Challenges of implementing sustainable solutions in commercial shipping

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Degree Thesis

International Business

2023

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Arcada University of Applied Sciences: International Business, 2023

Language: English

Identification number: 8817

Abstract

Commercial shipping contributes to climate change, and sustainable development has only recently become a well-known and influential megatrend. Shipping companies are facing the need to reduce amount of pollution and carbon emissions in order to match IMO and EU targets, especially in the sensitive region of the Baltic Sea. In this work, sustainability documents published by companies were analyzed, compared with each other and with an interview with an expert from Baltic Sea Action Group, and common trends and issues of sustainable development were outlined: future zero-emission fuels (green hydrogen, green ammonia, green methanol) require empirical data, green electricity, up-to-date legislation, suitable storage infrastructure and an industry-wide transformation. Until then, companies implement “transition stage” solutions like LNG, biodiesel, dual fuel engines and energy efficiency measures. In general, shipping companies have the financial resources for sustainable development, but coordination on different levels throughout the industry, testing of new technologies, the current state of green fuel market and the global scale of shipping (with its many economic and political factors that are often out of the companies’ area of direct involvement) are areas of issue.

Keywords:

Sustainability, transportation, shipping, Baltic Sea, climate change, carbon emissions, green fuel

Contents

1 INTRODUCTION

Climate change is a global trend that has numerous consequences. Issues such as global warming and ocean pollution are growing in influence on the state of the ecosystem and the quality of life. One of the causes of climate change is the utilization of fossil fuels in various areas, including transportation and energy (United Nations, 2022). Harmful emissions accumulate and contribute to natural disasters and the ecological and climatic destabilization of the environment. This situation calls for research in sustainable development. New projects are needed to reduce the amount of harmful impact that human activity is causing on the environment.

Commercial shipping is vital for the flow of goods around the world. However, it produces waste such as carbon and particulate emissions, wastewater, sewage and other types. The waste is harmful to the environment and is one of the causes of the global climate change. Combating different aspects of pollution requires different approaches, each specific to the individual situation. There are multiple regulations and action plans being put in place by the European Union (EU) Council, International Maritime Organization (IMO), and Baltic Marine Environment Protection Commission (HELCOM) to reduce the pollution of the region, as well as decrease shipping emissions in general. However, the question remains whether the shipping companies have the capability to not only adapt to the new regulations, but also do it at a pace that matches the progression thereof. Large transport ships are long-term investments, and there is a risk of regulations severely overtaking the developments and updates of shipping fleets.

1.1 Aim

The aim of this research is to determine the state of sustainable development programs of shipping companies and gain a better understanding of the limitations they face in their struggle to reduce the harmful effects of their operations and follow the new regulations. The environmental impact of shipping is a broad topic which calls for narrow insights. This study aims to answer the following questions:

RQ1: What solutions have been implemented or are currently being implemented to reduce pollutant emissions produced by shipping?

RQ2: What factors prevent or slow down the work towards reduction of emissions?

1.2 Demarcation

This work will be focused on the Baltic Sea region and companies that operate or have a branch/sub-division that operates there, not on global shipping all around the world. It is essential to concentrate on a specific area because that allows for studying concrete issues, regulations and projects aimed at one geographical area. The Baltic Sea is an economically and politically important region. The traffic in the Baltic Sea makes up 15% of global sea transportation (Finnish Shipowners Association) and, according to HELCOM, has about 2000 vessels at any given time.

The target groups of the research are Finnish shipping/ferry companies operating in the region and large companies that provide shipping and/or ferry services through the Baltic area, as from an environmental point of view, ferry companies face similar challenges to those of shipping companies, as ro-ro (roll-on/roll-off), ro-pax (roll-on/roll-off passenger) ferries and cruise ships have similar emissions. However, it is not feasible to analyze all the companies involved in the field, so the work focuses on the data from a selection of prominent ones. The analyzed companies vary in size and scale of operations in order to provide a broader perspective.

1.3 Definitions

IMO – International Maritime Organization, is an agency of the United Nations (UN) with the mission of overseeing safe, secure and sustainable shipping (IMO.org, 2019 a).

HELCOM - Baltic Marine Environment Protection Commission (also known as Helsinki Commission), is an organization working to preserve the Baltic Sea environment and protect it from pollution. It consists of 10 members: 9 countries of the Baltic region plus the European Union. (helcom.fi, 2023)

IPCC – Intergovernmental Panel on Climate Change, United Nations body for assessing the science related to climate change (IPCC.ch, 2023).

LNG – Liquefied Natural Gas, mainly methane, which takes around 600 times less volume in liquid form than as gas at normal atmospheric pressure. LNG is increasingly being used as fuel for road and sea transportation to reduce carbon emissions. (European Commission, 2022)

Energy density – amount of energy that a substance can store. In relation to shipping fuel, it means how much energy can be produced from the fuel in relation to its volume, and is a measure of fuel efficiency: fuels with higher energy density need smaller storage capacity and vice versa. (Energy Education, 2014)

Green, as in “green fuel” and more specific fuel names (“green hydrogen” etc.) – produced from renewable sources and carbon-neutral (MAN Energy Solutions, 2023).

Li-ion battery – type of rechargeable accumulator battery using lithium ions for energy storage. Used worldwide in modern consumer electronics, electric and hybrid vehicles, but toxic for the environment and difficult to recycle. (CAS, 2022)

2 THEORY

This chapter provides information on recent trends of climate change, prominent sources of pollution in shipping that affect the climate, and legal regulations aimed at combating the issue. The International Maritime Organization has done extensive research on shipping emissions, which is one of the bases of the study’s theory.

2.1 Climate change

One of the most impactful and well-known global crises nowadays is climate change. Climate change, including but not limited to increasing temperatures, rising sea levels and loss of biodiversity, is the result of human activity. Recent research displays high confidence that human-influenced climate change has consequences worldwide, including threats to wildlife, the environment and human health and wellbeing (IPCC, 2022).

One of the causes of climate change is the utilization of fossil fuels in various areas, including transportation and energy (United Nations, 2022). In 2018, global shipping resulted in 1076 million tons of CO2, representing around 2.9% of global emissions caused by human activities. (European Commission, 2022). Emissions also include other gases such as nitrogen oxides and sulphur oxides.

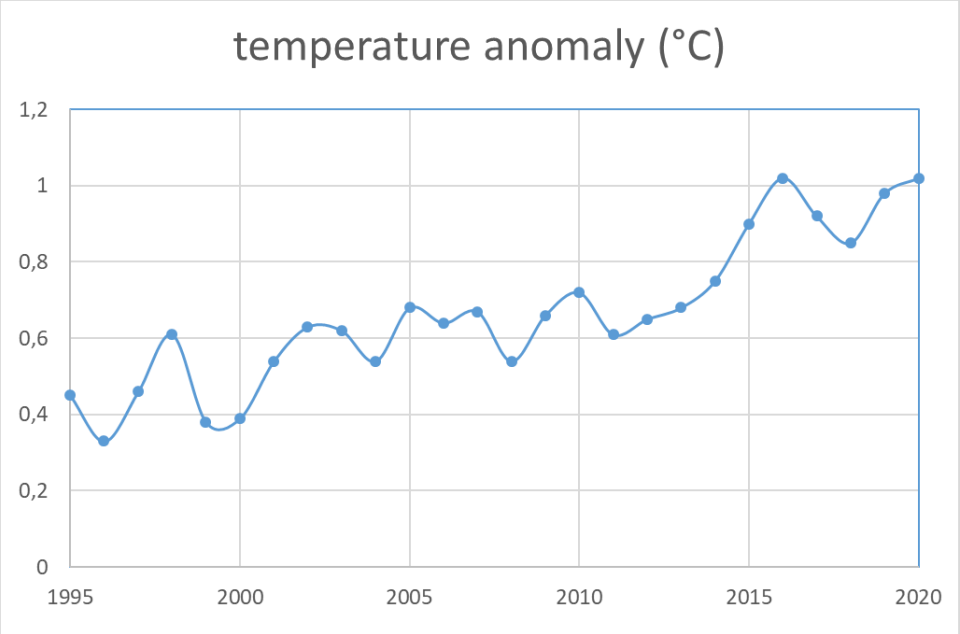

Figure 1. Change in global surface temperature compared to the long-term average from 1951 to 1980 (data by NASA/GISS, 2021)

The European Commission also highlights the necessity of addressing shipping emissions because they would drastically increase within the following 10-20 years if action is not taken. Emissions of greenhouse gases lead to increases in global temperatures, and recent years have shown a trend of that temperature increase becoming more intensive over time. The presented graph shows that trend by demonstrating changes in global surface temperature (in Celsius) compared to the long-term average from 1951 to 1980 (NASA/GISS, 2021).

According to this data, not only is global temperature increasing, but the rate of that increase is also becoming higher, thus making the temperature increase an exponential growth. As a result, the needed scale of implementation of less climate-impactful (and/or climate-neutral) solutions is also increasing.

2.2 Pollutants produced by shipping

Some of the most prominent climate-affecting pollutants of commercial shipping are greenhouse gas emissions and waste that ships often dispose at sea. The former has effects on the greenhouse effect in the atmosphere while the latter disrupts the balance of local ecosystems.

2.2.1 Greenhouse gases and particulate emissions from ships

Modern ships produce atmospheric emissions that contribute to global warming, such as carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NOx) and other gases. Greenhouse gases (GHG) are those that accumulate in the atmosphere, trapping heat and leading to the increase of global temperature. The core reason for these emissions also lies in the fuel burned for propulsion of the vessels and powering on-board equipment. The most commonly used fossil fuel for those needs is diesel, with some ships using heavy bunker fuel – a cheap but emission-heavy option. (European Commission, 2021).

Nitrous oxide emissions are an especially significant problem for the Baltic Sea region, which is especially vulnerable to nutrient pollution caused by it. Shipping activity in the region is outlined as one of the primary sources of this issue, as airborne NOx emissions from shipping end up in the sea (HELCOM, n.d. b)

The Finnish Meteorological Institute has calculated that in 2020, the IMO-registered shipping traffic in the Baltic Sea region emitted 12.5 million tons of CO_2 and 220 thousand tons of NOx, among other pollutants. Ship types responsible for the most emissions are ro-ro (roll-on/roll-off) ships (both passenger and cargo), tankers, container ships, general cargo ships and bulk carriers. HELCOM's report states that there is a trend of improvement in energy efficiency and a reduction of harmful pollutant release, as well as outlines a trend of transition from heavy fuel oil to less polluting alternatives such as distillate fuels and LNG. (HELCOM, 2021)

One of the other main climate-affecting pollutants produced by shipping is black carbon. Emitted by diesel engines, it increases global warming by converting sunlight into heat when suspended in the atmosphere. Black carbon emissions produced by ships were described to be responsible for "5% to 8% (100-year timescale) and 18% to 23% (20-year timescale) of the CO2-equivalent climate warming impact from shipping in 2015" (Comer et al, 2015). As black carbon is produced when diesel is burned, changes in fuel and engines of transport ships would be needed. HELCOM suggests using alternative fuel types such as ethanol or liquefied natural gas (LNG) for propulsion. The changes, however, would require a process of refitting, readjusting and, in some cases, rebuilding the engines to function with the new fuel types, the process being particularly lengthy and costly. (HELCOM, 2021)

2.2.2 Wastewater

Liquid waste generated after the use of water on ships, can be mainly divided into two types:
Greywater – runoff water from sinks, showers, washing machines and similar uses.
Blackwater – sewage waste from toilets, as well as grease from kitchens and drainage from medical facilities. (HELCOM, 2019 b)

Both pose a threat to the environment when dumped at sea, untreated wastewater being especially harmful due to health hazards, as well as containing chemicals that cause growth of blue-green algae and oxygen depletion in the local ecosystem. Some of the current issues is the lack of proper sewage handling experience in ports and the individual, case-by-case requirements of different location, each needing a "tailored solution" to fit the waste disposal needs of the ships. (Littfass, 2020).
Other types of wastewater include ballast water, which, if not properly treated, carries a risk of moving invasive species, and bilge water (oily water from ship machinery areas).

2.2.3 Impact of power generation

Electricity sources are an important factor in sustainability of green fuel production and shipping as a whole. With more power connection development at ports, be it for on-board power for ships at berth or for charging of batteries on ships utilizing hybrid electric solutions, it is important to take into account the environmental impact of a given country's electricity production. For instance, in Finland, one of the leading countries in the area of green electricity in the European Union (EU), connection of ships at berth to shore power is a more environmentally-friendly solution than, for example, in Germany, which has a higher share of electricity generated by burning coal and other fossil fuels, and in the recent years has made the choice to disconnect from nuclear power in favor of coal. The following chart from Eurostat demonstrates the share of electricity from renewable sources by country in Europe in comparison to the 2023 target. Out of the EU countries with access to the Baltic Sea, Poland and Germany have the lowest share of renewable electricity, which currently makes the use of shore power in those countries a less eco-friendly option than in the leading ones.

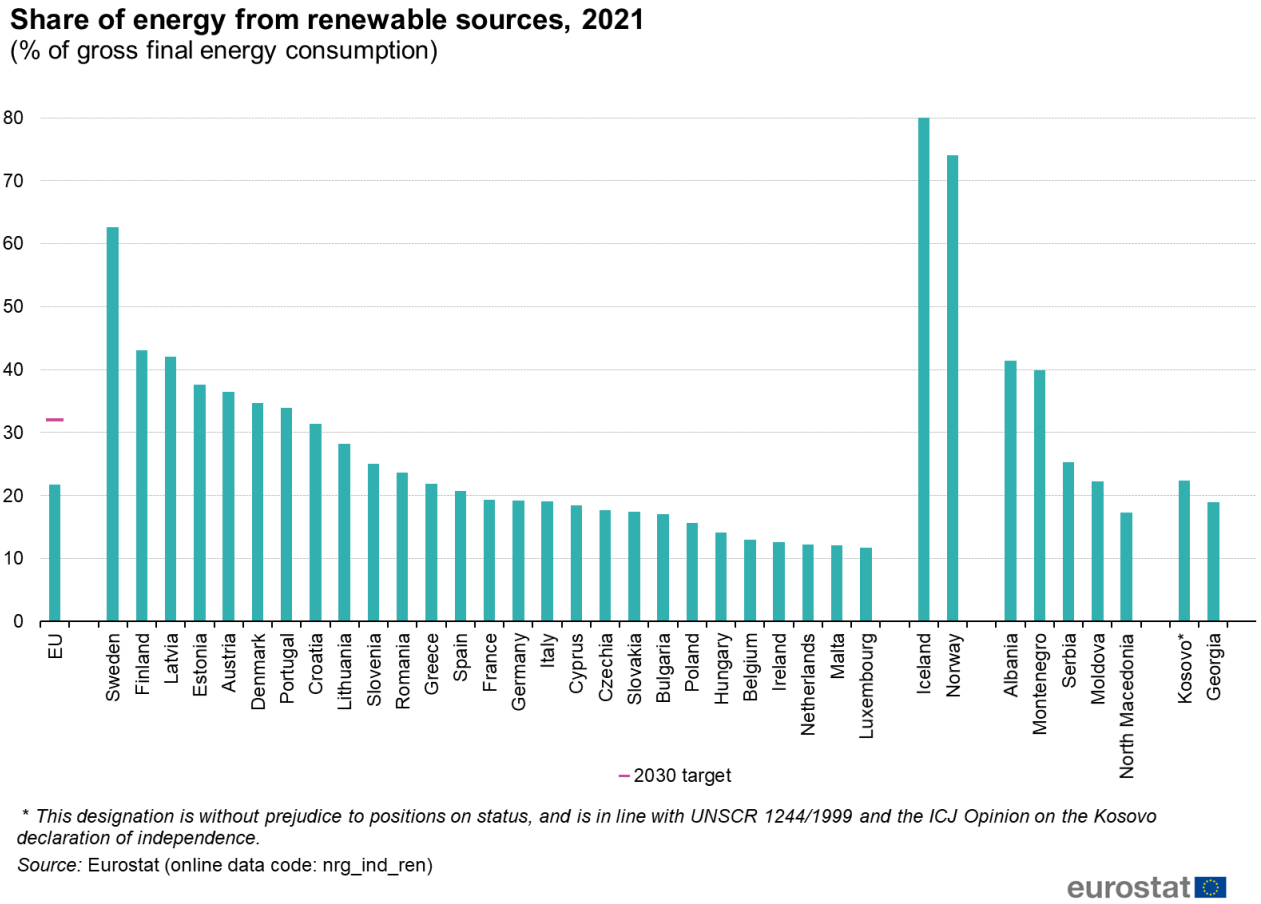

Figure 2. Share of energy from renewable sources, 2021

(source: Eurostat, 2023)

2.3 Organizations and regulations

Climate change, as a global crisis, is being addressed on a global scale. Regulations against pollution in shipping activity have been getting progressively more significant over the years. The main driving forces of those regulations in the Baltic region are the International Maritime Organization and the European Union government.

2.3.1 IMO

The amount of primary air pollutants in ships' exhaust gas, including sulfur oxides and nitrous oxides, is limited by MARPOL Annex VI, first adopted in 1997. Deliberate emissions of ozone depleting substances (ODS) is also prohibited (IMO, 2019 b).

Carbon dioxide emissions are monitored by IMO's Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI), which are indications of a ship's carbon dioxide emissions per capacity-mile of transportation. Since 2013, ships must meet IMO's guidelines on EEDI based on the ship type, with the regulations tightening over the following years to encourage innovation in energy and propulsion efficiency in maritime transportation. HELCOM's report, based on the data from the Finnish Meteorological Institute shows a 33% increase in energy efficiency in IMO-registered ships operating in the Baltic sea in the 2008-2020 period, as well as a trend of slow-steaming (speed reduction) being utilized for fuel conservation. (HELCOM, 2021)

The Baltic Sea area is designated a "special area" under MARPOL Annex IV, which prohibits discharge of sewage unless the ship is equipped with a certified sewage treatment plant that matches the requirements for removal of phosphorus and nitrogen. HELCOM's "Technical Guidance for the Handling of Wastewater in Ports of the Baltic Sea Special Area under MARPOL Annex IV" specifies that the treated waste must have its nitrogen level reduced by at least 70% and phosphorus level – by at least 80%. The guidance plan is aimed at port operators and shipping companies to simplify and speed up the process of developing innovative solutions and minimize issues with the acceptance of waste at ports. (HELCOM, 2019 b).

2.3.2 EU

The maritime transport strategy of the European Union (EU) is a part of the European Green Deal, which is a global plan of reducing emissions until Europe is made the "first climate-neutral continent", that being a continent that does not contribute to climate change through emissions. According to that plan, EU aims to reduce net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. (European Commission, 2022)

The strategy of the European Union to address greenhouse gas emissions in the shipping sector is categorized into the following steps:

- Monitoring, reporting and verifying (MRV) of CO_2 emissions
- Greenhouse gas reduction targets
- Further measures

The EU Regulation 2015/757 establishes the obligation going into force in 2018 for all vessels over 5000 gross tonnes visiting EU ports after to monitor, report and verify CO_2 emissions, as well as other information related to energy efficiency, such as fuel consumption and time and distance of the voyage. By that regulation, companies must also provide clear documentation on their methods and procedures of MRV of CO_2 emissions and the activity data of the ships. Further steps include putting a price cap on CO_2 emissions of ships, increasing demand for renewable and low-carbon fuels, stimulation of the alternative fuel infrastructure, and increasing the supply and use of renewable energy sources and fuel. (European Commission, 2021).

In addition, starting from 2024, maritime transport will also be covered by EU's emissions trading system – a set of regulations and tools to reduce emissions and combat climate change, with carbon dioxide being one of the main sectors of emissions monitored. Under the emissions trading systems, companies are encouraged to reduce their emissions and trade allowances to avoid paying extra fines for exceeding the emission cap which is decreased over time. (European Commission, Climate Action, 2023)

3 Method

As the aim is to outline trends and challenges in the sustainable development of companies operating in the region, the main methodology of the research is qualitative. With the main focus being on documentation analysis, it also includes interviewing a representative from Baltic Sea Action Group, to outline correlation and differences between company reports and insights from experts involved in environmental projects for the Baltic Sea region.

3.1 Choice of method

With different qualitative methods being used (documentary research and interviewing), this is a multimethod qualitative study. The approach to the research is inductive: a more insightful conclusion is worked towards by identifying patterns within the literature (Saunders et al., 2012).

The chosen methodology is qualitative in its nature, as the expected results are predominantly non-numerical. Though quantitative data will be studied as part of the researched materials (sustainability reports), the sought outcome is more event-oriented and answers non-numerical questions: “What is happening? Why? What is the reason? What information is presented?” etc.

3.1.1 Documentary analysis

In general terms, the documentary research method, or document analysis, is a study of written texts related to the studied phenomenon, investigating and categorizing them within the context of the study. Documents can be categorized into different types, depending on their origin and how they are retrieved. **Public records** (official organizational publications of activities) include annual reports, strategic plans, and other publications regarding the organizations’ operations. **Personal documents** (first-person accounts) are publications representing individual views and first-person involvement in a situation or event. They are such documents as social media posts, e-mails, reflections etc. Finally, **physical evidence**, as the name states, is physical documents found throughout the study process, such as flyers, posters and handbooks, among others. (Armstrong, 2021)
The main type of documents studied within this research is public records – sustainability reports, roadmaps and strategy publications made by shipping and ferry companies. The ample availability of public documents is a plus, as there is no shortage of information, but that factor is also a disadvantage as that makes it complex to select and evaluate data out of a large pool while maintaining a broad overall view on the issue. In order to yield usable data after the analysis, the documents must fulfill the following quality control criteria (Ahmed, 2010):

Authenticity – the documents are real, obtained from the actual source that is claimed as the origin, and not falsified or forged.
Credibility – the documents are trustworthy, follow objective standards of reliability, and are not manipulated for the sake of influencing the results of the research or for the benefit of the researcher
Representativeness – the documents contain on-topic evidence gained through generally accepted methods, without presenting extreme outliers and deviations as the status quo of the whole studied area

Meaning – the evidence within the documents is clear and understandable (it can be said that the documents "make sense"), the documents allow for fact-based interpretation of the data.

3.1.2 Interview

Interviews in research are classified by Saunders et al. into the following categories:
Structured – with an exact structure of the questions, which are read out in order, precisely as written, keeping to the predetermined schedule and maintaining as much neutrality as possible in the speech. The personal aspect only shows through clarification and explanation of the context of the questions posed.
Semi-structured – with a list of topics to discuss and some specific questions, but allowing for some variability during the discussion: some themes may be discussed in a different order or call for additional attention. The prepared material is there to guide the discussion, but not to control it fully, as more questions arise throughout the interview.
Unstructured (in-depth) – informal interviews without a prepared structure or list of questions. With an idea in mind, they are great for exploring the area, but leave a lot of freedom for the development of discussion, with the interviewee not being limited by a system or a pre-determined set of questions.
(Saunders et al., 2012)

The chosen type, the semi-structured interview, was chosen for the research because it combines structure with flexibility: there is pre-set guide of themes and questions, but there is room to build on the received answers. The aim of the interview with an expert within Baltic Sea Action Group is to receive insights from within a group of experts with experience in Baltic environmental preservation. The specialist is contacted online and receive information about the purpose of the study, as well as a form of consent for recording the interview and using it for academic research. The majority of the main points of the interview are based on the trends found in the published documents, to later compare the obtained information (the interview guide is attached as appendix B). However, some themes and questions forming the structure are formulated initially, without the results from the documentary analysis, such as:

- Carbon emissions and waste management: what solutions are currently looking promising? What slows down their implementation?

- Technological limitations: what technology would help resolve some of the issues within the area, but does not exist yet or cannot be implemented yet?
- Financial prioritization: do companies invest enough funds in sustainable development projects? If not – why not?
- Commitment: do participants of the collaboration maintain the schedules they set? If not – why not?

An interview in the format of a person-to-person discussion (at distance, through the use of connection through internet) allows for development of the discussion throughout the whole process of the interview, depending on the answers. However, extra effort is needed to avoid interviewer and interviewee bias, which pose bigger threat than in a structured interview because of the more personal nature of communication between the parties involved. On the bright side, there is confidence in the interviewee's truthfulness, as they have extensive experience in shipping and sustainable development, and are not affiliated with any company being studied in the research.

3.2 Data sources

Most documentation within the scope of the research is publications on sustainable development from corporations performing shipping in the region. That information is publically available from the companies' official websites and will be studied to outline the main highlighted trends and problematic areas. Another important factor is the amount and clarity of available information – the study takes into consideration the willingness to publish specific details in a credible way, that can be referred to academically.
The following table demonstrates the documents used in the research, providing information on the source of the documents and how they are relevant to the research topic:

Table 1. Data sources

Doc #	Document name	Type of document	Author	Relevance	Obtained from
1	MSC sustainability report 2021 + MSC cruises	sustainability report	Mediterranean Shipping Company	Biggest shipping company in the world, which also has a Baltic cruise branch	https://www.msc.com/en/sustainability https://www.msccruises.fi/about-msc/sustainability
2	Maersk 2022 sustainability report	sustainability report	Maersk	Second largest shipping company worldwide, also has a Finnish branch	https://www.maersk.com/sustainability/reports-and-resources
3	Finnlines annual report 2022	sustainability report	Finnlines	as a branch of Grimaldi group, Finnlines operates ro-ro and ro-pax vessels in the Baltic region	https://www.finnlines.com/wp-content/uploads/2023/03/finnlines-annual-report-2022.pdf
4	Viking Line Sustainability report 2022	sustainability report	Viking Line	one of Finland's biggest passenger cruise lines	https://www.vikingline.com/globalassets/documents/market_specific/corporate/environment/hbr2022-vikingline-en.pdf
5	"Viking Line väntar sig räkning på 25 miljoner euro för utsläpp – påverkar också passagerarpriser"	news article	Svenska Yle	The news article covers a fine issued to the company for emissions, as well as the information director's commentary on sustainable solutions	https://svenska.yle.fi/a/7-10033790
6	AS Tallink Grupp sustainability report 2021	sustainability report	Tallink	Tallink's Silja Line is one of the main passenger cruise lines in Finland	https://www.tallink.com/social-responsibility-reports
7	ESL Shipping sustainability report 2022	sustainability report	ESL Shipping	Finnish shipping company transporting dry bulk cargo in the Baltic region	https://www.eslshipping.com/hubfs/Documents/Sustainability%20Report%202022%20lowres.pdf?hsLang=en
8	Eckerö Line: Environment and Responsibility + Sustainability report 2022	sustainability report + webpage	Eckerö Line	Passenger ferry company connecting Finland and Estonia	https://www.eckeroline.com/environment-and-responsibility https://rederiabeckero.ax/wp-content/uploads/2023/04/sustainability_report_2022-2.pdf
9	DFDS Climate Action Plan	sustainability plan (webpage)	DFDS	DFDS is a Danish cargo and passenger ferry, operating across Europe, including Baltic Sea freighter and ferry operation, with a connection to Finland	https://www.dfds.com/en/about/sustainability/climate-plan
10	Port of Helsinki annual report 2022	annual report	Port of Helsinki	The port's sustainability strategy includes reducing emissions from vessels	https://vuosikertomus2022.portofhelsinki.fi/en/

3.3 Data analysis

The received data was analyzed through thematic analysis with the help of a table. The table served as a coding template developed based on the first, brief study of the initial data – this allowed for further extension, after the themes closely related to research questions have been outlined. The following steps, as described by Nigel King et al. (2004) form the process of template analysis:

Preliminary coding – a broad selection of themes useful for a better understanding of the analyzed area. Some themes relevant to the research questions can be identified in advance, as they help during the coding stage and can be modified or redacted later, based on the patterns of the themes.

Grouping of themes into clusters – putting related themes into distinct groups and mapping out how they relate to one another

Initial template – the formation of the coding template based on the results of previous steps after working with initial data

Application of the template – further data is analyzed with the guidance of the template, which is extended upon and modified with the progression of the study. As more data is studied, it becomes clearer which themes have to be added, redefined or removed. The later

analysis is an iterative process of applying the template to the data, forming a refurbished version of the template, and applying it further.

Finalizing – there is no strict rule or definition for which iteration of the template to call "final", as it is possible to continuously improve it and apply again to more data, so the "final" version of the template to be applied to the whole studied data set is up to the researchers' discretion. However, the template cannot be called finalized if its structure misses or leaves notable on-topic data that is useful for answering the research questions. (King, 2004).

Attached below – a screenshot of the table regarding ongoing/future solutions

Table 2. Current/future solutions

doc #	company	Fuel consumption	Fuel-based emissions	Waste mgmt	Infrastructure development	Sustainable goal commitments	Other notes and important quotes
1	MSC	More energy-efficient newbuilds, using IMO's EEOI, retrofitting energy-saving solutions like LED's and variable frequency drives for ventilation and pumps. **Digitalization** helps improve energy efficiency through monitoring and analysis	**Green ammonia, green methanol - likely dominant solutions**. **Green hydrogen, fuel cells, batteries** - **for shorter distances**. "Hybrid Exhaust Gas Cleaning System installations that can operate in both open and closed loop (being retrofitted)	Cruise ships: 11 ships (71% capacity) equipped with "advanced wastewater treatment systems". Newbuilds equipped up to "Baltic standard". "Requirements of EU directive (2019/883) fully integrated into waste management protocols"	"Working closely with governments and encouraging effective policy measures to support **an industry-wide transition**"	"Carbon net zero by 2050: more ambitious than IMO's targets", "MSC's pathway to logistics decarbonisation focusses on working towards carbon neutrality; supporting logistics transition solutions; and continuing energy efficiency programmes across the whole Cargo Division"	Net zero measures: "**Operational efficiency**", "low/zero carbon fuels", "retrofit technology", "progressive ship renewal". First **LNG-powered cruise ships** deployed, **hydrogen-powered** project in research
2	Maersk	"Improving fuel efficiency is an area Maersk knows well": **fleet and network optimization**, larger vessels", cargo optimization etc.	**Dual fuel methanol-engine vessels**. New ships ordered for **green methanol** while other solutions are researched. "methanol only scalable green fuel option this decade" it will take time to reach the scale to cover the demand, so an alternative 'drop in' fuel is necessary to fill the gap" (**biodiesel**)	Ballast water treatment systems, "During 2022, we issued such requirements across our business for a broad range of areas including waste management, spill prevention, control and response, water and chemical management"	"our efforts must be matched at the industry level in order to successfully accelerate a green and equitable energy transition" "switching to **renewable electricity, direct electrification, battery electric mobile equipment and green fuels when needed and possible**. We also deploy an energy optimization programme..."	"**2040 - net zero** across the business". Ocean: ~50% reduction in carbon intensity (EEOI) by 2030 (2020 baseline) Science-Based Targets initiative guidance - Aligned with a Science Based Targets initiative 1.5-degree pathway.	Regulators in Brussels were left with the difficult task of assessing and evaluating which input warranted real attention, and which positions were unhelpful to the goal of decarbonising shipping. Securing the **availability of green fuels at scale** is the **largest challenge** to our decarbonisation ambitions
3	Finnlines	More **energy-efficient hybrid vessels, optimization** of routing and scheduling. "**all types of engines and fuels are still needed** in order to enable a similar, gradual shift to more environmentally friendly fuels and engine technology **when they become available**"	"gradual transition to carbon-free and renewable fuels is being investigated", "All the Grimaldi Group's most recent newbuilding orders include an **ammonia-ready concept**". **Li-ion battery packs, air lubrication, exhaust gas abatement** on new hybrid ro-ro's	Ballast water treatment systems. "Finnlines' ro-pax vessels land black and grey water to onshore municipal sewage systems. Cargo ships are equipped with sewage treatment plants, which have been certified by the administration. The target is to gradually reduce and stop discharging also treated waste water into the Baltic Sea. When technically feasible, some of the cargo ships are already delivering their treated waste waters into shore	New **ERP** system, EDI messaging, started installation of **shore-side power connection** on Star-class ro-pax vessels in coop with the ports of Helsinki and Travemünde, investing in new tug masters with 96% less NOx emissions and 97% particle emissions	Aligned to **reduce carbon intensity by 40% by 2030, matching IMO targets.** Aiming at annual reduction of 2%	"Finnlines has installed exhaust gas cleaning systems on 21 vessels since 2015 and will continue the project by installing equipment on the two remaining vessels". "Finnlines co-operates with **waste** management companies to reuse, recycle or recover waste in an efficient manner and waste is **reprocessed into material or recovered as energy**" "In 2022, the focus continued to be on environmental investments in vessels and on improving vessels' **energy efficiency**."
4	Viking Line	"Since 2008, we have reduced our fleet's **energy consumption** per nautical mile by over 30% and we have tried several different cleantech solutions on our vessels. In recent years, **the work has intensified** and become more purposeful", "...finding solutions to **make the ships more energy efficient in order to reduce the need for fuel**"	Newbuilds "are built to be operated with **biofuels or synthetic natural gas**, that is, natural gas that does not have a fossil origin. This means that the ships are technically **ready to operate carbon-neutral today; the challenge is a sufficient supply** of alternative fuels and their significantly higher prices"	"Our vessels never discharge waste-water into the sea. Everything is pumped to municipal treatment plants on land." "On board Glory, biowaste is also collected and used in biogas production"	Viking Line is participating in a Finnish consortium that assesses opportunities to form a green transport corridor between Turku and Stockholm, one of the EU's TEN-T transport corridors.	Partners to support the Baltic Sea environment: John Nurminen Foundation, Keep the Archipelago Tidy Association University of Helsinki – Tvärminne Zoological Station. Fleet updating, operations modernized to match new standards - "We are thus **well positioned to meet future demands**"	"Viking Glory is one of the world's first ships to have Wärtsilä 31DF dual fuel engines and is powered by liquefied natural gas (**LNG**). They enable optimization of fuel use but produce no sulphur emissions at all. Furthermore, they produce fewer carbon dioxide emissions than do diesel engines. Like Grace, Glory will also run on **biogas or synthetic fuels** produced using renewable energy **when these are available in the future**"
5	Viking Line (Yle artcle)	"**Bränslepriserna** har redan fördubblats och nu kommer utsläppshandeln därtill"	Först måste rederierna satsa helhjärtat på att bli så **energieffektiva** och **bränslesnåla** som möjligt	-	"De finländska rederierna har traditionellt varit pionjärer inom fartygsdesign och **miljövänlig teknologi**"	På sommaren godkänns antagligen en ny strategi med målet att den globala sjöfarten ska vara **klimatneutral år 2050**	Utsläppshandeln får sjöfarten att försöka hitta så **kostnadseffektiva** sätt som möjligt att minska utsläppen
6	Tallink Grupp	"The main objective still shall be the development of adequate fuel consumption **measuring** capability. Adequate measuring will form a solid base for further **automation of data collection and the reporting routines** as much as possible in the future"	"we are definitely able to reduce our fleet emissions annually by 2%. It is not enough to reach the targets set for shipping by 2030, but it is the truth and a realistic target at a time when there are **no alternative fuels to get us to the goals set for our industry**"	Tallink works with BSAG to reduce nutrient emissions from maritime traffic, "4 years of zero-tolerance policy on unloading wastewater at sea" - blackwater and greywater unloaded at ports	**Shore power** where possible, auto-mooring, "We maintain and develop our Environmental Management System in order to improve continuously its performance and comply fully with all relevant legal and other obligations. The company's EMS will maintain its certified status.	"We **do not believe in claims like zero waste, zero emissions**, zero something else by **2030, 2040 or 2050** when we know that, as things currently stand and what we have available today, these goals are **already unachievable.** We are therefore much more focused on working hard at and chasing goals that will definitely deliver"	...CO2 per passenger reducing by 44.5% between 2009 and 2019. But every percentage point of reduction from now on takes more effort and is harder to achieve as we have picked all the low-hanging fruits already and now have to reach further and higher to achieve results. Carbon Efficiency indicator and other requirements "might turn out to be increasingly challenging and can become burdensome financially as well as technically, requiring a constant reassessment"
7	ESL Shipping	**Virtual arrival, electric-hybrid powertrain**, cargo space arrangement optimization, 1MWh **battery pack**	Neste co-processed marine fuel as **drop-in** fuel, **LNG vessels** capable of running on **liquified biogas**,	"All waste generated onboard is sorted and delivered to reception facilities ashore"	**Shore power** connection on newbuilds	"**Net zero CO2** emission operations by **2050**", 50% carbon intensity reduction by 2030, all greywater pumped to shore facilities by 2030, "Commiting to Science Based Targets by 2023"	
8	Eckerö Line	we **optimize operating speeds**, for example, and ensure the treatment of ship's hull, which in traffic directly affects fuel consumption and thus emissions. **Speed adjustments** and technical improvements..., LED lights	"To reduce greenhouse gas emissions, we use a low sulphur fuel with a sulphur content of 0.1%. Ship specific emissions are measured and monitored and the results are reported to the EU and IMO"	"All wastewater unloaded in shore facilities, sorted waste treated at Green Marine treatment plant"	Shore power development and other energy efficiency measures	The Group is committed to achieving the **IMO's target** of reducing emissions from the the shipping industry by **50% by 2050** measured from the 2008 level. Short-term environmental goals shall be set with this in mind.	"biggest sustainability challenge in terms of ecological responsibility is to find a way to power the propellers and produce electricity needed onboard without using fossil fuels in the future"
9	DFDS	Short-term plan:modifications of propellers and bulbs, improved coatings, decision support systems, **AI for monitoring**	**Green hydrogen, green ammonia, green methanol** seen as future solutions. Introducing small amts of methanol into existing engines **to push market demand.** Retrofitting scrubbers	"DFDS has invested in MASH Energy which is developing a method to produce commercially viable **biofuel** from agricultural waste"	Facilities and terminal development, sustainable procurement,	reduce emissions by 45% by 2030, be **climate-neutral by 2050**	
10	port of HEL		Making alternative fuel available at Helsinki ports is one of the targets for vessel emission reduction		completion of onshore power connections on both sides of West Terminal 2 for liner traffic vessels.	To reduce emissions from vessels by 25% by 2030, become carbon-neutral in terms of its own emissions by 2025.	Upturn in traffic increased carbon dioxide emissions

3.4 Research approach

After the interview was complete and the responses were recorded, they were analysed in comparison with the keywords and topics outlined in the document analysis. When commonly mentioned issues were reviewed, different approaches to obstacles have been seen, thus providing a view from different sides and allowing for comparison of points of view regarding the issues of sustainable development in shipping. In the obtained data, through common narratives and repeating keywords, problems and solutions are visible, allowing for specific conclusions in the area of sustainability in shipping and impact on the environment. The received insights were grouped in the table serving as a template. For each described environmental issue, a conclusion was drawn on what steps have been taken by the companies to reduce or counteract it and what stands in the way of eliminating it.

3.5 Validity and reliability

Validity is quality that shows that the research methods provide accurate assessment of the studied matter and measure what they are designed to measure. (Saunders et al., 2012). The data must be sufficient to answer the questions set by the research and provide the needed information. The validity of the documents is taken into account through the aforementioned four criteria of quality control: authenticity, credibility, representativeness and meaning (Ahmed, 2010).

Reliability is a characteristic of the research that is defined as the ability to "produce consistent findings" if the research structure and methods were used by another researcher or for a different occasion. Reliability is the reason behind thorough documentation of the process of the study, so that others can look into each part of the research. Reliability is threatened by errors from the participants' and the researcher's side – factors that obscure the data and the analysis thereof, and biases from both sides – alterations of responses and their interpretation in accordance to personal views and opinions. (Saunders et al., 2012).

The result of the research is expected to be a clear and concise outline of the most significant and impactful challenges the shipping companies operating in the Baltic Sea area face in their programs of sustainable development. In this setting, some criteria of validity are more difficult to uphold than the others:

While **authenticity** and **meaning** are not complicated to ensure when studying documents officially published by corporations (those publications are made on official company resources and are made to be clear and concise), **credibility** and **representativeness** are more problematic areas. While credibility in the literal sense is unlikely to be compromised (it is illegal to publish fabricated or fraudulent data in sustainability reports), the way data is presented is not always neutral. As companies tend to highlight the facts that benefit them the most, there is a certain degree of bias in the way the data is presented by companies for promotional purposes. One of the purposes of interviewing is the correction of that bias, since personal communication with a specialist in the field helps receive a different point of view than corporate publications on a popular topic. When it comes to representativeness of the documents, that quality is established throughout the process of data analysis, when documents are compared to one another. During applications of the template to the initial data, significant outliers and deviations are also noticeable (as opposed to common themes, trends and keywords), which allows for easier understanding of how representative the documents are in the field.

3.6 Ethics

One of the biggest ethical concerns in research involving interviews is confidentiality. The research follows the principles of privacy and informed consent when it comes to personal communication. Before the interview was conducted, the respondent was sent a consent form with a description of the purpose of the interview, anonymity of the respondent, and the use of received responses for academic research.

Another notable ethical question is potential bias in qualitative data of the studied documents and the presentation of the results. This work was not done in affiliation with any company, and none of the companies studied during the documentary research had any influence on the study, as the information was obtained from open-access public documents and analyzed independently from the publishers. The study adheres to principles of objective research, aiming to abstain from personal opinions in the analysis as much as possible.

4 RESULTS

This chapter presents the results of the research: first, the initial trends and patterns from the documents and the interview, and then more specific findings of the analysis. The results are grouped into two main areas by research question: what solutions are currently prominent in modern sustainable development in shipping, and what significant challenges are to be overcome.

4.1 RQ1 - current solutions for sustainable shipping

It is visible that carbon emissions are, by far, the most commonly mentioned environmental impact issue in sustainability reports and sustainable development strategy publications of shipping companies. Climate change impact reduction and preservation of marine ecosystems are commonly outlined aims of sustainable development, as companies use UN's sustainable development goals as categories in sustainability reports. Most companies' publications state the intent to be climate neutral by 2050 (or earlier), in accordance to IMO targets, however those claims are not unanimous, as there is also skepticism about such goals present in some publications.

In order to combat emissions, companies employ a variety of solutions, from immediate operational actions that are relatively quick to implement, to long-term net-zero plans which will be possible with sufficient infrastructure.

Energy/fuel efficiency measures are those that reduce pollutant emissions regardless of what fuel a ship uses, as they are aimed at reducing emissions by making a ship more efficient and use less energy and fuel to operate. They include:

- Routing, scheduling and navigation optimization: reduction of fuel consumption through slow steaming, implementing the virtual arrival system (thus reducing waiting time at ports), modernizing the planning, monitoring and management systems. Such solutions are possible thanks to developments in the IT, communication and data analysis areas, as both companies and ports implement new tools for more efficient operations.
- Implementing shore power connections, LED lights, technology for using engine waste heat for internal heating, battery packs and other power efficiency measures that lower

the need for on-board generated electricity, which is produced by the ships' on-board generators.

- Drag reduction, better cleaning of outside surfaces, air lubrication and more efficient hull shapes that help reduce the amount of energy needed per distance travelled.

These are needed before the transition of the industry to new types of fuel, as making ships more fuel-efficient and, as a result, more environmentally friendly, is not only a more feasible task in the scale of a company, but also would help save money on more expensive fuel in the future.

LNG is one of the most prominent solutions of today, as it is a significantly cleaner alternative to conventional fuels. It does not contain sulphur and it emits significantly less carbon dioxide and NOx when burned, and various companies are already using ships powered by LNG to reduce greenhouse gas emissions and meet IMO requirements. Compared to other alternative fuels, LNG is highlighted quite frequently, and the demand for it is rather high, and companies are already launching ships that either use it as fuel, or have the capability to do so, thanks to new engine technology.

Zero-emission fuels are promising future solutions in transportation of goods by ship. Some fuels have a chance of being zero-emission fuels if they are produced from renewable sources and ecologically clean energy – such as green hydrogen, green methanol and green ammonia. These solutions are enthusiastically viewed by companies as potential late stages of their long-term emission reduction and net-zero plans and some companies are beginning to implement them, but at this point there is no certainty in one specific "fuel of the future" definitely being superior to the others. All zero-emission fuels have advantages and drawbacks which are currently being researched.

As of this moment, companies find themselves in need of "**drop-in fuels**", that being those that not are not acting as the dominant long-term solutions, but can be implemented now or in the near future as means of reducing emissions to match the set regulations.

When it comes to waste management, companies announce their obedience to EU's and IMO's regulations regarding wastewater: equipping ships with obligatory ballast water treatment systems to prevent invasive species from spreading in the Baltic Sea, delivering generated waste to port facilities, and implementing other measures to conserve water and treat onboard

waste. Through collaboration projects, some waste like sewage, cooking oil and solid food waste can be converted to energy (as biofuel/biogas) or fertilizer.

4.2 RQ2 - Challenges of sustainable development in shipping

The **lack of availability of green fuels on the market at the scale needed for modern shipping** companies is one of the constraints of sustainable development. Given the technological limitation of propulsion systems on existing ships and the price issues, it is out of one single company's scope to currently transition main operations to a different type of fuel, but a decision of multiple actors in shipping, legislation, and the fuel and energy industries. EU's emission trading system is projected to reduce emissions in multiple sectors including shipping, but that would come at a cost for companies that cannot meet the requirements in time, and that is likely to affect consumers. The **market of alternative fuels is developing and unstable**, with price fluctuations adding to the risk.

"Initially, emissions-trading will be a direct tax for us, as there are no alternative fuels available to switch to" (translated from Swedish) was Viking Line's information director's commentary to the fines for carbon dioxide emissions that the company is facing in the near future, as EU's cap on carbon emissions would include maritime transport starting in 2024. The company is researching the market of alternative fuels, but right now there is no available replacement on an industry scale (Sandström, 2023).

The company's newest builds – Viking Grace and Viking Glory, which are currently operating, use LNG as their main fuel, and were built with biofuels in mind (as will be future ships ordered by the company), but currently cannot switch to them due to the lack thereof on the market. (Viking Line, 2022)

Tallink Grupp outlines this problem as the main deterrent in reaching emission reduction requirements – their aim of reducing fleet emissions by 2% annually is "not enough to reach the targets set for shipping by 2030, but <...> it is a realistic target as there are no alternative fuels to get [the company] to the goals set for [the] industry". Just like other shipping providers, this company is actively reducing carbon emissions by increasing energy efficiency, improving measuring and data collection systems for operational optimization, but these areas are short-term and secondary in comparison to the fuel aspect, as reducing carbon emissions becomes

more challenging over time. “We have picked all the low-hanging fruits already and now have to reach further and higher to achieve results” (Tallink Grupp, 2021).

> In shipping today, it is challenging to find zero-carbon fuels in large quantities, in several locations and engine technology with these fuels. Whichever option is chosen, it must be safe, reliable, maintenance proof, in compliance with national and international regulations and economically viable for the shipowner (Finnlines, 2022)

LNG is currently high in demand, however, it is still a fossil fuel, so many companies view it as a transition phase before zero-emission fuels can be reliably applied at scale. In addition, the unstable market and price fluctuations can also hinder its implementation. Europe imports its LNG, and the global geopolitical situation in the world affects the costs.

> [...] the lack of new solutions that would be commercially available - there are not very many. A few years ago LNG seemed like some kind of solution, although it is a fossil fuel and we need to get rid of those, but anyhow.
> But now? LNG is very expensive and I don't see that it would be a future fuel. (interview respondent from BSAG).

Extensive testing periods for new technologies, especially when switching to a different type of fuel is involved, also slow down their implementation. Transitioning to sustainable, low-emission or emission-free fuels requires lengthy periods of adapting and testing the new solutions and that process can be delayed by emerging challenges during the testing phase and while the industry is developing. “When you do research, then you need to test the new solution for some time, and sometimes you get some surprises during that part. <...> It takes many years to test a new solution” (interview respondent from BSAG). This is also named as an impactful cause for delays in fulfilling commitments to sustainable goals - initiatives made on a company or location level can be complete in time, but there is no guarantee that external factors would allow them to be implemented to the full potential in time.

> [When] there are intentions in the project like “in five years we will have this kind of ship” or such, I know that all the participants are doing their best, but sometimes the technology is just not ready. And for example, ammonia, is very difficult in the sense that we don't have enough data on the practical environmental effects (interview respondent from BSAG).

In the fuel industry, development of safety measures for production, storage, transportation and use also takes time to be sufficient for the management of hazardous factors, those being, among others, the leaks of unburned methane into the atmosphere when LNG is burned, the

toxic and corrosive nature of ammonia, and hydrogen's explosive potential in case of leaks when it combanies with air.

Energy density is another constraint, as a significant drawback of many alternative fuels like methanol and LNG is lower energy density than traditional fossil fuels like diesel. Transition to those would cause a reduction of container space on cargo ships, as more space would need to be allocated for fuel storage in comparison to diesel-powered ships. This is especially true for promising gas fuels like green ammonia and green hydrogen – more spacious bunkering (storage) facilities are needed to contain sufficient amounts of such fuel for modern shipping. In combination with the cost issues and an unstable developing market of alternative fuels, the energy density issue calls for more solutions in the areas of operational optimization and energy efficiency of both existing and newbuilt ships, to mitigate the effect that switching to green fuels is likely to have on the finances of the companies.

> When it comes to ships in motion, issues such as energy density, weight and volume, not to mention safety aspects, should be considered when choosing fuel and technology (Viking Line, 2022)

Country-wide and EU-wide **electrical infrastructure development** and EU's capability to influence raising **the share of green energy** of its members are also notable challenges in sustainable shipping. As more companies implement shore power connection while at berth instead of relying on internal power generation (a solution also known as cold-ironing), commercial shipping's impact on the environment depends more on production of electricity in countries where ships stay at ports. Apart from the shore power aspect, the sourcing of electricity is also true for fuel-based solutions, as the amount of emissions released during the production of such fuels as methanol, ammonia and hydrogen depends on the state of renewable electricity where it is produced. Such fuels can only be called "green" or "carbon-neutral" if the power used in their manufacturing is obtained from renewable, carbon-neutral sources.

> I think that hydrogen is one of those as a fuel solution because the production needs to be green, and for that we need green electricity. So most likely now that there are many projects with the wind and solar power, that will change the situation. (Interview respondent from BSAG).

The following table shows issues and general trends regarding some of the most frequently mentioned and implemented fuel/propulsion-based solutions (a more area-based table is attached as appendix 2):

Table 3. Fuel-based solution challenges

Solution	Challenges	Other notes
Green fuels (green hydrogen, ammonia, methanol)	Need more practical data, lack of availability and infrastructure, low energy density, green energy needed, demand must be shown to encourage development	In the long term, seen as zero-emission "future fuels"
Liquified natural gas (LNG)	still a fossil fuel, low energy density, methane slip, unstable market	One of the solutions seen as transitional
Biodiesel	Expensive/unstable price, lacks scale	One of the solutions seen as transitional
hybrid/battery packs	mainly for short distances, Li-ion battery recycling is an issue	Solution for reduction of GHG emissions but involves other pollutants
Operational / energy efficiency optimization	Needs good data, IT infrastructure, analysis methodology, retrofitting. Fuel replacement is still essential	Still helps reduce fuel consumption and GHG emissions

As for wastewater management, companies show willingness to deliver waste to ports. However, specifically in the Baltic Sea region, **information and communication** are an issue because of the region's special status. A publication by Port of Helsinki states:

> Cargo ships in particular are not aware of the special conditions in the Baltic Sea nor of the No Special Fee payment system at Baltic ports, where a waste fee is charged regardless of whether the ship leaves waste at the port or not (Port of Helsinki, 2021).

The Baltic Sea Action Group provides info on wastewater-related regulation of the region and the No Special Fee system, but it will likely take some time to get used to this relatively new aspect. According to BSAG, the "No Special Fee" system is there to simplify the process of discharging waste to port facilities and encourage ship operators in the Baltic Sea to do so, as the port infrastructure, including waste reception facilities, is evolving to accommodate the new needs.

A **constantly-changing global playing field** is another issue that cannot be overlooked, as commercial shipping is involved in a lot of affairs and affected by a multitude of factors. Influential regulations to combat climate change are a relatively new topic, legislation gets updated and there are many ongoing negotiations between companies, researchers and policymakers. In addition, viability of some solutions is affected by global crises like geopolitical conflicts, economic sanctions and war, while the companies are still processing the changes brought by the COVID-19 pandemic and the following recovery period. For some sustainable solutions, **immense amounts of collaboration between different organizations** of various levels is needed.

> Tackling the global climate crisis and realizing the ambition of reaching net zero emissions in time will require massive changes in industry, governance and society (Maersk, 2022)

5 DISCUSSION

This chapter provides an analysis and review on the received results of the study – what was discovered in the research and how the findings are related to one another and the previous theoretical information. Afterwards, the method is discussed, with its positive and negative sides, as well as what other research methodology could be used for more specific results.

5.1 Discussion of results

The documents show that companies acknowledge the impact of climate-impacting pollutants released by human activity, including shipping, and aim to follow the new regulations that involve reduction of pollution and emissions in shipping. Companies overwhelmingly use the UN's sustainable development goals when outlining their sustainability strategy and categorizing data within publications, as those goals are well-known in the area. Climate change-related goals (such as "Climate action" and "Life below water", among others) are given additional attention as those closely related to the companies' activities. The exponentially rising temperature increase also creates a sense of urgency regarding the matter, which is visible in the publications.

The current regulations by EU, IMO, as well as HELCOM's guidance, drive the sustainable development of companies, which, however, is not always in line with them, which requires additional financial resources to pay the related fines. Even though the time frames can be too

constraining in some cases, such regulations encourage the industry-wide transition towards which the shipping companies are working.

The high attention towards specifically carbon emissions can not only be explained by the tightening EU regulations, but also by the impact of CO2 as a more difficult to phase out climate-impacting pollutant than sulphur oxides (which, for example, are not present in LNG) and the volume of it, which is significantly higher than the volume of other pollutants released by ships, as HELCOM's calculations show. Pollutants like NOx and particulate emissions are usually not given as much attention because the eventual transition to carbon-neutral/emission-free "future fuels" aims to eliminate (or lower to negligible amounts) those pollutants as well, along with the "primary" mission of carbon neutrality. However, the special status of the Baltic Sea as an area with nutrient pollution issue drives forward today's development and implementation of more modern exhaust gas cleaning systems, as well as better waste management.

Throughout the whole analysis, it was apparent that most issues in the area are interlinked, and the development of solutions is going on at the same time in multiple directions. In general, the results show that today's shipping companies are active in sustainable development on multiple "fronts" at once, including developing collaborations with policymakers and third-party projects for sustainable fuel sourcing and waste management, in order to have better communication and achieve results in the whole industry. The studied companies, while working on multiple ways to reduce emissions at the same time, follow a pattern of order of prioritization based on what solutions are possible at this moment (like operational optimization and fuel consumption reduction) and which need more time for research and development. The efforts to reduce fuel consumption through operational means and design more efficient hulls would pay off in the long run, as the companies switch to more expensive fuels. The companies display similar views on future fuels: they view green fuels enthusiastically, but cannot yet fully rely on them, which is why they use dual-fuel engines in newly-built ships, as flexibility is needed.

When it comes to electricity, companies mention shore-power connections as a part of their sustainability strategy as they take into account the development of renewable energy towards the end goal of all electricity being produced sustainably. Such plans and decisions show the

companies' interest in the trend of renewable energy development and reduction of electricity production's impact on climate change, as well as take an active role in EU's climate strategy.

The final results, as the whole work, are limited by the author's level of expertise, as they concern multiple areas regarding transportation, energy, governance, and other directions of research. However, in this rapidly evolving field, they provide helpful insights about the state of the area at this point of time and the current developmental trends and issues.

5.2 Discussion of method

All in all, the chosen methods worked as intended during the research process. The analysis of the documents allowed to outline current solutions, future solutions, and challenges in the way, while the interview provided supplemental information, which, in some cases, aligned with the trends seen in the documents, and in other – showed a different perspective on the situation (for example, regarding the perspectives of LNG and the companies' fulfillment of sustainable development goals).

During the documentary analysis, the differences in structure and organization of the documents posed a certain difficulty: it was not always obvious which solutions a company prioritizes, and some areas (for example, CO2 emissions) were sometimes given more attention than others (such as wastewater management). Another way of researching companies' sustainable development would be more narrowly - with a quantitative analysis, using published figures on emissions and fuel consumption as data, and making predictions on future trends based on that.

In many cases, the broad definition of sustainable development was reflected in the documents: a lot of sustainability-related publications not only contained data on combating climate change, but also on areas like workplace equality and fair treatment of employees. While important in general, such chapters were not analyzed in the scope of this work, which focuses on climate-related sustainable solutions.

The interview went smoothly, and the respondent was eager to share their knowledge in the field of sustainable shipping, its recent trends and development of sustainable solutions. Real-life case examples were used to demonstrate obstacles in the area. However, some technology

questions proved difficult to answer in detail. For more in-depth technical data, interviewing different types of specialists (for example, in energy and engineering fields) would yield more details on the technological aspect of ships.

The validity of the study is influenced by the nature of the analyzed documents, in which the publishers, being corporations, aim to highlight themselves in a positive way to the customers and investors, as it is of interest in a competitive market. Because of that, certain commitments, such as specific future dates of achieving net-zero or other milestones, cannot be considered 100% accurate predictions, despite most companies being optimistic about achieving them. However, the publications still allowed to see which areas are more troublesome than others, which solutions are being implemented, and what is the course of future development.

6 CONCLUSIONS

Throughout the study, which aimed to gain a better understanding on the current state and issues of sustainable development, company publications on sustainability were analyzed and an interview was conducted to gain a better understanding on what barriers sustainable development in commercial shipping faces today. With the help of documentary analysis and interviewing an expert from a collaborative action group, it was possible to obtain the answers to the questions of what solutions are actively being (or have been) implemented today to reduce pollution in shipping and what challenges this direction of development faces.

All in all, the results show that modern shipping is rapidly evolving to match emission reduction regulations by IMO and EU by implementing an array of solutions on their path to becoming climate-neutral. The regulations, while pressuring, do not seem unreasonable or unfeasible to most studied companies. However, there are several obstacles that make that development more challenging and, in some cases, not fast enough to follow the regulations' requirements. Some of the most notable at this point in time are:

Viability/availability of alternative fuels – such fuels currently exist and ships powered by them are already being used by shipping and ferry companies, but it is still a developing industry which would **need a lot of coordinated effort** to replace traditional fossil fuels**.** What is more, multiple alternative fuel solutions are being researched and implemented at the same time to fulfill different purposes.

The scale of the industry – the size and amount of ships and the resources and infrastructure involved in shipping make fleet updating a slow and costly task. However, with the recent trend of sustainable development and with companies working in collaborations with each other, researchers, Baltic Sea protection organizations, ports, fuel producers and lawmakers, the anticipated **industry-wide changes** are becoming more feasible.

Information and communication issues are bound to happen with a lot of actors in the area, but at least to some extent, this issue is being resolved with more up-to-date digital systems, data collection and analysis utilized by companies active in the area.

Electricity must be renewable in order for "green fuels" to be emission-free and for solutions like shore power and hybrid/electric propulsion being sustainable. The progress in this direction is country-specific and depends on long-term strategic decisions.

A general high uncertainty in the area caused by a multitude of factors: new, often updated legislation, ongoing negotiations, unstable political relationships.
Despite these drawbacks, as various organizations work together to fight climate change and related challenges, the situation is projected to improve, as new technology is being developed and tested and companies are getting more experience in the developing and essential area of sustainable development.

The results show the high need for research in the whole sustainable development area, not only in shipping, but in other industries that it in some way interacts with, which is a very wide range.

7 Suggestions for future studies

"Sustainable solutions" and "sustainability in shipping" are broad terms, various aspects of which were examined in this study, but this work cannot provide in-depth coverage of the whole area, as there are many factors involved on corporate, governmental, local and global scales. For more in-depth research, more specific areas (for example, certain fuels or technology in shipbuilding) should be chosen for examination.

There is a lot of research room in ship propulsion, green energetics, alternative fuels, waste processing and eco-friendly transportation, different topics requiring different qualifications and academic backgrounds.

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APPENDICES

Appendix 1 – Current solutions

doc #	company	Fuel consumption	Fuel-based emissions	Waste mgmt	Infrastructure development	Sustainable goal commitments	Other notes and important quotes
1	MSC	More energy-efficient newbuilds, using IMO's EEOI, retrofitting energy-saving solutions like LED's and variable frequency drives for ventilation and pumps. **Digitalization** helps improve energy efficiency through monitoring and analysis	**Green ammonia, green methanol - likely dominant solutions**. **Green hydrogen, fuel cells, batteries - for shorter distances**. "Hybrid Exhaust Gas Cleaning System installations that can operate in both open and closed loop (being retrofitted)	Cruise ships: 11 ships (71% capacity) equipped with "advanced wastewater treatment systems". Newbuilds equipped up to "Baltic standard". "Requirements of EU directive (2019/883) fully integrated into waste management protocols"	"Working closely with governments and encouraging effective policy measures to support **an industry-wide transition**"	"Carbon net zero by 2050: more ambitious than IMO's targets", "MSC's pathway to logistics decarbonisation focusses on working towards carbon neutrality; supporting logistics transition solutions; and continuing energy efficiency programmes across the whole Cargo Division"	Net zero measures: "**Operational efficiency**", "low/zero carbon fuels", "retrofit technology", "progressive ship renewal". First **LNG-powered cruise ships** deployed, **hydrogen-powered** project in research
2	Maersk	"Improving fuel efficiency is an area Maersk knows well": **fleet and network optimization**, larger vessels", cargo optimization etc.	**Dual fuel methanol-engine vessels**. New ships ordered for **green methanol** while other solutions are researched. "methanol only scalable green fuel option this decade" It will take time to reach the scale to cover the demand, so an alternative 'drop in' fuel is necessary to fill the gap" (**biodiesel**)	Ballast water treatment systems, "During 2022, we issued such requirements across our business for a broad range of areas including waste management, spill prevention, control and response, water and chemical management"	"our efforts must be matched at the industry level in order to successfully accelerate a green and equitable energy transition" "switching to **renewable electricity, direct electrification, battery electric mobile equipment and green fuels when needed and possible**. We also deploy an energy optimization programme..."	"**2040 - net zero** across the business". Ocean: ~50% reduction in carbon intensity (EEOI) by 2030 (2020 baseline) Science-Based Targets initiative guidance - Aligned with a Science Based Targets initiative 1.5-degree pathway.	Regulators in Brussels were left with the difficult task of assessing and evaluating which input warranted real attention, and which positions were unhelpful to the goal of decarbonising shipping. Securing the **availability of green fuels at scale** is the **largest challenge** to our decarbonisation ambitions
3	Finnlines	More **energy-efficient hybrid vessels, optimization** of routing and scheduling. "**all types of engines and fuels are still needed** in order to enable a similar, gradual shift to more environmentally friendly fuels and engine technology **when they become available**"	"gradual transition to carbon-free and renewable fuels is being investigated", "All the Grimaldi Group's most recent newbuilding orders include an **ammonia-ready concept**". **Li-ion battery packs, air lubrication, exhaust gas abatement** on new hybrid ro-ro's	Ballast water treatment systems. "Finnlines' ro-pax vessels land black and grey water to onshore municipal sewage systems. Cargo ships are equipped with sewage treatment plants, which have been certified by the administration. The target is to gradually reduce and stop discharging also treated waste water into the Baltic Sea. When technically feasible, some of the cargo ships are already delivering their treated waste waters into shore	New **ERP** system, EDI messaging, started installation of **shore-side power connection** on Star-class ro-pax vessels in coop with the ports of Helsinki and Travemünde, investing in new tug masters with 96% less NOx emissions and 97% particle emissions	Aligned to **reduce carbon intensity by 40% by 2030, matching IMO targets.** Aiming at annual reduction of 2%	"Finnlines has installed exhaust gas cleaning systems on 21 vessels since 2015 and will continue the project by installing equipment on the two remaining vessels". "Finnlines co-operates with **waste** management companies to reuse, recycle or recover waste in an efficient manner and waste is **reprocessed into material or recovered as energy**" "In 2022, the focus continued to be on environmental investments in vessels and on improving vessels' **energy efficiency**."
4	Viking Line	"Since 2008, we have reduced our fleet's **energy consumption** per nautical mile by over 30% and we have tried several different cleantech solutions on our vessels. In recent years, **the work has intensified** and become more purposeful", "...finding solutions to **make the ships more energy efficient in order to reduce the need for fuel**"	Newbuilds "are built to be operated with **biofuels or synthetic natural gas**, that is, natural gas that does not have a fossil origin. This means that the ships are technically **ready to operate carbon-neutral today; the challenge is a sufficient supply** of alternative fuels and their significantly higher prices"	"Our vessels never discharge waste-water into the sea. Everything is pumped to municipal treatment plants on land." "On board Glory, biowaste is also collected and used in biogas production"	Viking Line is participating in a Finnish consortium that assesses opportunities to form a green transport corridor between Turku and Stockholm, one of the EU's TEN-T transport corridors.	Partners to support the Baltic Sea environment: John Nurminen Foundation, Keep the Archipelago Tidy Association University of Helsinki – Tvärminne Zoological Station. Fleet updating, operations modernized to match new standards - "We are thus **well positioned to meet future demands**"	"Viking Glory is one of the world's first ships to have Wärtsilä 31DF dual fuel engines and is powered by liquefied natural gas (**LNG**). They enable optimization of fuel use but produce no sulphur emissions at all. Furthermore, they produce fewer carbon dioxide emissions than do diesel engines. Like Grace, Glory will also run on **biogas or synthetic fuels** produced using renewable energy **when these are available in the future**"
5	Viking Line (Yle article)	"**Bränslepriserna** har redan fördubblats och nu kommer utsläppshandeln därtill"	Först måste rederierna satsa helhjärtat på att bli så **energieffektiva** och **bränslesnåla** som möjligt	-	"De finländska rederierna har traditionellt varit pionjärer inom fartygsdesign och **miljövänlig teknologi**"	På sommaren godkänns antagligen en ny strategi med målet att den globala sjöfarten ska vara **klimatneutral år 2050**	Utsläppshandeln får sjöfarten att försöka hitta så **kostnadseffektiva** sätt som möjligt att minska utsläppen
6	Tallink Grupp	"The main objective still shall be the development of adequate fuel consumption **measuring** capability. Adequate measuring will form a solid base for further **automation of data collection and the reporting routines** as much as possible in the future"	"we are definitely able to reduce our fleet emissions annually by 2%. It is not enough to reach the targets set for shipping by 2030, but it is the truth and a realistic target at a time when there are **no alternative fuels to get us to the goals set for our industry**"	Tallink works with BSAG to reduce nutrient emissions from maritime traffic, "4 years of zero-tolerance policy on unloading wastewater at sea" - blackwater and greywater unloaded at ports	**Shore power** where possible, auto-mooring, "We maintain and develop our Environmental Management System in order to improve continuously its performance and comply fully with all relevant legal and other obligations. The company's EMS will maintain its certified status.	"We **do not believe in claims like zero waste, zero emissions**, zero something else by **2030, 2040 or 2050** when we know that, as things currently stand and what we have available today, these goals are **already unachievable.** We are therefore much more focused on working hard at and chasing goals that will definitely deliver"	...CO2 per passenger reducing by 44.5% between 2009 and 2019. But every percentage point of reduction from now on takes more effort and is harder to achieve as we have picked all the low-hanging fruits already and now have to reach further and higher to achieve results. Carbon Efficiency Indicator and other requirements "might turn out to be increasingly challenging and can become burdensome financially as well as technically, requiring a constant reassessment"
7	ESL Shipping	**Virtual arrival, electric-hybrid powertrain**, cargo space arrangement optimization, 1MWh **battery pack**	Neste co-processed marine fuel as **drop-in** fuel, **LNG vessels** capable of running on **liquified biogas**,	"All waste generated onboard is sorted and delivered to reception facilities ashore"	**Shore power** connection on newbuilds	"**Net zero CO2** emission operations by **2050**", 50% carbon intensity reduction by 2030, all greywater pumped to shore facilities by 2030, "Commiting to Science Based Targets by 2023"	
8	Eckerö Line	we **optimize operating speeds**, for example, and ensure the treatment of ship's hull, which in traffic directly affects fuel consumption and thus emissions. **Speed adjustments** and technical improvements..., LED lights	"To reduce greenhouse gas emissions, we use a low sulphur fuel with a sulphur content of 0.1%. Ship specific emissions are measured and monitored and the results are reported to the EU and IMO"	"All wastewater unloaded in shore facilities, sorted waste treated at Green Marine treatment plant"	Shore power development and other energy efficiency measures	The Group is committed to achieving the **IMO's target** of reducing emissions from the the shipping industry by **50% by 2050** measured from the 2008 level. Short-term environmental goals shall be set with this in mind.	"biggest sustainability challenge in terms of ecological responsibility is to find a way to power the propellers and produce electricity needed onboard without using fossil fuels in the future"
9	DFDS	Short-term plan:modifications of propellers and bulbs, improved coatings, decision support systems, **AI for monitoring**	**Green hydrogen, green ammonia, green methanol** seen as future solutions. Introducing small amts of methanol into existing engines **to push market demand.** Retrofitting scrubbers	"DFDS has invested in MASH Energy which is developing a method to produce commercially viable **biofuel** from agricultural waste"	Facilities and terminal development, sustainable procurement,	reduce emissions by 45% by 2030, be **climate-neutral by 2050**	
10	port of HEL		Making alternative fuel available at Helsinki ports is one of the targets for vessel emission reduction		completion of onshore power connections on both sides of West Terminal 2 for liner traffic vessels.	To reduce emissions from vessels by 25% by 2030, become carbon-neutral in terms of its own emissions by 2025.	Upturn in traffic increased carbon dioxide emissions

Appendix 2 – State of solutions by area

	Energy efficiency / fuel consumption measures	Alternative "drop-in" fuels of today	Transitional fuel/propulsion	"Future fuels" for net-zero goals	Waste management
Prominent solutions	Shore power connections, operational optimization measures (virtual arrival, route management and speed optimization), drag reduction	Biofuels (biodiesel, biogas, HVO), fuel from waste oil etc.	LNG, dual-fuel capacity engines, hybrid-electric technology with Li-ion battery packs (for short distances)	Green hydrogen, green ammonia, green methanol	Delivering waste to port facilities, fuel-from-waste projects, ballast and bilge water treatment systems
Order/priority of implementation	Already implemented, additional development continues, new ships build with shore power connections	Being researched and implemented on test scales in some companies	Actively being implemented on a number of ships. Use projected to increase as infrastructure develops, new ships being built with LNG capacity	Methanol implemented on a number of ships and amount of new orders increases, but in general, at this point, LNG implementation is of larger scale.	Actively being implemented in accordance to regulations.
Feasibility, according to companies	One of the "quickest" directions to advance today, but to a finite extent (this does not remove the need to switch to more sustainable fuels)	Easy to use in existing engines without major technical rebuilds, but price and availability are significant constraints	Feasible for reduction of GHG emissions, but not as "net zero" solutions, especially batteries	Can't be implemented on an industry-wide scale today, but seen as perspective emerging solutions, for which there is demand in the long run.	Generally, not seen as a problematic area to comply with the regulations

Appendix 3 – interview guide

INTERVIEW GUIDE: Maksim Sumin

The thesis: "Challenges of implementing sustainable solutions in commercial shipping"

The thesis is the degree thesis of the study program "International Business" with a major in logistics. The aim of the research is to gain a better understanding on what sustainable initiatives are currently taking place and what obstacles are the most notable in implementation of sustainable development initiatives by shipping companies.

The primary method of research is documentary analysis of published sustainability reports, plans and roadmaps of companies performing shipping operations in the Baltic Sea area. The interview is done with the purpose of receiving supplementary data from an in-field expert to compare with data from written sources.

The interview will be referenced in the thesis as one of the sources, but the original recording, as well as the name of the interviewee, will only be available to the author, the research supervisor, and the thesis assessor.

Respondent information

The interview, which is supplementary to documentary research, is carried out with an expert from Baltic Sea Action Group. BSAG is a collaborative project aimed at preserving the Baltic Sea environment and implementing sustainable projects, including those in the area of commercial shipping.

The original recording and text of the interview, being sensitive information, will not be published with open access, but handled as confidential data. Before the interview happens, the interviewee would receive a consent form to sign, which states:

- The academic purpose of the interview
- The interviewee's permission for the use of the interview data in research
- The fact that the interview is being recorded and the information about confidential handling of received material
- The right to refuse to answer any question the interviewee chooses not to answer, or withdraw the consent to use the data before the thesis is published

The right to contact the researcher or the institution (Arcada) with possible further questions about the research

The interview

Place and date of the interview: online, 17.05.2023
Company: Baltic Sea Action Group (BSAG)
Name of the respondent: anonymous
Position of the respondent: anonymous

The questions (by topic / by research question)

Introductory:

- Technical questions (connection, sound, recording)
- Experience in the field: "What is your experience in the area of shipping?", "How long have you worked with reduction of shipping's impact on the environment?", "How long have you worked in the current position?"
-

RQ 1: What sustainable development initiatives are currently taking place in shipping?

- What solutions are currently being implemented to reduce carbon and other greenhouse gas emissions?

- What solutions are currently being implemented to reduce fuel consumption?

- What solutions are currently being implemented to reduce amounts of waste being released into the sea?

- What other prominent sustainable initiatives of today can you name?

-In your opinion, what further legal action is needed to speed up sustainable development?

RQ2: What are the obstacles in implementation of sustainable development initiatives by shipping companies?

Carbon emissions:

- What are the main barriers in reducing carbon emissions in shipping? Why do you see _____ as (a) significant obstacle(s)?

- Is it feasible for companies to reach net-zero carbon emission goals by 2030? If not – why not?

Waste management:

- What are the main challenges with ship-generated waste management?
- Can ports eventually accommodate all needs of ships in terms of waste processing?
- Can the need for unregulated/illegal waste disposal be eliminated? How? If not – why not?

Technological limitations:

- What main technological challenges regarding sustainability in today's commercial shipping can you name?
- What pollutants cannot be removed now due to technological limitations?
- Can technological development keep up with tightening legal regulations from EU authorities and IMO? Why – what makes it feasible / infeasible?

Finances:

- do companies invest enough funds in sustainable development projects nowadays? If not – why not?
- what solutions are currently expensive, but can get cheaper as the industry develops? (green fuel? carbon/GHG emission filtration? wastewater processing?). Why would/wouldn't they get cheaper?
- Commitment: do participants of the collaboration maintain the schedules they set? Are sustainability commitments realistic? If not – why not?

Ending

The interview is complete when all the questions are considered answered and sufficiently discussed. At the end, the interviewee is thanked for the time they allocated to help the study and for their contribution to the research.