will be a top priority. As per today, the shipowners on average save between 20-25% of their fuel purely from EET retrofitting. The shipowners believe demand will increase as the vessels still need to become even more energy efficient if the predicted future fuels' prices turn out to be true.

5.5.3 Key findings of "Clients"

EET retrofitting have a highly positive impact on shipowners' market competitiveness, as charterers are explicitly looking for energy efficient and environmentally friendly vessels. It is easier to get C/Ps when offering highly EET equipped vessels, and it also allow shipowners to charge higher charter rates. Offering fully upgraded vessels helps build relationships with the charterers and a direct effect of this is often extensions of C/Ps.

Enhanced CSR and green company appearance is a powerful outcome of EET retrofitting. Shipowners' EET retrofit investments are presented in their annual reports to show charterers and other stakeholders that they are invested in sustainability. Stakeholders favor sustainable companies, which therefore benefits the shipowner.

Principal-agent problems from charterers' EE requirements are very common. This mostly involves pledged fuel consumption, but retrofitting with EETs is regardless necessary to successfully achieve it. Some charterers do require specific EETs or suppliers, but in these situations, cost-sharing the investments or other financial contributions from the charterers are often made. Sometimes, the charterer refuses to financially help the shipowner and meeting their requirements is therefore not economically feasible. The shipowner must then consider either losing the client or evaluate if their required new investments can be made without creating huge disadvantages.

6.0 Discussion

This chapter has interpreted the findings from the data analysis (Results), and compared it to existing research and theory (literature review). In other words, discussed the research question; "***What Key Drivers Encourage Shipowners' EET Retrofit Investments?***" The comparison of primary data with secondary data revealed similarities, differences, and confirmed and disproved assumptions, which was used to fill the research gap and answer the research question. A continuation of the structure of the previous chapter is followed; 6.1 Discussion regarding compliance, 6.2 Discussion regarding economy, and 6.3 Discussion regarding clients. Ultimately, the soon to be uncovered key drivers that encourage shipowners' EET retrofit investments, was in section 6.4 used to propose practical solutions for breaking the knowledge barrier.

Preeminently, Armstrong & Banks (2015) suggested that no matter what industry, the three reoccurring groups compliance, economy, and clients will always have the main influence upon EE investment decisions. This theory is suggested to be confirmed for EET retrofit investments as well, as all identified findings from the results could be categorized accordingly to these groups with no exceptions.

6.1 Discussion regarding compliance

This section discusses how compliance with the EEXI, CII, and Carbon Emissions Trading (EU ETS) impact shipowners' EET retrofit investment decisions.

6.1.1 Discussion regarding the Energy Efficiency Existing Ship Index

The results confirm a unanimous commitment by all shipowners to EEXI compliance, as they have either already complied or are in the final stages of doing so. As proposed by Clarksons Research (2023), the shipowners emphasize the three possible solutions for achieving compliance; EET retrofitting, EPL, and early retirement. Of these, EET retrofitting as a sole solution was in most cases sufficient for compliance. Notably, the decision-making process leading to retrofitting with these EETs occurred for most shipowners independently of the EEXI as an impending regulatory change. These shipowners did not find it difficult to comply or took any extra actions towards doing so, because they had already achieved high enough technical EE due to their EET retrofit investments from previous years. The shipowners revealed that the economic aspect and marketing of cost-efficient shipping operations to charterers was the biggest drivers for these particular investments. This is conflicting with previous research by Comer *et al*. (2020). The research indicates that the disadvantage of being forced to expand existing or ordering new vessels from doing EPLs and early retirements, is why EET retrofitting is shipowners' favorized solution for compliance. However, there are two significant findings supporting why one cannot argue that the EEXI normally does not solely drive EET retrofit investments.

Firstly, the remaining shipowners that did not invest in EET retrofits prior to the EEXI announcement stated that they now needed to do so in order to comply. Also, as mentioned, the shipowners that did not make any new changes said that this was solely due to their vessels already being energy efficient enough – as a result of their previous EET retrofit investments.

Secondly, regarding the shipowners that had to do EPLs, everyone simultaneously retrofitted with EETs. For these shipowners, one can argue that doing the EPLs was technically the solution for their compliance, but their vessels would however be "useless" without at the same time retrofitting with EETs. To elaborate, the "side effects" of solely doing EPLs according to the shipowners, were too low motor power levels for safe operations, which in shipping is a top priority, and MEPC guideline violations, which one must comply with to sail. Additionally, maintaining sufficient sailing speeds to obey charterers' requirements would not be possible. Therefore, they did the EPLs for compliance purposes, but were also dependent on doing EET retrofitting in order to operate properly. In distinction to the previous research mentioned, only sailing speed was considered as a side effect of EPL. It was suggested that shipowners might be forced to expand existing or ordering new vessels to fill the supply gap lost from the reduced speed. However, this study instead suggests that compensating with EET retrofits avoids this ultimatum.

Regarding early retirement, the interview findings and literature review are in consensus. Castagna (2023) suggests if a shipowner frequently scraps vessels, it is necessary to compensate by expanding the current or building a larger fleet to maintain the same supply capacity. But, the severe loss of money from retiring young vessels and the non-recoverable new CAPEX-related investments is why none of the shipowners considered this solution. As Mr. Moeller stated, if the ultimatum of early retirement was to be considered necessary, which is very rare, the vessels would be attempted sold instead.

This study shows that the three solutions for EEXI compliance; EET retrofitting, EPL, and early retirement can theoretically be done separately. But, as assumed in the literature review, the major resource consumption of solely doing EPL or early retirement limits these options. Therefore, this study suggests that the only two realistic approaches are either solely doing EET retrofitting on good performing vessels, or a combination of EPL and EET retrofitting on worse performing vessels. In conclusion, this study suggests that the EEXI is a key driver for EET retrofit investments.

6.1.2 Discussion regarding the Carbon Intensity Indicator

The findings support the existing theory by the IMO (2021), that CII-ratings are theoretically driven by operational EE. This was clearly identified through examining a pattern amongst the shipowners' good and bad rated vessels. Good calculated ratings seem to usually be awarded to VC-vessels and can be justified by the shipowner's own encouragement to e.g. sail slower (operational measure). Additional EET retrofit investments are therefore rarely necessary for these vessels in order to comply with the CII.

However, Tveter's (2023) argument that only considering operational measures for improving CII-ratings is grossly overestimated, is highly supported from this study in regard to TC-vessels. As the charterer has the operational control over the vessel in TCs and is almost always sailing at maximum speed due to the lack of CII-related clauses, the vessel's EE becomes drastically reduced – resulting in bad ratings. One may argue that this for now does not matter, because there are no consequences of bad ratings announced by the IMO yet. Simultaneously, charterers will anyway most likely require good rated vessels, based on the shipowners' current and previous experience of the impact RightShip GHG-ratings have on their C/Ps. This is currently mostly speculation amongst the interviewed shipowners, but still remains a valid argument as O9 has already experienced that their bad CII-rated vessels are hinders to being awarded C/Ps. One may consider the charterers' perspective in this context as ironic or hypocritical, based on the fact that they require good CII-ratings, but is indicated to be the main reason for the bad ratings in the first instance. Nevertheless, the findings show that the power still is in the hands of the charterers, as the shipowners choose to obey their requirements by EET retrofitting to compensate.

Considering vessels operating with VCs, this study does not for now acknowledge the CII as a driver for EET retrofit investments. This is because on VC-vessels, the theoretical principal of operational EE having the most impact on the CII-ratings is by this study suggested true and in consensus with existing theory (IMO, 2021). In contrast, for vessels operating with TCs, this study clearly indicates that the CII encourages EET retrofit investments due to the charterers' negative impact on the vessels' operational EE. For a future outlook, when the CII-consequences are finally announced, this research suggests that it will naturally put more pressure on the shipowners to maintain good ratings. However, this does not necessarily mean that it will increase demand for EET retrofit investments, as CII-related clauses will more likely be implemented by the shipowners due to today's C/Ps are soon expiring.

6.1.3 Discussion regarding Future outlook: Carbon Emissions Trading

Psaraftis (2019) suggested that the EU ETS will drive shipowners to increase EE in order to profit economically by buying less and selling their unused CO_2 allowances. As EET retrofitting is considered a main solution to becoming energy efficient in shipping today, it was natural to study this topic.

The most important consideration is that the EU ETS is geographically regulated and a vessel's involvement is dependent on how much of its sailing (freight routes) is in the EU. During the literature review, it was assumed that shipowners may profit from EET retrofit investments if emissions reductions are great enough to sell significant amounts of CO_2 allowances. In similarity to the previous research by Psaraftis (2019), the shipowners acknowledge that their EET retrofits will provide sufficient energy savings to affect their CO_2 allowances trading. However, if its significance will "drive" or "encourage" shipowners to do EET retrofit investments as the previous research indicates, is discussable. Most of the shipowners interviewed only consume around 25% of their fuel within the EU. Because of this, they said that CO_2 allowances trading will not be a "main" business area for them and currently they do not have any active strategies for this. The results therefore indicate that the highly energy efficient shipowners' market in the EU should be well over 25% if they are to considerably benefit from the EU ETS. As Mr. Opedal mentioned, future freight routes, how often and how long one sails in the EU, are very hard to predict and dependent on the future market – shipowners must wait and see. Additionally, as deep-sea shipping is intercontinental, a shipowner will very rarely experience a single geographic region, such as the EU, that they operate drastically more in compared to others. It is also important to not forget that CO_2 allowances trading will directly only impact the operator of the vessel, which for the shipowners, is only during VCs. In essence, it is indicated that carbon emissions trading in the EU ETS will not work as a driver for deep-sea shipowners' EET retrofit investments.

However, it is important to keep in mind that all the shipowners support the academic community's (Halim *et al*., 2018, Ge *et al*., 2018, Holsvik & Williksen, 2020) discussion and arguments regarding a global IMO regulated carbon emissions trading system. Shipowners are one of the main stakeholders in the shipping industry and have major influence upon the IMO. Their consensus of favoring the implementation of an international carbon emissions trading system makes it realistic for the IMO to take it into consideration. Hypothetically, if the IMO would implement this, this study suggests two direct effects would be experienced. Firstly, the argument of freight routes' impact would no longer be valid, as operators' full carbon emissions trading potential would be unlocked. VC-owners would therefore most likely invest more in EET retrofits to become as energy efficient as possible, just like Psaraftis (2019) suggested. Secondly, the argument that the EU ETS only impact VC-owners would also lose its validation. This is because charterers would most likely now put much more pressure on TC-owners to retrofit with EETs, in order to stay competitive in the CO_2 allowances trading.

This study suggests that the EU ETS starting in 2024 will unlikely be a driver for EET retrofit investments among deep-sea shipowners, unless the majority of their fuel is consumed within the EU. However, for a possible future outlook, this study suggests that a global IMO regulated carbon emissions trading system would most likely to the highest degree be a driver for EET retrofit investments amongst shipowners.

6.2 Discussion regarding economy

In regard to EE in shipping, Erginer & Kaya (2021) stated that economy is about minimizing OPEX and maximizing revenue by reducing fuel-costs. To understand what applies specifically for EET retrofitting in this context, this section has attempted to uncover the unknown theoretical reality of its economic cost-benefit aspect.

6.2.1 The cost aspects of EET retrofitting

The literature review identified that EET retrofit investment-costs include purchase prices of the technology, operational and maintenance expenses, and resource consumption of planning, procurement and installation processes (off-hire/ dry-docking) (Armstrong & Banks, 2015, Erginer & Kaya, 2021, Gao, 2022). The impression one gains from reviewing the existing literature is that shipowners generally are overwhelmed by all these kinds of different resource consuming posts and see EET retrofitting as just a burden with a large economic risk. This was supported by Rehmatulla (2012), who identified that lack of reliable cost-information is a major barrier for implementing EE measures. The researcher wanted to further investigate this theory and assumed that there is a possibility that shipowners over-consider the cost aspects of EET retrofitting compared to what really defines its reality.

Interviewing the shipowners revealed a shocking conflicting find against Armstrong & Banks' (2015), Erginer & Kaya's (2021), and Gao's (2022) studies. This study indicates that the supposedly major resource consumption of EET retrofitting that these existing studies suggests, which make shipowners reluctant to invest, seem to be as assumed severely overexaggerated. There are two findings that can argue for this statement.

Firstly, the interviewed shipowners technically consider the dry-docking phase as the most resource consuming post because it causes off-hire. To minimize expenses, it is necessary to make this process as efficient as possible. The interviewed shipowners said that the process is always well planned a long time in advance and only done during the 5-year interval of required dry-dockings. Therefore, the argument by Armstrong & Banks (2015) regarding EET retrofitting may cause several off-hires due to different installment periods at the yard, do not hold up in reality with this study's findings. Armstrong & Banks (2015), Erginer & Kaya (2021), and Gao (2022) also emphasized the problem of operational- and maintenance expenses may cause unexpected dry-dockings. This statement is somewhat supported, but only one of the shipowners interviewed, Mr. Lalic, has experienced this. However, Mr. Lalic does not consider this a negative anyway, as dry-dockings like these are completed rather fast and do not matter as the benefits of EET retrofits largely outweigh these minor inconveniences. It is therefore worth mentioning that reluctant shipowners with only dry-docking experience from e.g. long repair periods of their vessels, may believe the same applies for EET retrofitting, but in reality, it is just a "Formula 1 pitstop" as O7 refers to.

Secondly, as Erginer & Kaya (2021), and Gao (2022) also highlight, the shipowners confirm that purchasing the actual technologies is a significant cost aspect of EET retrofitting. Although the EET retrofits generate cost-savings over time, the products are not considered cheap to acquire and significantly increases CAPEX. This mainly applies to TC-owners as they do not benefit directly financially from the fuel-cost savings. Most shipowners mentioned that the charterers therefore often provide financial contributions through either cost-sharing the investments, paying premiums of the fuel-cost savings, or approaching the suppliers themselves for discounted prices. Mr. Aasen also mentioned that on very long TCs, the charterers even usually do the EET retrofitting all by themselves. The researcher has not identified that these possibilities for reduced expenses are mentioned in any of the existing research reviewed, which may explain why the cost-aspects are considered a barrier for EET retrofit investments.

Remaining arguments from Erginer & Kaya (2021), and Gao (2022) regarding resource consumption of planning and procurement were not addressed by any of the interviewed shipowners. This study can therefore not suggest that these statements are untrue, but not mentioning them indicates that the shipowners do not consider these as significant resource consuming posts. However, the study supports that the dry-docking phase and purchasing prices of the EET retrofits are the largest cost-aspects of the investments. Although this was already established from the existing research, it is now instead indicated to be overexaggerated due to lack of knowledge about efficient dry-docking and reduced investment-costs possibilities. This study therefore suggests that the cost-aspect of EET retrofitting should no longer be considered a strong barrier for EET retrofit investments.

6.2.2 The economic benefit aspects of EET retrofitting

A vessel's fuel-costs account for 60-70% of its OPEX (Ang *et al*., 2017), and this study found that EET retrofitting on average can save upwards of 30% of those expenses. What this equal to in numbers naturally varies between different vessels and market conditions. However, Mr. Berntzen stated that only considering the Becker Mewis Duct retrofit, which on their particular product-tankers and dry-bulkers provide around 6% in fuel-savings, an average of over USD 500 000 in cost-savings is achieved annually per vessel. If USD 500 000 is achievable from "only" 6% fuel-savings on one single vessel, hypothetically 30% total fuel-savings, which is realistically achievable according to the interviewed shipowners, would equal to USD 2 500 000 in annual cost-savings. For a large container vessel, Ang *et al*. (2017) claimed that 1% fuel-savings equals to USD 300 000 in cost-savings. This study was not able to validate this statement, but if it is true, in the case of 30% fuel-savings, it would be equivalent to USD 9 000 000 in annual cost-savings per vessel. It is important to mention that considering the volatility of fuel-prices, these numbers are only rough estimates, but they still show that the potential for fuel-cost savings caused by EET retrofitting is large.

The shipowners could naturally agree that the economy is a strong driver for their EET retrofit investments. In that matter, they want to maximize this potential, as in consensus with the economic theory of Erginer & Kaya (2021). Stopford (2008) stated that how well shipowners can recover and profit from investments is heavily dependent on right vessel conditions, i.e. age and size, and services operated, i.e. level of activity.

Regarding vessel age, Rehmatulla & Smith (2020) found that the newer the vessel is, the less economic risk one poses due to a longer period for ROI before scrapping or selling. Most shipowners interviewed seem to agree with this, as they suggest that there must be a forecast of long-term viability performance for their vessels to consider EET retrofit investments financially worth it. The study reveals that the optimal vessel-age is 5 years (first required dry-docking) and is justified by this being the first ever possibility for a vessel to do EET retrofitting – which will create the highest ROI. The shipowners consider the maximum age to be 10 years (second required dry-docking). This is because the vessel will likely be sold around the time of the third required dry-docking at 15 years, and according to the shipowners, the EET retrofit investments need 0.5 years to 4 years to recover.

Longarela-Ares *et al*. (2020) suggested that the larger and more operated (high level of activity) vessels can also drive investment decisions. These vessels consume greater amounts of fuel and therefore naturally increases the potential to save more overall costs per investment. Most shipowners interviewed highlight this theory, but specify that they are only speaking hypothetically, because they have the opinion that all vessels require EET retrofitting regardless. Conflicting to the other interviewed shipowners, O9 seem to practice the theory by Longarela-Ares *et al*. (2020), by being very selective considering vessel size and activity level. In essence, these findings indicate that it is favorable for shipowners to retrofit their entire fleets if they are in a comfortable position to do so, but if they are not, they should be selective and prioritize the theory.

The potential for upwards of 30% cost-savings from EET retrofits generates generally fast pay-back periods and further high ROI. Especially considering the interviewed shipowners' prediction of a soon 4-6x cost increase for future fuels, the pay-back period will become drastically shorter and the ROI will increase – putting more pressure on demand for EET retrofitting. Therefore, this study suggests that the "economy", or simply put, fuel-cost savings, is a key driver for EET retrofit investments. This study can also suggest the right vessel characteristics in order to maximize the economic benefits of EET retrofitting. These involve that shipowners should not prioritize vessel size or level of activity, unless one has limited resources and is forced to do so, as the major fuel-cost savings will benefit all vessels from being retrofitted with EETs regardless. However, shipowners should aim to do EET retrofitting during the first required dry-docking (5-years), and no later than the second required dry-docking (10 years). The earlier one chooses to retrofit, the greater the investment financially pays off. Shipowners may experience having to retrofit beyond the second required dry-docking due to e.g. compliance reasons. This study suggests that this may be a likely scenario for many shipowners as the world fleet's average age is 12.3 years (Clarksons Research, 2023), but if so, they must therefore be prepared to keep their vessels for a longer time than normal (until the investments are recovered).

6.3 Discussion regarding clients

This section discusses how market competitiveness and charter rates, and principal-agent problems impact shipowners' EET retrofit investments decisions.

6.3.1 Market competitiveness and charter rates

The researcher identified two conflicting opinions while reviewing existing research on EE measures and their impact on market competitiveness. Erginer & Kaya (2021) suggests that market competitiveness is increased when shipowners can offer highly energy efficient vessels. In contrast, Gao (2022) built upon this exact research through a quantitative study, specifically investigating what applies for EET retrofitting instead of EE measures in general. However, he suggested that EET retrofitting are negatively impacting shipowners' market competitiveness.

The researcher determined that it was necessary to investigate these conflicting theories, in order to not leave an undisclosed hole in the field of study. The results of this study show that the arguments of Erginer & Kaya (2021), regarding market competitiveness increases when doing EET retrofitting, was as assumed in the literature review, fully supported, whilst Gao's (2022) conflicting opinion, has zero support. There are three main findings that can argue for this.

Firstly, Gao (2022) states that the reasoning for EET retrofitting negatively impacting shipowners' market competitiveness, is that the investments are significantly resource consuming and disrupt the regular operations of vessels (causes off-hire periods). These arguments have already been brought up when discussing economy and was suggested disproven. Resource consumption of EET retrofitting is in fact overexaggerated, and off-hire is always aimed to be timed with the required dry-dockings to minimize its cons. Here it is interesting to see how similar studies on EET retrofitting can receive totally different outcomes, depending on whether it is qualitative or quantitative. There are two reasons why the researcher believe Gao (2022) received negatively loaded and arguably inaccurate results regarding this specific topic. 1. Gao did not investigate the cost-information barrier qualitatively, and therefore did not have the opportunity to receive concrete answers from shipowners who have specific experience with this. 2. Gao conducted data collection with a random sample of shipowners, which to the highest possibility included several who are reluctant to EET retrofitting, as they have a lack of knowledge about the real cost-information (ref. Rehmatulla (2012)).

Secondly, this study fully supports both arguments of Erginer & Kaya (2021). This involve that highly energy efficient vessels have the advantage of being chosen over less energy efficient ones when competing for C/Ps, and at a higher charter rate. All interviewed shipowners emphasized how they strive to make their vessels as energy efficient as possible, because high EE is a main criterion amongst charterers when searching for vessels today. The shipowners also state that the increased market competitiveness involve more easily building long-term relationships with the charterers. The most significant effects of the long-term relationships they experience, are as previously mentioned, C/P extensions and financial contributions. Additionally, the argument regarding charging higher charter rates is supported, as the shipowners indicate that the charterers seem to value high EE over low charter rates. This has basis in the previous economy discussion, regarding that charterers have the potential to save millions of dollars annually in fuel-costs, choosing highly EET retrofitted vessels. It also has basis in the fact that vessels with good RightShip GHG-ratings (predictably soon CII-ratings) are explicitly searched for by the charterers, and according to the interviewed shipowners, higher charter rates are charged on good rated vessels.

Thirdly, this study naturally indicate that market competitiveness is reduced without EET retrofitting. Shipowners will lose the advantages of the increased market competitiveness EET retrofits bring, whilst more energy efficient shipowners gain them. This especially involve having as mentioned a much harder time being awarded C/Ps. In addition, most interviewed shipowners multiple times highlighted that the consequences of less favorable C/P conditions, including lower charter rates, would reduce their earnings, having to operate on a smaller margin compared to their more energy efficient competitors.

This study hereby suggests that increased market competitiveness and the potential to charge higher charter rates are key drivers for EET retrofit investments.

6.3.2 Principal-agent problems

Armstrong & Banks (2015) stated that charterers' EE requirements are driven by their own motivation to become sustainable and improve their CSR. Consensus with this was found when interviewing the shipowners. The shipowners emphasized how a powerful outcome of EET retrofit investments is that it enhances their CSR and help them build up a "green" profile/ appearance for their stakeholders. Mr. Aasen said that maybe the biggest driver for most companies today, especially the major energy companies such as Equinor and BP, is their goal to become sustainable. It can therefore be indicated that the charterers are again driven by larger companies striving to achieve sustainability in the whole supply chain, whereas shipping operations play a significant role.

Longarela-Ares *et al*. (2020) further built upon Armstrong & Banks' (2015) study. She found that charterers are achieving their CSR-goals through enforcing requirements upon shipowners regarding pledged fuel consumption, and sometimes having to implement specific types of EE measures. Although it immediately may seem like a win-win for the charterer and the shipowner, both existing research (Agnolucci *et al*., 2014) on EE measures in general and this study on EET retrofitting, are in consensus about client's requirements are causing principal-agent problems.

As addressed earlier, EET retrofit investments is not directly economically feasible for TC shipowners. Faber *et al*. (2010), Smith *et al*. (2013), and Rehmatulla & Smith (2015), could all conclude that various operational measures have a higher implementation rate in TCs than in VCs. The reasoning for this is that it is cheaper for the shipowner to take operational actions instead of investing in "expensive" EETs.

Based on this, it was assumed in the literature review that the same findings would apply when interviewing the shipowners. The results show that the shipowners seem to agree with the theory. However, they find it unrealistic in practice due to charterers' EE requirements making it necessary to do EET retrofitting in order to be competitive. These conflicting findings are suggested justified by EET retrofits more likely being prioritized amongst charterers today, compared to between 2010 and 2015 when these last previous studies on this topic was conducted. The researcher argues for this with basis in the fact that EET retrofits' importance was not emphasized by the IMO (and other authoritative bodies) before the short-term GHG emissions reduction strategy was announced in 2018.

TC-owners experiencing principal-agent problems are as revealed earlier, sometimes compensated financially by the charterers. On the other hand, this is also shown to not always be the case. In the end, it is as O6 states, a "power game" between the shipowner and the charterer, and this study's findings indicate that the power generally lies with the charterer.

This study suggests that principal-agent problems can work as a key driver, by forcing shipowners' EET retrofit investments decisions. As assumed, this is not considered a beneficial driver like the earlier suggested drivers, but the second and far worse option for the shipowners is not being competitive in the market. In essence, if shipowners experience principal-agent problems, they should still consider the investments to be worth it.

6.4 Practical solutions for breaking the knowledge barrier

The key drivers discovered in this study provides a qualitative understanding of shipowners' investment decisions behavior for EET retrofitting. This section will provide recommendations to concrete solutions for breaking the barrier in regard to shipowners' lack of knowledge about the commercial advantages and benefits of EET retrofitting. These solutions are primarily aimed towards EET suppliers and authoritative bodies promoting EE enhancement in the shipping industry.

Preeminently, as Clarksons Research (2023) has shown that most of the world fleet's shipowners are reluctant to do EET retrofitting, approaching them, instead of waiting for them, is indicated to be necessary. Additionally, it has been discovered that not all vessels are equally compatible for EET retrofitting. To solve these challenges, using vessel databases such as Clarksons' World Fleet Register to locate the most suitable vessels/ shipowners to approach, streamlines the work towards promoting EET retrofitting in shipping. In order to locate highly potential shipowners, this study suggests that a main criterion should be locating the less energy efficient vessels between the age of 5-10 years, as these are considered most suitable for being retrofitted with EETs. It is also important to mention that Erginer & Kaya (2021) emphasized that not all EETs are compatible with all vessels. Supportively, according to Sales Manager, Alessandro Castagna, in Becker Marine Systems, as the EET Becker Mewis Duct is not compatible with e.g. offshore service vessels, these vessels instead often use different EETs such as waste heat recovery systems [2]. Suppliers can therefore use their experience from previous projects to narrow down their searches by adding criteria for specific vessel types and other technical specifications. The end result is an identified overview of possible customers with the highest demand for EET retrofitting.

[2] (Personal communication, November 27th, 2023)

Furthermore, the researcher considers the most important approach to be listening to and acknowledging the customer's (shipowner) intentions for considering EET retrofit investments in the first instance. This study has shown that different shipowners are motivated by different drivers to invest. For instance, a VC-owner who has already complied with all regulations and/or do not experience pressure from charterers, may only currently be driven by the fuel-costs savings he can achieve. Conversely, a TC-owner, not economically benefiting from fuel-costs savings, may instead be driven solely by compliance reasons or principal-agent problems. These examples illustrate the diverse combinations of drivers experienced by shipowners. Understanding the customer's goal(s) with EET retrofitting allows to better shape arguments towards their individual needs.

Regarding compliance with IMO regulations, it is recommended to switch the emphasis away from the products (EETs) and the shipbuilding aspect itself. Instead, the focus should be on promoting EET retrofitting through the universal understanding of *solutions for compliance*. As the study suggests that the EEXI and the CII are both key drivers, informing shipowners how EET retrofitting can help them comply is a better approach than explaining difficult technicalities about the products. This could be done through e.g. offering EEXI and CII calculations comparing with and without the "compliance solutions" (EETs) applied.

Regarding economy or, i.e., fuel-cost savings, providing shipowners with a *factual basis of the economic cost-benefit aspect* of EET retrofitting is recommended. Although the economy is suggested as a key driver in this study, it shows that there is a high possibility that new potential customers might be reluctant due to lack of knowledge about the real cost-information of EET retrofitting. Suppliers and authorities are suggested to present analyses for potential customers, illuminating the total resource consumption of investing compared to pay-back periods and ROIs achievable. Besides detailed and personal analyses, to immediately catch an eye amongst potential customers, suppliers should have charts with achievable fuel-cost savings easily available. Doing simple quantitative surveys with their existing customers is a great start to get an overview of achievable fuel-cost savings for different vessel types and market segments.

Regarding clients or charterers' influence, the recommended solution for promoting EET retrofit investments is to provide the potential customers with *factual information about the increased market competitiveness* one can gain. Suppliers and authorities should use valid arguments demonstrating how charterers favor highly EET retrofitted vessels and explain how they often also have requirements for this. This study found that EET retrofitting is advantageous when competing for C/Ps, beneficial for negotiating higher charter rates, and helps building long-term relationships with charterers (pros: C/P extensions and financial contributions). In other words, it is scientifically tested that high EE is a highly weighted criteria amongst charterers. Furthermore, this study suggests this will soon become even more important, as the shipping industry will highly likely experience that stricter IMO regulations and increased future fuels' prices are putting more pressure on shipowners to have as energy efficient vessels as possible – driving demand for EET retrofitting.

7.0 Research criticism

This chapter has criticized the research process by having in section 7.1 elaborated on its potential limitations, and in section 7.2 proposed suggestions for future research needed to strengthen its validity and reliability.

7.1 Potential limitations

There are potential for limitations in all research projects no matter how precise and thorough the researcher has been. Limitations can lead to misleading or wrong conclusions. For researchers to correctly build upon each others' studies and establish new knowledge, it is important to be transparent and clarify all potential limitations. Some of this project's potential limitations were informally discussed throughout chapter 4.0 Methodology, but the researcher finds it favorable for the reader to dedicate an own section at the end of the paper as a summary of the most significant ones.

For this project, the first potential limitation is the general characteristics of a qualitative research method. Firstly, all primary data is collected, processed, analyzed, and interpreted directly by the researcher, not a computer. A main consequence of this according to Larsen (2017), can be that the data is misjudged by the researcher's personal opinions. Another possible limitation is that the interviewed informants may provide information that does not reflect the exact reality – say what they believe is right to say, instead of their actual opinions. E.g. the shipowners in this project may have been excessively positive towards EET retrofitting because they were approached by one of their favored suppliers (the internship host).

Furthermore, this project was constantly under very strict time pressure, which can have impacted how precise and thorough the project has been conducted. Only having four months for conducting a research project is severely short and uncommon. This was additionally combined with an internship, further constraining the available time for a comprehensive investigation.

Regarding the research paper itself, it is assumed that what findings apply for the Norwegian and German shipowners, also applies to the deep-sea world fleet. This "generalization" is based on the fact that the shipowners interviewed all directly operate within deep-sea shipping and represent all freight market segments. However, this assumption may not be valid. Other shipowners, especially in other continents, may have different opinions on how to best increase short-term EE. Closely related is the fact that all the shipowners interviewed were mutually positive towards EETs, but not all EET shipowners in the world may have the same perception. Although the qualitative approach was and still is considered the right choice, the results would be considered more valid if more shipowners was interviewed and preferably of a more random international selection. But again, the time pressure limited this approach.

In addition, existing literature on the topic of specifically EET retrofitting, not EE measures in general, was identified by the researcher to be almost non-existing. This study's discoveries can therefore not yet surely be either confirmed or disproven, but instead provide arguments-supported suggestions. Something that could in a larger degree help evaluating this study's validity and reliability, was if it existed previous studies on EET retrofit investments from e.g. the charterers perspective. Section 7.2 Future research will further elaborate on this.

7.2 Future research

For future research, there are several various aspects and angles that the research gap needs further investigation from. Firstly, it would be interesting to test the transferability of this study by approaching it from the charterers' perspective. The charterers are found to have a main role through this entire project, but their personal opinions were not investigated. As per this limitation, the interviewed shipowners have commented on what they experience apply for the charterers, but this cannot surely be confirmed if not approaching the charterers directly.

Another intriguing opportunity is to investigate the gap from short-sea shipowners' perspective. The short-sea fleet is often characterized by e.g. smaller vessels, larger ratio of VCs, and different segments such as offshore. The EEXI and the CII would not apply to as many vessels as it does for the deep-sea fleet, and assumably, charterers' requirements would have less influence on shipowners' investment decisions, whilst "economy" would have more. An additional draw is that this study indicates that regional or continental carbon emissions trading systems would highly likely be strong drivers for short-sea shipowners. These examples illustrate the many possible diverse assumptions that should be empirically studied.

Lastly, it could be interesting to study shipowners' EET investment decisions for newbuildings (building eco-ships) and compare the findings with this study. For newbuildings, some distinctions to existing vessels are that different IMO regulations apply, the cost-aspects are different (e.g. the dry-docking phase does not exist), the vessel-age criterion loses its relevance, charterers are immediately offered the best performing vessels etc.

Due to the limited existing scientific literature on EETs, the three mentioned approaches for future research could together generate a good overview and solid foundation for this sub-division in the academic field of EE in shipping.

8.0 Conclusion

A rapid decarbonization of the shipping industry is necessary to contribute to achieving the universal targets of the Paris Agreement. The IMO's short-term target of 20% GHG emissions reduction by 2030, compared to the 2008 levels, is the first of two large steps before the industry can reach its net-zero goal by 2050. Reaching this target is not possible without increasing the world fleet's implementation rate of EET retrofits (IMO, 2023). This study has attempted to investigate and contribute to overcoming one of the main barriers for implementation; shipowners' lack of knowledge about the commercial advantages and benefits of EET retrofitting. With basis in previous research on EE investments in general, and the researcher's own qualitative study, the research question has been discussed:

What Key Drivers Encourage Shipowners' EET Retrofit Investments?

It was discovered several different key drivers under the three main identified influencing groups compliance, economy, and clients.

Regarding compliance, this study suggests that the EEXI and the CII work as key drivers. The EEXI work as a driver for all shipowners, as solely EET retrofitting, and a combination of EPLs and EET retrofitting, is indicated to be the only two realistic solutions for compliance. For the CII, it only works as a driver for TC shipowners. This is because the charterers' negative operational impact force the shipowners to compensate by EET retrofitting, to achieve compliance. For a possible future outlook of a global IMO regulated carbon emissions trading system, the study indicates that it would become a driver as it would unlock shipowners' and charterers' full carbon emissions trading potential.

Regarding economy, this study suggests that fuel-cost savings is a key driver. This has basis in shipowners' potential to save upwards of 30% of their fuel-costs by retrofitting with EETs. Fuel-costs account for 60-70% of a vessel's OPEX, which is by far the largest group of expenses for shipowners. The "economy" driver is expected to become stronger if the predicted future fuels' prices become a reality – driving more demand for EET retrofitting. The study also suggests the right vessel characteristics to maximize the economic potential of EET retrofitting. This involves prioritizing retrofitting vessels during preferably the first required dry-docking (vessel-age 5), but no later than the second required dry-docking (vessel-age 10). Vessel size and level of activity should not be prioritized unless the shipowner has limited resources.

Regarding clients, this study suggests that increased market competitiveness, the potential to charge higher charter rates, and principal-agent problems, are key drivers. High EE is a main criterion amongst charterers today, whereas EET retrofits give an edge when competing for C/Ps, and help building long-term relationships with charterers. Significantly higher charter rates can be charged, because of the fuel-cost savings achievable and good RightShip GHG-ratings. Regarding principal-agent problems, they work as drivers by forcing shipowners' to equip EETs. If shipowners do not obey the charterers' EE requirements, the second and far worse option, is not being competitive in the market.

This thesis has examined shipowners' investment decisions behavior for deciding to retrofit their vessels with energy efficiency technologies. It has contributed to fill a research gap within the academic field of EE in shipping, and introduced something new to its sub-division of EET retrofitting. Additionally, it provided recommendations on how to utilize its discoveries in practice, which have potential for professional transfer value to EET suppliers and authoritative bodies promoting and stimulating EE growth in the shipping industry.

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Attachments

I. Interview guide

Pre interview checklist

Introduce myself and purpose of the project

Clarify expectations and time duration (approx. 30-60 min) of the interview

Get the consent form signed by the participant

Guarantee anonymity and duty of confidentiality (if necessary)

Clarify whether the participant has any questions regarding the interview

Start electronic recording

1.0 General

1a) What is your job position and areas of responsibility?

1b) Which freight market segments do your company operate in?

1c) What proportion of your fleet has been retrofitted with EETs?

- On average, how many different EETs have you installed per vessel?

1d) In total, what percentage of fuel savings do you typically achieve per vessel through your EET retrofits?

2.0 Compliance

2.1 Energy Efficiency Existing Ship Index (EEXI)

2.1a) Have your vessels already complied with the EEXI?

2.1b) What measures have you taken or plan to take to ensure compliance with the EEXI?

2.1c) Does your company consider EET retrofitting as a necessary part of complying with the EEXI? Why or why not?

2.1d) How do you view engine power limitation and early vessel retirement compared to EET retrofitting in meeting EEXI compliance?

2.2 Carbon Intensity Indicator (CII)

2.2a) Have you or are you planning to increase your fleet's energy efficiency to meet CII compliance in the coming years? If so, what measures have you implemented or plan to implement?

2.2b) Does your company consider EET retrofitting necessary for compliance with the CII? Why or why not?

2.2c) Besides compliance, does favorable CII-ratings offer your company any additional advantages?

2.3 Carbon Emissions Trading (EU ETS)

2.3a) How has your company prepared for or is preparing to comply with the upcoming EU ETS?

2.3b) Will EET retrofits impact your compliance with the EU ETS? Why or why not?

2.3c) Will EET retrofits increase your potential to trade CO_2 "allowances"? Why or why not?

2.3d) Would your answers differ if it was a globally IMO regulated system instead? Why or why not?

3.0 Economy

3a) What annual fuel-cost savings (average per vessel) do you achieve from your EET retrofits?

Considering the pay-back period of your EET investment costs:

3b) What is the optimal vessel-age to retrofit with EETs, and why?

3c) What is the optimal vessel size to retrofit with EETs, and why?

3d) Do you prioritize your EET retrofit investments in vessels with higher annual activity (days at sea/ distance travelled)? If so, why?

3e) How long is the average pay-back period (per vessel) for your EET retrofit investments?

3f) How do you foresee the demand for EET retrofits post-2030, and what are the reasons behind your expectations?

4.0 Clients (charterers)

4a) How has your EET retrofits affected your competitiveness amongst other shipowners?

4b) Does your EET retrofits provide any advantages when dealing with charter party agreements? If so, in what ways?

4c) Have your EET retrofits affected the charter rates you offer? If yes, how and why?

4d) What client (charterer) requirements in terms of energy efficiency do you experience?

4e) Do your vessels' most frequently used charter parties (Time charter or Voyage charter) affect your prioritized EET retrofit investments? If so, why?

5.0 Closing

5a) How would you rate the factors compliance, economy, and clients from most to least influencing considering your EET retrofit investments? And why?

> 5ab) Do you expect your perspective on this ranking to change after 2030? Why or why not?

5b) If mandatory regulations and charterer requirements were not relevant, would you still invest in EET retrofits? Please explain your reasoning.

5c) Are there any additional expected benefits, drivers or other relevant outcomes from EET retrofit investments that have not been mentioned yet? If so, please specify.

II. Consent form

Are you interested in taking part in the research project *"Increasing Ship Energy Efficiency with Technical Retrofits: What Key Drivers Encourage Shipowners' Investments?"*?

This is a question for you to participate in a B.Sc. research project with the purpose to find out what key drivers encourage shipowners to retrofit their vessels with fuel-saving technology. In this document, we will provide you with information about the aim of the project and what a participation will entail for you.

Purpose of the project

The purpose of the project is to highlight and examine a research gap that has been identified regarding the decision-making process of shipowners for installing energy efficiency technologies (EETs) on existing vessels. Previous studies show that EET retrofits have experienced limited implementation from shipowners despite their significant fuel-saving potential. Of almost 80 000 vessels worldwide, only around 5 000 vessels have installed any form of EET (Clarksons Research, 2023 As in consensus with the IMO's (2023) short-term GHG emissions reduction strategy, these numbers must increase considerably in order to reach the short-term target by 2030. Several scientific reports have concluded that a main barrier for implementation is a lack of knowledge about the commercial advantages and benefits shipowners can achieve from installing EET retrofits. Shipowners are reluctant to install EET retrofits as they have a hard time considering the cost/benefit aspect of it. They see it as a very resource-consuming burden, but do not know if the pros outweigh the cons – which makes investments risky.

As the knowledge barrier is a major hinder for EET retrofitting, empirically studying drivers that encourage investments is necessary to overcome it. There is from a **commercial perspective** conducted zero qualitative research to the *specific* drivers for installing EET retrofits. To add effort to solve the problem of low implementation of EETs on existing vessels, the research question is formulated as the following:

By answering the research question, the researcher aims to make the technology more attractive for shipowners to acquire and potentially uncover new selling points for the suppliers. The idea behind this approach is to contribute to stimulate the growth of vessels being retrofitted with EETs – which will increase the world merchant fleet's overall energy efficiency, ultimately contributing to reaching the IMO's emissions reduction targets.

Which institution is responsible for the research project?

Andreas Kastel, B.Sc. student in Shipping Management at the Norwegian University of Science and Technology (NTNU) and intern at Becker Marine Systems GmbH, is responsible for the project. The project is conducted under supervision from Prof. Jan Emblemsvåg at NTNU, & Mr. Henning Steffen, Director of Sales and Projects, at Becker Marine Systems GmbH.

Why are you being asked to participate?

The research has the purpose of solving a problem seen from the shipowner's perspective. You as a decision-maker in a ship owning company which have installed EETs is therefore highly qualified to participate. The population has been selected between those who Becker Marine Systems believe are best suited to participate in the study. There are 10 participating shipowners including yourself.

What does participation involve for you?

If you choose to take part in the project, this will involve either an online or physical interview – based on practicality. The interview will take approx. 30-60 minutes. Relevant topics for the interview will be: EET's retrofits influence on compliance with EEXI and CII regulations, carbon emissions trading (EU ETS), the economic cost/benefit aspect of installing energy efficiency technologies for retrofitting, crucial ship conditions and charter parties for EET retrofitting, charterer's influence and energy efficiency requirements, and company appearance (CSR). Your answers will be recorded electronically.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you choose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified here and we will process your personal data in accordance with data protection legislation (the GDPR). Personal data in this project involves the use of the participant's name, company, job position, and electronic recording of interview answers. The student and supervisor responsible for the project, Andreas Kastel & Prof. Jan Emblemsvåg, in connection with the Norwegian University of Science and Technology, and Mr. Henning Steffen, in connection with Becker Marine Systems, will have access to your personal data during the project. The participant's name, company, job position, and interview answers will be published in the final report.

What will happen to your personal data at the end of the research project?

The planned end date of the project is December 18th 2023. The electronic recording will be deleted after the end of the project.

Your rights

As long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you,
- request that your personal data is deleted,
- request that incorrect personal data about you is corrected/rectified,
- receive a copy of your personal data (data portability),
- send a complaint to the Norwegian Data Protection Authority regarding the processing of your personal data.

What gives us the right to process your personal data?

We will process your personal data based on your consent. Based on an agreement with the Norwegian University of Science and Technology, The Data Protection Services of Sikt – Norwegian Agency for Shared Services in Education and Research has assessed that the processing of personal data in this project meets requirements in data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

• The Norwegian University of Science and Technology via either Andreas Kastel on E-mail: andrekas@ntnu.no or Prof. Jan Emblemsvåg on E-mail: jan.emblemsvag@ntnu.no

If you have questions about how data protection has been assessed in this project by Sikt, contact:

• email: (personverntjenester@sikt.no) or by telephone: +47 73 98 40 40.

Yours sincerely,

Jan Emblemsvåg (Supervisor)

Andreas Kastel (Student)

Consent form

I have received and understood information about the project *"**Increasing Ship Energy Efficiency with Technical Retrofits: What Key Drivers Encourage Shipowners' Investments**"* and have been given the opportunity to ask questions. I give consent:

□ *to participate in an interview*

□ *to an electronic recording of the interview*

□ *for information about me to be published in a way that I can be recognized in a final report*

I give consent for my personal data to be processed until the end of the project.

(Signed by participant, date)