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The Emission Accounting Ecosystem

Case: Finnish Domestic Passenger Shipping Industry

DEGREE PROGRAMME IN MARITIME MANAGEMENT
2023

ABSTRACT

Lähde, Pyry: The Emission Accounting Ecosystem, Case: Finnish Domestic Passenger Vessel Industry
Master´s Thesis
Maritime Management
May 2023
Number of pages: 85

The aim of the study was to map the general emissions from domestic passenger ships and to examine the carbon footprint of the industry. The study also presented the calculation and modelling of emissions for a more detailed future mapping.

The study was conducted as a multi-method study. The numerical proportions included quantitative research, and the interview part, in which other main emissions were mapped in addition to exhaust emissions, consisted of a qualitative research approach. Statistical articulation methods were used in the evaluation of the study.

The research results show that the carbon footprint of domestic passenger ships is statistically significantly lower than that of passenger ships that consume 100-200 MT of exhaust emissions. The study also clarified the calculated share of other exhaust emissions in addition to carbon dioxide emissions. In addition, the results of the qualitative share show that the entire industry has already taken significant measures to promote carbon neutrality through local food and the circular economy.

Keywords: carbon footprint, domestic passenger vessels, ocean-going passenger vessels, co2 calculation

FOREWORD

I would like to thank the domestic shipping companies and their representatives who participated in my thesis, whose role during the research was relevant and whose time commitment to the research was significant. I would also like to thank Sami Skog, a logistics expert, and Kimmo Kauko, a chief engineer and lecturer, who assisted with the technical aspects of the project. I would also like to thank Soile Kiuru, the English language checker, for an excellent language check. To the thesis supervisors, Ninna Roos and Peter Sandell, I would also like to express my thanks for completing the work after a major undertaking. I thank my family and friends for supporting me in my work.

I wish readers a pleasant reading time and, along with international travel, enjoyable experiences on domestic cruises!

CONTENTS

LIST OF SYMBOLS AND TERMS

EN	European standard (Standard in the EU area).
EU MRV	European Union Monitoring, Reporting, Verifying system for greenhouse gas reporting
GHG	Greenhouse gases.
GT	Gross tonnage measure for ship´s overall internal volume.
IMO DCS	Emission data collection system for vessels subject to IMO regulations.
ISO	International Organization for Standardization.
Lipasto	The calculation system for exhaust emissions and energy consumption in Finnish transport.
Standards	Norms that contain requirements, recommendations, or characteristics for products, systems, and services.

1 INTRODUCTION

The EU has ratified the Paris Agreement of 2015 which, in summary, “sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C.” (European Commission, 2022 part of Paris Agreement). The EU law concerning environmental regulation ratified by the European Parliament has been much more precise and directly addressed to the Member States. In particular, the regulation underlines two essential points. The EU is committed to reducing all its greenhouse gas emissions from the 1990 levels by at least 55% by 2030, and its aim is for the economy and society of Europe to become climate-neutral by 2050. (Regulation EU 2021/1119)

Each Member State has set its own objectives for achieving the goal based on their gross domestic product. Emission trading in shipping and transport, which is linked to reduction objectives for Finnish business and shipping, has caused debate at the national level. The EU Sulphur Directive, which came into force in 2015 and is based on the IMO air protection regulations, limits the sulphur content of ships operating in the Baltic Sea, the North Sea and the English Channel to less than 0.1% (IMO Sulphur emission control areas, 2022). This can be done with a low-sulphur fuel or a sulphur scrubber. (Finnish Ministry of Transport and Communications, 2022).

To be able to look at the objectives of companies' operations, a program must be created for the industry to look at overall emissions and, on a case-by-case basis, to see what can be done to reach the goal. In companies, climate issues have become the focus of future business processing in strategy development. The strategy is based on information about the company's actual carbon footprint.

A great deal of companies that have been operating for decades have acted responsibly. However, a company must have concrete evidence to demonstrate the sustainable commitment of Business Finland (Business Finland, 2021). Financial institutions and tour operators have the opportunity to verify that companies are responsible and that their operation is run in a sustainable manner.

In reaching the emission goals, consideration of shipping is also listed as part reducing overall emissions. The overall emissions from shipping are very different for each vessel and ship due to different types of vessels and shipowners. The calculation also varies. For passenger ships, the role of the economic department and passenger emissions also need to be considered very differently than, for example, a container ship that does not have the same services or number of crew as passenger ships, that has instead a couple dozen crew members carrying thousands of containers. However, the emissions from carrying a ship can be classified in the same categories, and the same types of ships are comparable.

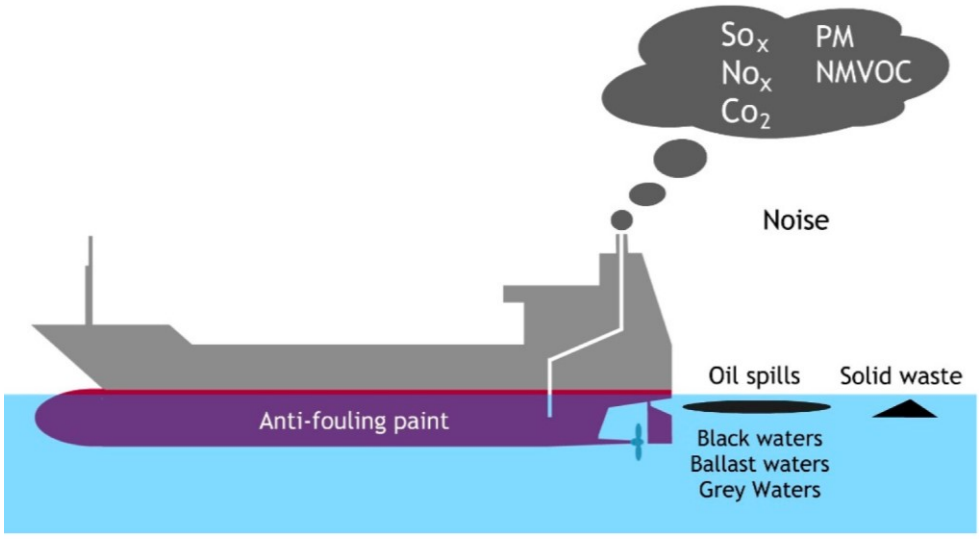


Image 1: The most common emissions from operating a ship (Bacalja et al. 2020, 2)

The main environmental impacts of ship emissions fall into three categories: marine, gas and noise emissions. These categories have a significant global impact, for example through the atmosphere or the impact of emissions or noise on the marine ecosystem. Greenhouse gases from ship exhaust fumes commonly include nitrogen oxides (NOX), carbon monoxide (CO), volatile organic compounds (VOC), sulphur dioxide (SO2), particulate matter (PM) and greenhouse gas (carbon dioxide (CO2)). Marine emissions include sewage, litter, ballast water from various ecosystems and antifouling paints. The significance of noise emissions is currently the subject of considerable debate.

To identify ship-specific emissions, protocols for calculating the emissions that have been developed directly from or by application of national or international legislation must be applied. For determining emissions from ship companies and vessels, similar models can be applied to the same extent as those used by companies in different sectors, from the identification of emissions and the analysis of the initial situation to the implementation of changes in the activities inspected. It is essential to look at emissions and company activities as a whole. The thesis focuses on determining CO2 emissions from domestic passenger ships and comparing them with passenger ships operating in international traffic, which are not subject to the international EU and IMO regulatory frameworks in the Baltic Sea region.

1.1 The purpose and objectives of the study

The purpose of the study was to find the sources of the carbon footprint of passenger ships of less than 500 gross tonnage operating in domestic traffic in Finland, and to determine the carbon footprint of ships of less than 500 gross tonnage. The aim is to acquire the most accurate general impression of the current situation. The purpose of the thesis is also to briefly present solutions for the future and to examine the responsibility of domestic water transport in relation to larger operators of different sizes. The results of the thesis serve as a basis for creating future strategies for shipping companies and they can be used as indicators of the responsibility of companies. The locations where the

ships operate determine their total carbon load, making it possible to use the results of the survey as a location-specific assessment of the carbon footprint.

1.2 The research tasks and topics of the study

The research question was defined at the beginning of the study as the most common CO2 emission sources of domestic passenger ship cruise operations. The research goals were defined by four questions:

- What kinds of emission sources exist on domestic passenger ships? --

- How does the amount of CO2 emissions of the main engine per customer compare with the emissions of the reference group of ocean-going cruise vessels?

- How can emissions be measured and verified?

- What are the indicators of sustainable tourism in Finland?

The core issues of the study include the amount of carbon dioxide caused by different types of vessels, the effect of the number of passengers, and the age and type of construction of the vessels in the final result. Secondary issues are the utilisation of the circular economy in spare parts and determining raw CO2 emissions from restaurant operations. The results provide an answer to perhaps the most important question about how ecological inland waterway tourism compares to defined larger passenger ships.

1.3 General information on the types of vessels to be studied

The vessels examined in the reference section of the study consisted of 30 samples. Fifteen of the vessels were operating in Finland (domestic area), either in Lake Finland or on the Baltic Sea coast in passenger traffic. The vessels are subject to the Finnish flag state, EU, and IMO regulations. Domestic passenger vessels engaged in carrying passengers domestically within Finland either on the coast or inland waterways, and whose traffic area in Finland is classified as Domestic traffic area I-III. The other 15 vessels operate mainly

on the high seas: generally in the Atlantic or the Mediterranean. Ships operating on the high seas are subject to the IMO regulations of ships and to flag state specific regulations. The ocean-going vessels concerned fly the flag of Bermuda, the Bahamas or Panama.
Their passenger capacity ranged from 2730 to 6687 and the total main engine effects between 15 samples ranged from 33,600 kW to 91,980 kW. The vessels surveyed in the ocean trades were built between 2000 and 2013 and had a gross tonnage range between 82,950 and 225,282.

The gross tonnage of surveyed Finnish domestic passenger ships ranged from 20 to 250 and had a passenger capacity between 18 and 220. The main engine effect of inland passenger vessels had a range of 235 to 350 kW. In domestic transport, the vessels were built between 1948 and 2019. In the study, the comparison has been made by calculating the hourly carbon dioxide emission load per customer per hour between the hourly consumption of vessels and the number of passengers and comparing it between two groups: Finnish domestic traffic passenger vessels and ocean-going passenger vessels. Domestic vessel consumption was obtained from the figure provided by the shipowners, which was further verified by performing the consumption calculation for domestic vessels as presented in the study (P*consumption g/kwh*0.85).

The information on ocean-going vessels (engine power and number of passengers) had to be obtained from other sources, such as the companies' websites and the Fakta om Fartyg website, in order to discover the engine power and number of passengers on board as well as the general hourly consumption of diesel engine types via websites of the major equipment manufacturers Wärtsilä and MAN. As the calculation of domestic traffic offered consumption data up to 35% higher than the actual consumption of the vessels, a safety margin of 35% was applied to the consumption figures for cruise ships (n=15) in ocean traffic in order to make the figures comparable.

1.4 Discretionary sample

The domestic vessels included in the survey were selected by random sampling in order for the survey to cover both sea and lake areas. A snowball sampling method was used to increase the sample size through interviews.
The response rate for domestic transport was 50%. A random selection of ocean-going vessels was made through the Google search engine to search for passenger shipowners, and when the first potential shipowner was found, 2-7 vessels were identified depending on the size of the fleet to make a sample of 15 vessels. For ocean-going vessels, a condition of conventional propulsion and year of construction between 2000 and 2013 was set to exclude the possible application of the latest Nox TIER III emission directives on board.
It was also considered that the ships' area of operation would be ocean-going as the figures would not have allowed for a calculation in line with the new emission standards. The fifteen samples represent about 3.8 % of the population. There were 391 cruise-only vessels in the world in 2017 (ISL 2017, Shipping Statistics and Market Review 2017, volume 61 - No. 8).

In turn, 191 passenger vessels operated in Finland in 2021, so the survey represented 7.8% of the whole population. The size and age of the vessels are very varied, representing a diverse Finnish domestic fleet. However, the sample numbers are so small that any wider generalisation of the results should be put in context. The study is, however, intended to show that domestic tourism can be seen as an environmentally conscious choice when considering carbon emissions, for example. The study has also qualitatively examined the overall emissions from domestic passenger cruises as a phenomenon through interviews. It is essential to note that a significant proportion of the meals consumed on cruises are of local origin and that the recycling of spare parts is seen as an important issue in ship maintenance.

1.5 Choice of CO2 measurement method between two groups: domestic passenger vessels and ocean cruise vessels

In general, customer-specific CO2 emissions are modelled on a per-customer basis, based on kilometres or miles travelled by different modes of transport. However, this study decided to compare the customer-specific CO2 emissions from main engines of domestic passenger vessels and ocean-going passenger vessels on an hourly basis. This was due to the fact that a comparison over longer distances would not be relatively feasible due to the different nature of domestic and oceanic transport. In Finland, cruises on domestic passenger vessels are generally 1-3 hours long, meaning that the number of miles per day on such routes is not very high. The ships spend the night in port during which they are connected to shore power. In turn, cruise ships spend periods of days at sea in addition to the time spent at various destinations. The cruising speed of domestic vessels often deviates from the cruising speed defined in the study: for example, sightseeing cruises do not cruise at an average speed of 9 knots, but in some cases at a much slower speed.

According to Marine Traffic, the average speed of a cruise ship is 20 knots, as cross-continental journeys between destinations can sometimes be considerably longer. For comparison purposes, it has been calculated that both groups use a common 85% power for all cruises. For domestic transport, the consumption figures include not only the main engines but also auxiliary engines, while for ocean transport the consumption of auxiliary engines is not taken into account. Consumption for all vessels has been calculated using light fuel oil (LFO) values, as conventional passenger vessels in domestic transport run on light fuel oil (LFO).

2 IMPLEMENTATION OF THE STUDY

2.1 The subject of the research

The subject of the study is to find out the sources of carbon footprints of passenger ships in Finnish domestic traffic as widely as possible. The intention was to make the most comprehensive survey possible with different passenger ship operators from different parts of Finland. The study also serves as a platform for CO2 calculating softwares.

The experimental group of the study is limited to passenger ships within the borders of Finland with a GT of less than 500. Statistical values of defined bigger passenger ships were used as a control group (vessels that have a capacity between 2730 and 6687 passengers). The data of large passenger ships were compiled using the engine power of the vessels reported to the Marine Traffic system in the formula. In the interpretation of the study, the limitations of the research results have been considered by the fact that these are statistical and computational values. There is no public database of large vessels that would extend beyond the network of authorities from which vessel consumption data could be systematically collected. Limiting the topic can reduce the possibility of misinterpretation in research and bring relevant research value to the industry. At the time of conducting the study, no similar targeted research has been found on the carbon dioxide emissions of Finnish passenger ships.

The aim is to achieve the most comprehensive picture possible of the current situation of operators in the sector and to identify potential ways of reducing emissions. The study also provides an interface to the feasibility of reductions. A small proportion is also arranged for comparison with a larger actor in the study. The aim is to compare the main engine power emissions of a small passenger ship (less than 500 GT) with the exemplary average emissions of 15 larger passenger vessels.

2.2 The concrete execution of the research

The research was carried out by getting acquainted with international strategies related to the researched material and climate, and by interviewing various actors in Finland both in inland waters and coastal areas. The subject of the research is not only topical but also a certain kind of preliminary research, so the compilation and acquisition of source material and the study-related entity were strongly part of the overall result of the research.

2.2.1 Data collection through a quantitative questionnaire and qualitative interviews

The data from domestic passenger vessels was collected through a questionnaire, which was sent to eight (8) domestic shipping companies through random sampling as an e-mail attachment in different transport areas and cities: inland waterways and coastal transport. Four shipping companies replied to the questionnaire and sent them back to the researcher as an e-mail attachment. The responses cover data from 15 different types of passenger vessels, representing 7.8 percentage points of the total population. The responses were analysed using both quantitative statistical methods with the SPSS statistical software and qualitative interpretation to provide a more detailed analysis of the phenomenon. The responses were also supplemented by three interviews of which one was conducted through a telephone and the other two in the shipping office.

The questionnaire consisted of a structured section asking for detailed technical information on the vessels and their traffic areas. In the second part, the questions were open-ended, allowing the interviewees to freely describe, for example, the local food quality of the meals served, their composition, the need for spare parts, annual repairs and the use of the circular economy. The questionnaire also helped to determine waste accumulation and distribution. The third section consisted of docking and maintaining activities. It included open and semi-structured questions about annual repairs, maintenance and

average requirements for spare parts. The study also sought to identify the contribution of the circular economy to spare parts.

The conformity of the questions in the questionnaire with the research problem and objectives was verified before carrying out the survey. At the beginning of the questionnaire, it was specified that only the fuel consumption figures could be analysed and that the other components should be analysed and systematised using qualitative methods so that the whole phenomenon of domestic passenger ship transport could be defined more accurately (APPENDIX I). According to the research plan, the questions were sent to eight suitable shipping companies in different parts of Finland. Replies were received from four different companies, making the response rate 50 %. The interviews included 15 different domestic passenger ships.

2.2.2 Meetings

Three meetings were held as part of the study, two of which were held in person and one as a telephone meeting. One of the in-person meetings had representatives from two shipping companies, while the other had participants from just one.

The meetings were held in order to study valuable information and companies' views in addition to the structured interview results. The companies' strategic views on responsibility more generally were a significant contribution to the project. The meetings were free-form and the representatives of the companies were given the opportunity to present their business widely. An informal meeting type was chosen since strict questions would require a more broad and comprehensive knowledge of business activities. It is much easier to create solutions for the future when the history of a company is known.

2.2.3 Literature Review

A sufficiently comprehensive public database did not exist for the precise figures of CO2 emissions in the passenger ship sector. The core of the source materials was mainly to determine the future environmental requirements at European level and their impact on domestic transport, as well as the practical possibilities for tourist operators to achieve carbon neutrality. However, a significant core of the research is conducted by us, as reliable research data on similar activities is very limited even after an extensive investigation of search services.

The source literature was examined using both the standard Google and Scholar search engines and the Finna service in order to optimise the search results. The purpose of this was to examine the reliability of the source literature after the search project.

2.2.4 Comparability with other studies

No similar studies about the subject were found in Finland through defining the keywords in accordance with targeted Google Scholar and Finna searches. Finnish passenger ships with more than 5,000 GT have extensive requirements for reporting fuel information. However, no similar requirements exist for ships under 500 GT and below in the study. When the reports are published after 2019, however, it is possible to adjust the valid, tabulated and reported data required for the study.

All Finnish passenger ships in international traffic that became known at the beginning of 2022 also carry cargo. As a result, the passengers and cargo will have to be allocated. According to the SF-EN 16258 standard, allocation can be done in two ways: the first option is to determine the cargo and passenger shares of the ship by dividing its deadweight by the total weight of the cargo and passengers (including passengers, baggage and cars).

Another option is the allocation of passenger and cargo spaces. The latter option is generally chosen as a method of measuring the alternatives in passenger transport since the share of passengers and their goods in the deadweight is quite small, while the space reserved for passengers is significant compared to mainly cargo vessels, for example. According to the Finnish Lipasto database, the measurement methods differ by up to 70%.

Lipasto is known as the calculation system for exhaust emissions and energy consumption in Finnish transport. It covers the sectors of road, rail, water and air transport and non-road machinery. It was funded between 2013 and 2017 by the Finnish governmental institutions Traficom, the Ministry of Transport and Communications, the Ministry of the Environment and Statistics Finland. However, after 2022 a part of the website will no longer be updated, and the information will have to be found in other sections. (Lipasto, 2019)

Data on ships that only carry passengers internationally formed a small part of the research. However, the comparison of the obtained interview data with the Finnish RoPax vessel offers an important point of view to the study. Since accurate consumption data have not been provided by luxury cruise ships alone, the data are based on study by a professor at the University of Illinois Urbana-Champaign (Navigator 2019) as well as the calculated fuel consumption data represented in the implementation phase of the study.

2.3 Validity

In the assessment of validity, the study refers to the correspondence of the research approach and methods for studying the phenomenon. When choosing a method for research, the research group must first consider the set strategy, i.e. what is desired for the research.

The measurement method should be chosen according to the phenomenon that is being studied, and the method should be considered in terms of what exactly the researcher wants to measure (Hirsijärvi et al. 2004, 213).
"Validity refers to the study or the validity of the claim, i.e. whether it is justified material, research methods and obtained the results of the allegations made" (Nummenmaa et al. 1997, 203).

2.3.1 Review of study-specific validity achievements

In the validation of the research, the functionality of the set research strategies is evaluated. The research has used multi-method and survey strategies.
The research material is in accordance with the research problem and objectives, and statistical models have been used to compile its statistical significance. Validity can be considered at length through the relationship of the research problem to the set questions. The questions provide enough information to draw the conclusion that the objectives of the research have been achieved.

The aim of the study is to survey the carbon footprint of domestic vessels.
Valid research data on the carbon footprint of passenger ships operating within Finland are not available based on an extensive review. When evaluating the choice of methods, attention was paid to utilising the most practical research methods possible.

The research approach was to create accurate structured material in which the layout of questions was narrowly defined. In addition, discussions with companies assessed the clarity and unambiguity of the survey. At minimum, a telephone conversation was conducted with each shipping company about the purpose of the survey and the significance of the question layouts. All quantities determined by the questions are measurable and observable. By testing the questionnaire, the survey teams found it to be effective in relation to the research problem. For the interviews, the groups were asked for their opinion on the questionnaire.

For an overall picture, the research setup covered the ship's entire sailing period, from annual maintenance and docking to various cruise products and their contents as well as technical details of the ships. The companies monitored their operations at their best over decades and determined their operational average over the years. The layout of the questions sought a qualitative answer to what had been assessed as the most measurable questions in the research strategy work.

The written sources in the study included mainly background information to support the changes required by future climate strategies and to show the purposes of the preliminary work on the law. A comparison with larger ships provided an important additional measure for the study in order to make the value of measuring the environmental impact of smaller passenger ships more comprehensible to the public.

2.4. Reliability

The reliability of a research result generally refers to the measurement of a phenomenon or the reliability and reproducibility of a research method. When dealing with reality, one often talks about the possibility of an error in what is being measured and the formation of equal results in repeated measurements.

When considering the reactivity of a research method, special attention should be paid to four different main principles. These include a review of the measurement results of various indicators and how similar the results are, the similarity of the observations of the phenomenon, and the understanding of the objectivity and subjectivity of the frame of reference among the observers. The continuum of observations should be as similar as possible (Hiltunen, 2009).

For a study to be reliable and valid, the results must serve the purpose for which the study was conducted. The research plan should be supported by what is being measured (Hiltunen, 2009).

2.4.1 Review of research-specific reliability achievements

The items measured in the survey from the technical and general data of the vessels are reproducible measurements, but not dependent on the metre. Quantities measured from consumption values are defined as a long-term average over at least one sailing period, so the deviating effect of one voyage does not affect the reliability of the survey results.

The characteristics, for example a subjective or objective view or the mental alertness of the person responsible for the survey, are not relevant for the measurements of the study. The measurements can be verified from several sources and after the sailing season, for example by means of consumption monitoring when invoices are used as evidenced inspection tools. In addition, the study has a reference point conducted from four shipping companies and there were no major differences in the numbers given between similar types of vessels.

The measurability and repeatability of the study is weakened by the small sample size of the study, which was considered both in selecting the statistical significance test and examining the results. Statistical testing was carried out in accordance with general research ethics by selecting a non-parametric testing method (Mann Whitney U-test) and indicating the methods used in the research report.

Ship-specific fuel consumption data from large ships are not generally available, so the comparison had to be performed computationally based on general models of passenger ship types, engine power, passenger numbers, the ISO SFOC value of diesel engine consumption of 170g/kwh and a common way to determine the fuel consumption of ships at 85% power. For both groups, four carriers and as many different vessels as possible in terms of number of passengers and engine power were used in the comparison in order to exclude the effect of an individual in the result.

The fuel consumption data for large ships were determined using the long-standing expertise of Kimmo Kauko, a mechanical engineering professor at Satakunta University of Applied Sciences.The course of the study and the implemented methods are clarified in the report and the limitations of the study must be taken into account by the interpreter. The survey response rate for domestic passenger vessel companies was 50%, which can be considered above average compared to general survey response rates (20-30%), despite the small sample size.

3 REGULATIONS GOVERNING SHIP EMISSION SCOPE OF IMO AND EU EMISSION LEGISLATION

3.1 EU MRV-regulation

The European Parliament's regulation, which has entered into force in 2015, lays down the rules of the monitoring, reporting and verification of CO2 emissions as well as fuel consumption, transport work and average energy efficiency from ships with a GT greater than 5000 operating in the EU economic area. EU MRV-regulation means maritime regulation on monitoring, reporting and verification of carbon dioxide emissions from maritime transport. The regulation applies to ships irrespective of their flag state, undertaking following voyages in EU (and EFTA) regions. The regulation also states that the information about ships sent by the owners must be verified by external verifiers and that the emissions of individual ships must be published in the Commission's annual report (REGULATION (EU) 2015/757 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/EC). The shipowner transmits the information to the flag state authority of the ship and to the EU Commission through the reporting system.

3.2 IMO Data Collection System (DCS) in general and the national implementation of the database in Finnish Maritime Environmental Protection Act

The IMO Data Collection System (DCS) for the fuel consumption of ships was introduced on 1st of March, 2018. From 2019, vessels with a gross tonnage of 5,000 or more have been required to collect data on the ship's fuel consumption as defined in the Appendix IX of Annex VI to MARPOL convention. The information required by the regulations shall be provided to the authority designated by the flag State after the end of the year.

The authorities of the flag State shall transmit the data to the IMO ship fuel oil consumption Database. The IMO shall produce an annual report to the IMO Marine Environment Protection Committee (MEPC), (IMO.org, 2021).

In accordance with national legislation, the International Maritime Organization (IMO) database on fuel consumption of ships from 2019 onwards requires the annual information to be provided, and its verification is directly applied in the domestic body of legislation with minor refinements. Among other things, domestic legislation specifies the time when shipowners must send a report to the flag guard authority, which is Traficom in Finland. According to current national regulations based on MARPOL convention, Finnish vessels with a gross tonnage of 5000 GT and above must submit the data for the past year to Traficom by the end of March (Trafi, 2021).

3.3 The EU greenhouse gas reduction commitment to international maritime transport

Unlike other modes of transport, international maritime transport is not included in the EU's greenhouse gas reduction commitment. Nevertheless, the EU Commission issued a statement in June 2013 on the integration of maritime emissions into EU proceedings to reduce greenhouse gases.

The EU MRV is an intermediate stage for maritime emission trading or otherwise a market-based means of reducing emissions from maritime transport. EU shipping ministers proposed joining the emission trading scheme In Opatija's declaration in March 2020: the ministers referred to the IMO emission reduction goals and the overall goal of zero greenhouse gas emissions in the EU by 2050. The continuing development of market-based emission reduction measures will be discussed in 2023 in accordance with long-term measures in line with the IMO greenhouse gas strategy.

The ministers emphasised the importance of the distribution of alternative fuels and ports. The green growth program also emphasises the development of ships discharging into maritime and inland waterway transport, as well as the development of shore-side electricity in ports, as well as restrictions on accessing the port for high-emission ships. The details of the goals are being discussed in more detail (Andersson et al. 2020, 161-199).

3.4 Significant differences between IMO and EU regulations for international traffic

According to the IMO's binding emission goal, the greenhouse gas emissions from international shipping must be reduced by 50% by 2050 (ECSA, 2021). The EU regulation requires the collection of more information on the ships' transport performance in line with the IMO act. Emission data for individual vessels are also published in the European Commission's annual report (Andersson 2020, 161-203). The weakness of MRV data today is that they represent only a part of the total consumption of ships when operating outside the EU, where emission regulations can be more lenient than in the EU (Jalkanen 2022, Email). No sufficient information has been published on digitalization development work or the combination of reporting which could be used in the reporting system at the time of the study. The information for the reports is generated on board ships (Port Activity App 1 year- webinar 10.05.2022).

	EU MRV	IMO DCS
Entry into force	1st July 2015	1st March 2018
Scope	Ships above 5'000 GT Voyages to / from EEA ports of call	Ships 5'000 GT or above International voyages
First monitoring period	2018	2019
Procedures	Monitoring Plan (37 sections)	Data Collection Plan (SEEMP Part II) (9 sections)
Compliance (procedures)	Assessment Report (no need to be on-board)	Confirmation of Compliance (must be on-board)
Reporting	Fuel consumption (port / sea) Carbon emissions Transport work (actual cargo carried) Distance sailed Time at sea excluding anchorage	Total fuel consumption Distance travelled Hours underway Design deadweight used as proxy
Verification	Independent accredited verifiers	Flag administrations or Authorized Organizations
Compliance (reporting)	Document of Compliance (June 2019)	Statement of Compliance (May 2020)
Publication	Distinctive public database	Anonymous public database

Table 1: Differences between the EU and the IMO collection (Verifavia Shipping, 2022)

3.5. IMO and EU regulations for reducing sulphur emissions

Since 1st of January 2015, ships sailing in the English Channel, North Sea and Baltic Sea must use bunker fuels with a Sulphur content of maximum 0.1% m/m (IMO MARPOL Convention Annex VI, the EU Sulphur Directive 2016/802). The IMO has also set a global Sulphur limit of 0.50% m/m from January 1, 2020. In order to be compliant with the new limit, new fuels are going to be introduced. To achieve this, shipowners may use exhaust cleaning systems instead of refuelling in low-sulphur areas as defined by the IMO and EU (ECSA, 2021).

3.6. Impact of international regulation on domestic passenger shipping

According to research data published by the Government in 2020, Finland does not have separate numerical goals for reducing emissions nationally from maritime and inland waterway transport. The numerical goals come from the EU, IMO and climate regulations.

Finland's national climate strategies aspire to be at the forefront of reducing emissions in the EU. Finland is a member of the EU, IMO, and Baltic Marine Environment Protection Commission. In addition, the impact efforts of Nordic co-operation in the IMO and the EU are, among other things, related to Baltic Sea transport, local transport and winter shipping.

The decisions of the Finnish Government are, in principle, related to Finland's strategy for the Baltic Sea region (15a / 2017), and the guidelines for Finnish Maritime policy 2019: 4 (Prime minister's office 2022) underline the leading position of maritime logistics and the entire Finnish maritime cluster in reducing emissions (Andersson et al. 2020, 170).

According to the current programme of the government led by Prime Minister Marin, a development programme for inland waterway transport will be drawn up, which will take into account the business community and the most important objectives for water protection (Andersson et al. 2020, 170).
The government's programme also generally underlines the biodiversity and carbon-neutrality in Finland, which can also be proven to include all functions (Programme of Prime Minister Sanna Marin’s Government, 2019).

The goals of international traffic are related to emission trading, pricing and economic incentives, ship design, speed reduction, and the transition to shore-side electricity. Finnish domestic passenger vessel traffic has recently been encouraged to switch to using electricity and battery-hybrid vessels due to various experiments on routes with shore-side electricity connections (Andersson et al. 2020, 166-170).

3.7 EU and IMO regulations for inland vessel engines

The scope of the EU and IMO regulations was not clear at the time of the study. After a more detailed examination, it could be seen that in Finland the EU regulation is generally defined as the directly applicable law in Member Countries.

The framework for the Finnish inland waterway vessel emission standards is therefore both a regulation 2016/1628 of the EU Parliament and the Council on particulate matter emissions from diesel engines for non-road mobile machinery and inland waterway vessels and a Tier I-III regulation on nitrogen oxides in Annex IV of the IMO MARPOL Convention. Both regulations apply to machines put into service in 2019, 2020 or 2021 depending on the power range of the machine. In addition, since 2007 a previous EU regulation (Stage III/A) has already imposed obligations on emissions. STAGE IV standards came into force progressively in 2019 and 2020. Both regulations have set maximum emission limits for inland waterway engines in the EU region (Dieselnet 2023, Chapter: Standards, Nonroad engines). There have also been different requirements for fuel and machinery earlier, which have already been covered by international EN (European Standard) and ISO (International Organisation of Standardisation) standards.

The EUROSTAT website defines an inland waterway vessel as follows: "*Inland waterway vessel: A floating craft designed for the carriage of goods or public transport of passengers, which navigates predominantly in navigable inland waterways or in waters within, or closely adjacent to sheltered waters or areas where port regulations apply.*" This definition is used in the study so that the vessels under investigation that operate off the Finnish coast can be included in the same category based on emission regulations (Eurostat 2022).

IMO TIER I-III REGULATIONS

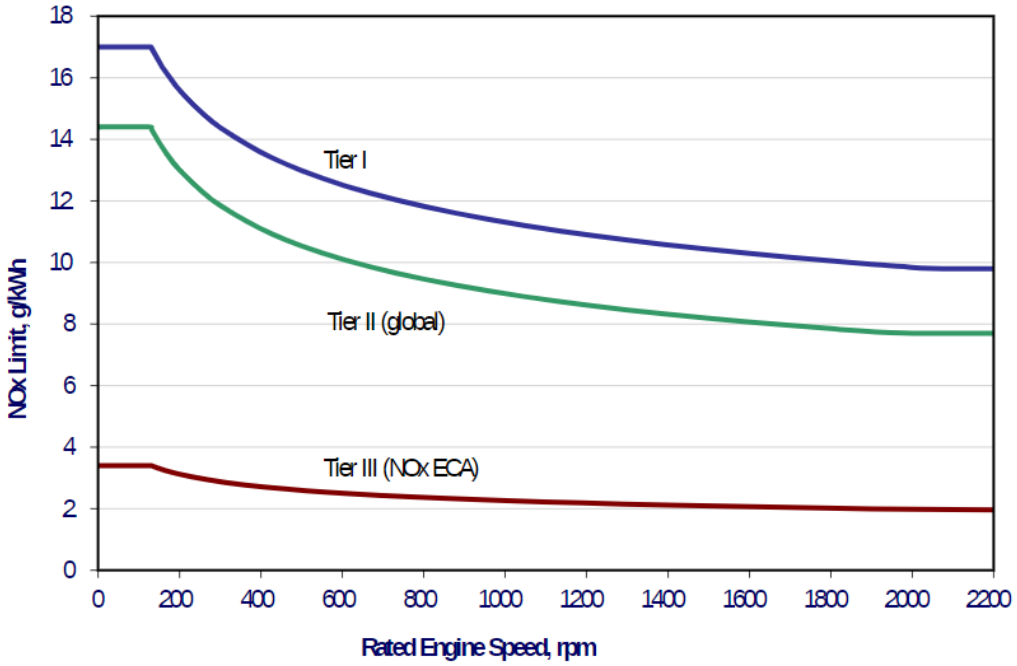


Chart 1: IMO Tier I-III Nox Limits for machines with an engine power exceeding 130 kw. Tier I emission level requirements apply to machines installed between 2000 and 2010, Tier II requirements to machines installed between 2011 and 2020 and Tier III requirements to machines installed on or after 1 January 2021 (Dieselnet 2022).

EU STAGE V REGIME

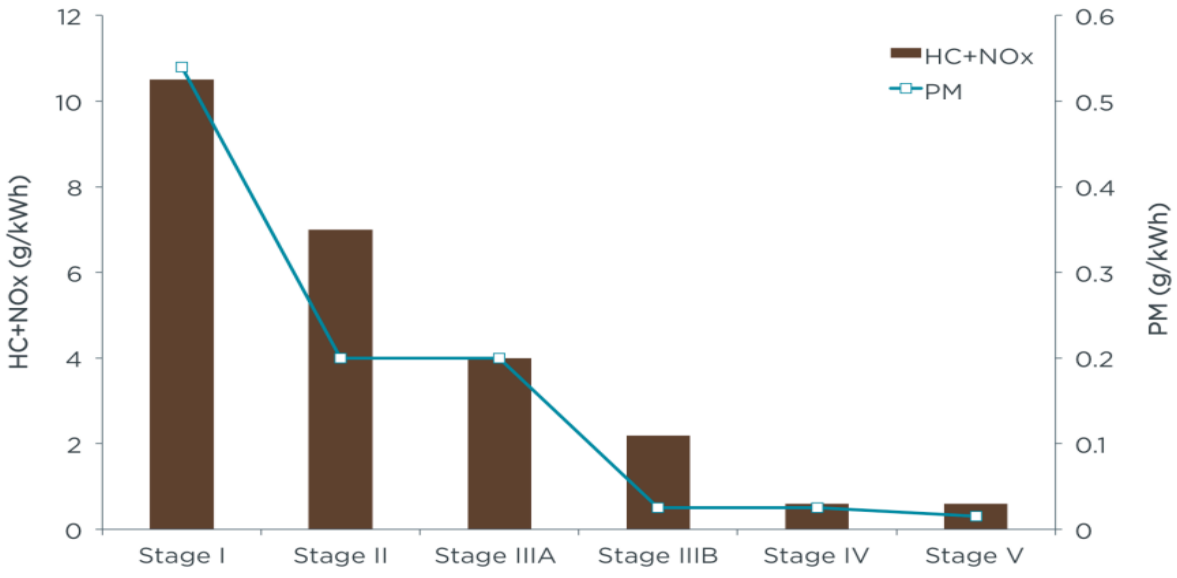


Chart 2: EU Stage III/A emission standards for engines in inland waterway vessels. Standards III/A and IV are used for inland waterway transport. The standards apply to main and auxiliary engines above 19 kW (ICCT 2016).

4 STARTING POINTS FOR DEFINING A COMPANY-SPECIFIC CARBON FOOTPRINT

4.1 What are carbon footprints?

A carbon footprint is generally defined as the environmental impact of a product, service or activity. Any entity that emits greenhouse gases is considered to be a carbon footprint. The effects of greenhouse gas emissions on global warming have been studied. The main long-lasting greenhouse gases contributing to global warming are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and hydrofluorocarbons (HFC) (European Environment Agency 2020). A more precise definition of the carbon footprint mentioned in scientific publications is expressing the amount of greenhouse gas emissions during the life cycle of an entity in terms of carbon dioxide equivalents.

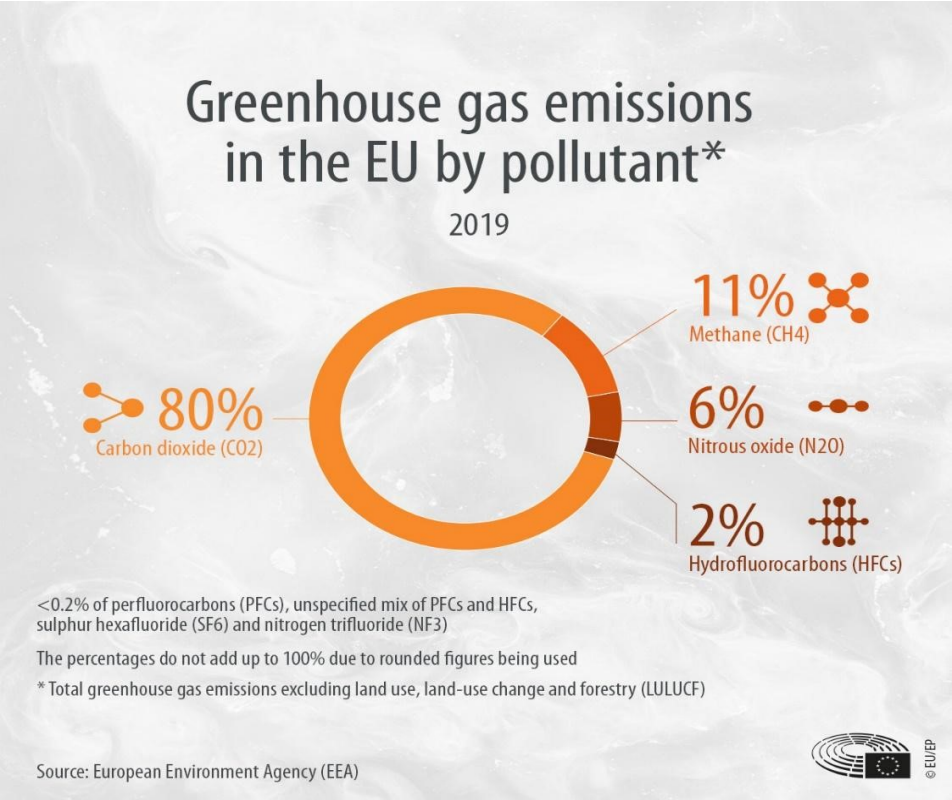


Image 2: Greenhouse gas emissions in the EU by pollutant (European parliament News, 2021).

4.2 Carbon dioxide as a measure of greenhouse gas emissions

Carbon dioxide equivalent (CO2e) is a method that co-measures the effect of greenhouse gases on the atmosphere. Carbon dioxide equivalents are used to detect greenhouse gases in order to determine the relative climatic load of different gases (NGS Finland, 2021).

Equivalent emissions of CO2 include carbon dioxide emissions multiplied by one, methane emissions (CH4) multiplied by 25, and nitrous oxide (N2O) multiplied by 298. Equivalent CO2 emissions are thus treated as a starting point for calculating the cumulative values of the other compounds (Lipasto 2017).

4.3 The impact of companies on carbon footprints in general

The starting point in this study is that almost every product or service produced by a company or corporation's day-to-day operations cause carbon footprints directly or indirectly. They may differ greatly in each company due to the nature of their business. However, carbon footprints are calculated using similar formulas. Today, this is a very common phenomenon as defined in the Finnish Occupational Safety and Health Act, so in addition to one’s own company, it may be necessary to define the carbon footprints of partner companies. It is important to assess the degree of interdependence between companies, for example through joint activities (Finnish Occupational Safety and Health Act 2002).

Companies are in very different situations with carbon neutrality goals. For some companies, the goals can be easily achieved by changing a few functions, for example, while for others it might not be entirely possible to make their activities carbon neutral. The choices of corporate customers, consumers, investors and financial institutions greatly guide the actions of the corporate field in the strategic organisation of business (Bank of Finland, 2021).

4.4 Protocols measuring greenhouse gas emissions

4.4.1 Greenhouse Gas Protocol

The Greenhouse Gas Protocol (GHG) refers to a comprehensive, globally standardised framework for measuring greenhouse emissions. The protocol includes sections dealing with activities in the private and public sectors, value chains, and mitigation efforts (European Union, 2022).

The carbon footprint of a company is based on direct and indirect emissions. Although companies are all different, various standards have been developed to calculate carbon footprints in order to facilitate analysis. The modification of standards for individual industries is done in accordance with the work of defining the totality of carbon footprints.

Classifying and determining carbon footprints is a vital starting point for further action. Indirect emissions, which consist of everything but the company's own energy production, account for up to 90% of greenhouse gas emissions in certain industries.

Greenhouse Gas Protocol – Corporate Value Chain Accounting and Reporting Standard is one of key standards that also clarifies the determination of indirect greenhouse gas emissions. In the example standard, emissions are divided into three categories. Category number one defines direct emissions from the production of energy by the plant, number two the emissions from purchased energy, and category number three all other indirect emissions (Ekokompassi, 2021).

Figure [I] Overview of GHG Protocol scopes and emissions across the value chain

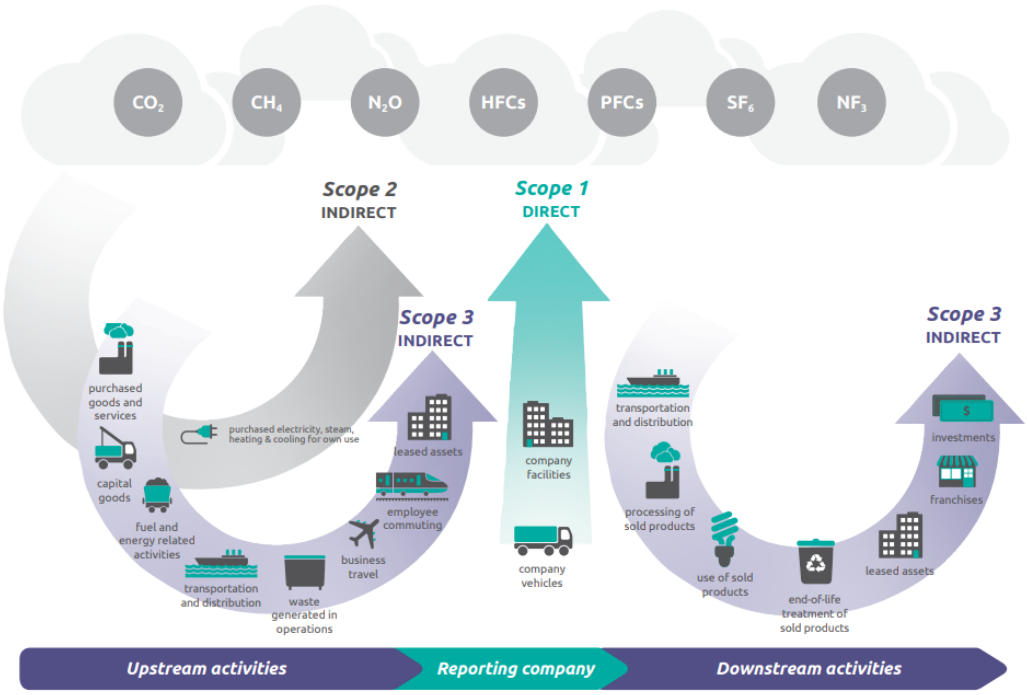


Image 3: GHG Protocol. (Barrow et al. 2021, 6)

4.4.2 Calculating emissions according to the ISO-standard

According to the standard, the starting point in the greenhouse gas inventory is that the organisation must document direct greenhouse gas emissions, emission reductions, indirect energy emissions, other indirect emissions and direct carbon dioxide emissions from burning biomass. Disclosure of emissions is presented both per facility and at the organisational level, and the results are reported in tons of carbon dioxide equivalent. The greenhouse gas inventory may, in addition to the actual inventory, include a plan on how emissions could be reduced. The second part of the ISO 14064 standard deals with the consideration of emission reduction in greenhouse gas inventory (Luhtio 2011, 7-12).

4.5 The effects of the EU regulatory framework and objectives on Finnish business life

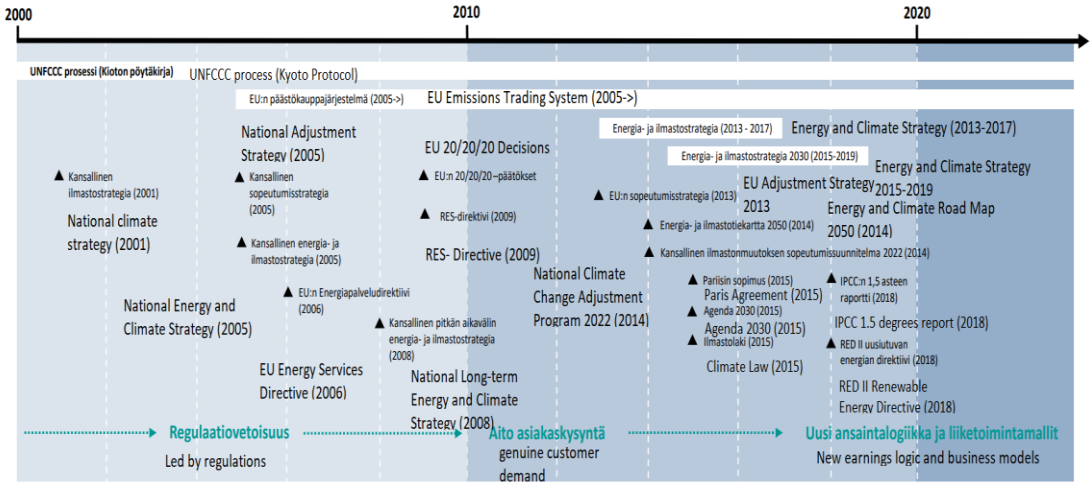


Image 4: Regulations and common objectives have formed the markets (Hjelt et al. 2020, 7-8).

The impact of the legislation and objectives introduced by international agreements on the Finnish business community is significant. In addition to the challenges, Finland's rapid and conscientious response has opened up many opportunities for companies. The basis for competitiveness in Finland is the qualitative operation of companies and their prior response to change.

Changes have originally been triggered by regulation over the last two decades. Until 2010, the focus had been on energy efficiency and there had been little demand from customers. However, in the 2010s, goals have been reflected in business strategies and customers have also been more interested in the topic.Today, the climate business and low-carbon forms of energy are at the strategic core of the entire industries of companies, and global competition is fierce in finding new solutions in carbon neutrality (Hjelt et al. 2020, 1-35).

4.6 Carbon neutralisation programmes in small and medium-sized enterprises in Finland

Carbon neutrality means a product, company, municipality or government that produces only as much carbon dioxide as it can eliminate. The carbon footprint of a carbon-neutral product is zero throughout its entire life span.The opportunities for companies to achieve carbon neutrality goals differ significantly. In some companies, changing a few small day-to-day operations already makes them carbon-neutral, while in others the means are much more demanding. In some companies, full carbon neutrality is simply not possible. However, various formulas and calculation models are available to help achieve carbon neutrality. Companies differ substantially from each other, so the options offered by this study are more general - each company should consider the best possible scan model for its own strategies. In any case, companies need to analyse the initial situation through which their activities can be seen as a whole. In addition to this, the introduction of a quality system is one way to look at day-to-day operating models. The quality system also enables the introduction of an eco-label which is visible to the customer when the requirements related to the labels are included in the quality system.

4.6.1 Initial analysis in general

Systematically reviewing the company's operations in the initial situation is a concrete step towards a more sustainable business. The best outcome for the review is achieved when the activities of the entire company are involved, from personnel management to material flow management.

The resource survey form of the Waste for Exploitation project results from an entirety that allows companies to be viewed relatively comprehensively. The list should be read taking into account the size and resources of the company. There are notable differences in the size of companies, and in the smallest ones the management work related to environmental issues is included in the rest of the activity.

When looking at environmental and quality management, consideration is given to the organisation of quality and environmental leadership and whether the company has a quality system in place at all. The review should also take into account the wishes and requirements of the customers in the company conducting the business in question.

In the management of material flows, it is important to study the flow of materials from procurement and storage to the final and waste products. The chain of main materials and end products, as well as the material flow of by-products, must be investigated. Companies that also incorporate a management philosophy that eliminates unnecessary functions are already taken into account in advance. The logistics chains, storage and transport arrangements of the material flows of companies should be reviewed precisely, e.g. what is the storage time of materials in stock and how much waste material is generated? Checking the functionality of waste management from the perspective of the circular economy is an important core point.

The operation of the company's production itself is under review, from the different stages of production to checking the functionality of subcontracting chains. Defining these chains and their operations according to sustainable thinking, as well as involving employees in development work, are ways to review the production process of the entire company.

It makes sense to consider energy sources if electricity, heat and hot water account for 2% or more of turnover. Energy auditing and the possible introduction of renewable forms of energy are ways to reduce energy consumption.

In addition, depending on the company's activities, the examination and updating of the training of the personnel, the development of joint procurement chains with other companies, and the inspection and certification of the company's equipment are related to the ranges of means available.
The resources of the personnel must be made available for correctly targeted measures (Laasasenaho K et al. 20, 45 - 50). When developing companies,

the fulfilment of environmental quality and customer service criteria must be considered. All of this is the easiest to achieve when the company and management are developed as a whole.

4.6.2 Introduction of the quality system

When a company wants to make changes in terms of environmental values, it also involves updating the quality system and auditing. The development of environmental and quality systems partly includes the same starting points as the productivity and customer satisfaction sector. When a company aims to develop its environmental system, the audits also consider qualitative criteria.

When planning the implementation of a quality system, a company must first look at what quality means on a company-by-company basis. There is no complete consensus on the definition of quality in the business field, but contextualization influences the definition. The efficiency and profitability of a company's operations as well as customer satisfaction are generally considered quality criteria. A company can implement an appropriate quality system, but it is not necessary for all companies to move to complete quality management immediately despite the introduction of the system. However, the benefits of introducing a quality system will disappear if the system is not a step towards a transition to quality management. Total quality management is seen as an entity that incorporates values, techniques and tools as an overall assessment of leadership. It is possible to move to a comprehensive quality management system that describes total customer satisfaction by analysing the company's processes, while achieving development and flawlessness with the help of the entire staff of the company (Ruonti 2014, 1-41).

4.6.3 Labels of sustainable, responsible and qualitative operations

When a company wants to make changes in terms of environmental values, it also involves updating the quality system. Considering the big picture when creating a strategy makes the company a responsible operator in the future business field as well.

Eco-labels can be found from national, Nordic, European and international extrusion. The environmental friendliness and responsibility of products and services is a general starting point for awarding brands. The life cycle model is also an important part of the criteria for the labels. Eco-labels make it easier for consumers to make environmentally friendly choices and for companies to prove the responsibility of their operations (Joutsenmerkki 2021).

Eco-labels are awarded objectively when companies have demonstrated through audits that their activities meet the conditions of the label. Designated authorities will supervise the companies' compliance with the standards and criteria required for the use of the label in the future.

Energy efficiency and environmental certificates for ships or shipping companies have been used for years. The Clean Shipping Index (DNV 2022) and RightShip (Sustainable Shipping 2022) bring international ships’ emission data to the ship market prominently. Certification helps shippers, banks, investors, passengers and consumers choose the ships and shipping companies that produce the least greenhouse gases. The certificate marking also adds value to shipowners. Once indicated, the vessel may also receive discounts on regional or national port and fairway fees, for instance. The consistency of certifications in the EU, as well as other financial incentives for shipowners and the reduction of statutory operational fees by making more environmentally friendly choices for equipment, will be increasingly on the agenda in EU bodies in the future.

The eco-labels related to domestic traffic and the perspectives brought by Visit Finland will be a significant factor when investigating domestic passenger ship traffic in the future. There is still a long way to go in emission trading in domestic traffic as the statistics for domestic passenger ships today are not sufficiently accurate due to being broken down by boat or international traffic, for example.

International and domestic eco-labels suitable for the tourism industry, which show the responsibility of a company's operations, have been available for years. At present, however, no financial incentives are yet available for domestic transport despite eco-labels. A more open dialogue will certainly take place in the future.

Ecolabelling

Ecolabel Finland governs both the Nordic Ecolabel – the Nordic Swan Ecolabel – and the EU Ecolabel in Finland.

Regarding both of these labels, the Ecolabel Finland:

- participates in the preparation of the product group-specific eco-labelling criteria;
- processed companies' eco-label applications; and
- issues the licenses for the label's use.

The Nordic Swan Ecolabel

Established in 1989, the Nordic Swan Ecolabel is the official ecolabel of the Nordic countries. It is licensed only to products and services that are the best in terms of the environment. A manufacturer, importer or service provider may apply for the Nordic Swan Ecolabel for a product or service whose eco-labelling criteria have been confirmed by the Nordic Ecolabelling Board. The criteria have been confirmed for nearly 70 product groups.

EU Ecolabel

The EU Ecolabel was established in 1992. As is the case with the Nordic Swan Ecolabel, the EU Ecolabel can be granted only to products or services that are the best in their category. The labelling covers a little less than 30 product groups. At the beginning of 2017, there were approximately 40,000 products and services with an EU Ecolabel on the market.

Image 5: EU ECO LABELS (Motiva 2021)

4.6.4 Reviewing the responsibility of companies related to tourism

According to the Tourism Industry Report, the number of environmental certifications is increasing in the tourism industry, and larger tour operators have already started to require certifications from their partners. There are hundreds of small and medium-sized enterprises that largely meet the criteria for sustainable tourism in Finland.

Until 2019, there had been no such clear national Eco-label in Finland that would produce international criteria in the tourism industry sector. Today, the sustainable link of Visit Finland has responded to the deficiency (Publication of the Finnish Minister of Economic Affairs and Employment 2020:18, 1-47).

To obtain a certificate, a company must adopt the following 7-step programme required by Business Finland. Once the company has carried out an initial state analysis of its operations, as well as qualitative certification, it will be easier to achieve the requirements of the label.

The 7- step programme of Visit Finland

"The 7-step programme is traversed on an online platform specifically built for the purpose. The platform is supported with an 'e-guide' e-learning environment, accessible only by those accepted to the Sustainable Travel Finland programme.
Step 1. Commitment
Step 2. Increasing know-how
Step 3. Development plan
Step 4. Responsible communication
Step 5. Certification & Auditing
Step 6. Verification and measurability
Step 7. Agreement & Continuous development" (Visit Finland, 2022)

EcoCompass as an environmental Management System and certificate

EcoCompass is known in Finland as an environmental Management System and certificate. The EcoCompass management system and certification is suitable for many business sectors. When auditing a company, the company can use the system as a tool for identifying its most relevant environmental impacts. The consultant creates an environmental programme with objectives and concrete measures through which the auditing company learns relevant environmental laws and regulations. In addition, the partners and employees of the company get to know what is done concerning environmental issues.

"*The EcoCompass certificate demonstrates commitment to continuously improving and complying with the following 10 criteria of EcoCompass*

- *Environmental legislation (1)*
  The organisation undertakes to comply with the applicable environmental legislation and regulations
- *EcoCompass contact person (2)*
  An Environmental Manager has been appointed for the organisation
- *Environmental impact scoring (3)*
  The organisation surveys the current status of the environmental management and identifies the most significant environmental impacts
- *Environmental pledge (4)*
  The organisation has an environmental pledge by which it commits to continuous improvement in the mitigation of its environmental impact.

- *Internal training (5)*
  The organisation instructs its personnel to take environmental matters into account in its operations.
- *Waste management plan (6)*
  The organisation has a waste management plan and acts in compliance with the requirements of the Waste Act.
- *Hazardous waste (7)*

- *The organisation keeps a record of its hazardous waste, keeps them separated, stores them safely and submits them for appropriate processing for disposal.*
- *Chemicals (8)*
  The organisation stores and lists the chemicals it uses in compliance with the requirements laid down in the chemicals legislation. MSDSs are available for the personnel and the personnel have been trained on the safe use of chemicals.
- *Environmental programme (9)*
  The organisation cooperates with our expert to create an Environmental Management Program that contains the objectives and measures for reducing environmental impact. The program is updated annually. The objectives are set again every three years or more frequently. The objectives are set for a minimum of two areas of corporate responsibility and they must be based on the most significant environmental impacts.
- *Reporting (10)*
- *Each year, the organisation publishes a report on the actualisation of the actions and the status of the indicators in the Environmental Management Program. The management and personnel are aware of the progress of the environmental work.*“ (Ekokompassi, 2021)

4.6.5 Future of low carbon fuels in shipping

International shipping is expected to use a variety of fuels to produce propulsion in the upcoming decades. Some of the fuels can be used on board alone, but in the future there will also be solutions where fuels are combined according to their purpose.

Current fossil fuels can increasingly be combined with other energy sources - such as wind, wave or solar - for ship operations. Liquefied petroleum gas and biofuel liquid or gas are already well-used alternatives today. Liquefied natural gas (LNG) and biofuels are estimated to be classified as transitional fuels. Although CO2 emissions from liquefied natural gas are 15% lower than those

from fossil fuels and nitrogen and sulphur emissions are not the result of fuel combustion, methane emissions are high (Balcombe et. al, 2022, 1-3).
Whether it is possible that liquid biomethane will replace the use of LNG on ships is a big question for the future (Jivén et. al, 2022, 27-30). In addition to these, alternative fuels for shipping that require further development are currently estimated to be increased due to use of shore-side electricity and batteries, as well as the use of hydrogen or methanol in fuel cells. The last two options are carbon dioxide-free if no fossil energy is used for their production.

Today, nearly all the hydrogen used is made from natural gas. Natural gas is also used in the production of methanol. Both are carbon dioxide free. When burned, methanol produces some sulphur dioxide and nitrogen dioxide. Methanol can be used as an additive. In addition to electricity, only heat and clean water are released from hydrogen in fuel cells, but the problem with hydrogen is its storage and cost.

In general, the idea that internal combustion engine technology could also serve the needs of new propulsion systems can be observed in the development of machine manufacturers. Old technology can be used to build something new.

5. COUNTER-CURRENT CALCULATION FOR FINNISH MERCHANT VESSELS

5.1 Starting point for calculation and measurement accuracy

In Finland, emissions are calculated by the Finnish Meteorological Institute. The starting point for emission calculations is based on AIS data and a Hollenbach resistance current calculation for each vessel. When traffic is based on AIS data, vessel traffic can also be seen. There is no separate distinction between domestic and international traffic. A comparison with European MRV data also constitutes limitation on undisputed emission measurement. The weakness of MRV data is that it only represents a part of total consumption if the vessel's area of operation is outside the EU. The regulation based on emissions outside the union is often not quite as strict as in the EU. There are also still several countries in the world that are not subject to IMO regulation. The route-based emission calculation system is still in the pilot phase. The purpose of this upcoming pilot development work is to make it possible to look at the traffic areas between home and abroad in different entities. Development outside the EU is also needed. More detailed research evidence doesn’t exist yet on the suitability of the model for smaller, mainly domestic passenger vessels (Jalkanen 2022, Email).

5.2 Automatic identification system for vessels (AIS)

Due to the IMO regulations on automatic identification of ships imposed on member states, AIS (Automatic Identification System for vessels) has to be fitted aboard all ships of 300 gross tonnage or higher engaged in international voyages. It is also obligatory for vessels carrying cargo of 500 gross tonnage or higher that are not engaged in international voyages, and all passenger ships despite the size. The requirement entered into force for all ships by 31 December 2004 (SOLAS regulation V/19 - Carriage requirements for shipborne navigational systems and equipment).

According to Finnish regulations, AIS must also be on board all kinds of non-SOLAS vessels over 24 metres long when operating on the sea. Inland waterways do not have similar regulations yet, except for defined areas on Lake Saimaa where it is obligatory to participate in a statutory vessel traffic control service (Law on the technical safety and safe use of a vessel, 2009).

The use of the AIS data makes it easier to achieve an accurate database of ship traffic, including a detailed instantaneous location and speed of each vessel in the area defined for examination. The AIS equipment receives information about the vessel's movements through the GPS / DGPS receiver integrated in the device. GPS is short for global positioning system based on satellites and DGPS for global positioning system for comparing location data between satellites and ground-based stations. The accuracy of a position can be determined within a radius of a few metres at best.

"*The AIS is based on transponders located on vessels and other locations that transmit and receive information on dedicated VHF frequencies. Once set up for a voyage, information is transmitted continuously from each vessel without requiring attention from the mariner, unless something changes*", (Bole et al, 2019 Chapter 5).

The identification, position, status, course information, instantaneous speed and technical data of vessels are the most common data to be used from the AIS database when emission modelling is carried out. With a model based on the use of AIS data, it is not possible for vessels to be divided into domestic and international traffic, for example (Jalkanen et al., 2009, 1-5).

5.3 The Hollenbach method for resistance current calculation of vessels

The resistance of ships due to moving in water is still determined today by the Hollenbach method (1998). The Hollenbach method eliminates certain types of computational problems which appeared in Holtrop-Mennen's resistance current calculation in relation to the ship's planned speed, for example.

In the current model, resistance current calculation can be determined without knowing the speed planned for the ship in the construction topic. Thus, there is no need to use the less accurate average speed of the ship.

The Hollenbach method is based on the model tank tests of 433 ships performed by the Vienna Ship Model Basin between 1980 and 1995. The purpose of the tank test was to improve the reliability of the performance prognosis of modern cargo ships in the preliminary design stage.

While using the Hollenbach method, one of the coefficients described the shape of the hull. In addition to this, the block coefficient (Cb) and propeller diameter of a ship should be known since they are used in evaluating the residual resistance coefficient. The IHS Fairplay Technical database is used when finding technical data on the vessels.

$$C_b = 0.7 + \frac{1}{8} atan\left(\frac{23-100\,F_n}{4}\right)$$

Cb can be defined as shown above, where Fn is Froude number, which can be calculated as follows: vessel speed/ (gravity constant × waterline length). If the waterline length and the length above surface are not readily available, the average value of overall length in metres (LOA) and length between perpendiculars in metres (LBP) can be used instead (Jalkanen et al. 2009: Chapter Hollenbach).

When the propeller diameter d is unknown, the method described by Watson (1998) will be used. The calculation is conducted by using the following estimate:

$$d = 16.2\frac{P_S^{0.2}}{N^{0.6}}$$

"*Where Ps is the service power of the main engine (80 % of the maximum continuous rating) provided in kilowatts and N is the propeller's angular velocity expressed in rpm (revolutions per minute).*

Propeller rpm is required to estimate the propeller and transmission losses and the required main engine power. If the number of propellers is unknown, then the ship is simply assumed to operate with a single propeller. " (Jalkanen et al., 2009: Chapter Hollenbach)

"From total resistance (in kN), the propelling power (PPropel, in kW) is obtained by PPropel = RTotalv where v is the instantaneous vessel speed (in m s−1)." The main engine cannot be completely transformed into the actual propelling power of the ship. The dimensionless quasi propulsive constant ηqpc is used to describe the effectiveness of converting the main engine power to real propelling power. The calculation should consider the propulsive losses arising from transmission, hull, shaft, and the propeller itself. According to the Watson theory (1998) it can be written as

$$\eta qpc = 0.84\frac{N\sqrt{LBP}}{10{,}000}$$

where N is the rpm of the propeller and LBP is the length between perpendiculars (in m). Propeller efficiency is commonly significantly less. Usually 60–80 % of the main engine power is transmitted into the water through the propeller (Watson, 1998). If propeller rpm cannot be determined from ship technical data and it cannot be estimated using Eq. (5), the power is predicted based on the previous version of the model called Steam I" (Jalkanen et al., 2009)

The balancing of loads between machines must be calculated in the modelling. All engines are assumed to be identical in multi-engine setups. The number of operational engines can be calculated in the following way. The model is suitable for both main and auxiliary engine methods of balancing loads, but in the case of diesel-electric engine setups the model is a bit different as mentioned in the following formulas:

$$n_{OE}\frac{Ptot}{P_E}+1$$

where P Total is the total instantaneous power of the engines, and PE is the maximum continuous rating of a single installed engine. n_{OE} *is rounded down to an integer.*

For all setups, the engine load (EL) is then determined from

EL= $\frac{Ptotal}{PEnE}$

where nE is the number of installed identical engines.

A limitation in this approach is that the model treats all main engines as equal and neglects engine setups where one engine of a pair is larger than the other.

"(Jalkanen, et. al, 2009, Hollenbach resistance current calculation)

As a part of the thesis, the modelling obtained from the shape of a ship and the number of machines was examined. The modelling also includes the calculation of more precise emission shares and consideration of auxiliary machines (Jalkanen et al. 2009, Hollenbach resistance current calculation).

6. CALCULATION AND COMPARISON OF CARBON DIOXIDE EMISSIONS OF MAIN ENGINES FOR DOMESTIC AND OCEAN-GOING PASSENGER SHIPS

6.1 Statistical significance and limitations of the comparison

The statistical analysis of the quantitative part of the survey was carried out using SPSS software. First, SPSS was used to test the statistical significance of the claims between the compared groups. The hypothesis (h1) of the study was that the customer-specific CO2 emissions of domestic passenger vessels, calculated from the fuel consumption of the main engine, are statistically significantly lower on average than the carbon dioxide emissions of ocean-going passenger vessels of the comparison group on a customer-specific basis. The counter hypothesis (h0) was that there is no statistically significant difference between the groups. The study was concluded by rejecting h0 and accepting h1. Statistical testing showed that the carbon footprint per customer of domestic vessels is statistically significantly lower than that of the control group of ocean-going passenger vessels. The maximum number of passengers and the hourly fuel consumption of the ships at 85% power were used as variables and in calculation in the per-passenger comparison of carbon dioxide emissions.

The normal distribution of the groups was tested with the Levano test. According to the test, the figures were not normally distributed and the sample size was relatively small, so a nonparametric Mann Whitney U-test had to be used instead of a T-test to survey the statistical significance. The Mann Whitney U-test clearly showed that the difference between the groups was statistically significant, so the h0 could be rejected and h1 accepted. According to the h1, there is a statistically significant difference in the amount of CO2 emissions between the surveyed groups of domestic passenger vessels and ocean-going passenger vessels, while the h0 stated that there is no statistically significant difference between the two.

Both sample groups were relatively small. According to the statistics of 2019, the population of Finnish passenger ships is around 191 vessels, so the examined vessels accounted for 7.8 % (Stat, 2022: Merchant fleet, Statistics Finland). The surveyed ocean-going passenger vessels represent 3.7 percentage points of the population (Shipping Statistics and Market Review 2017, volume 61 - No. 8). However, domestic passenger ships have been of many sizes, the GT of the ships has varied between 20 and 250. The ships are very different from each other, so the sample can be said to be representative. Ocean-going passenger ships were chosen randomly from shipping companies with several ships. Their traffic area was emphasised as ocean traffic, so that it could be ensured that the regulation would not require stricter emission reduction requirements for ships as their determination based on databases and calculations would not have been possible in the research group.

Since information on fuel consumption was poorly available for large passenger ships, the modelling was done using a formula with a 35% (0.35) safety margin. The margin was determined based on the fact that in domestic passenger ships, the calculation showed consumption to be 15-35% higher than the actual measured consumption, so a maximum margin of safety was made for ocean passenger ships in order for the research result to provide a truthful picture.

On the other hand, for the 15 vessels in domestic traffic with sizes of 20-250 GT and passenger capacity 18-220, the shipping companies reported accurate total consumption data including both the main and auxiliary engines. The database represents the total consumption while the inland vessel speed is about 85% of the maximum speed. In larger passenger ships, the marching speed was defined as 21-23 knots and passenger numbers ranged between 2730 and 6687. The effect of crew sizes on consumption was not calculated for either control group.

Mann-Whitney Test				
Ranks				
	Traffic area	N	Mean Rank	Sum of ranks
CO2/ passen-ger	Domestic passen-ger vessels	15	8.00	120.00
	Ocean-going passenger vessels	15	23.00	345.00
	Total	30		

Test Statistics (Grouping variable traffic area):	
Mann Whitney U	0.000
Wilcoxon W	120.000
Z	-4.667
Asymp. Sig. (2-tailed)	<0.001
Exact Sig. [2*(1-tailed Sig.)]	<0.001

Table 2: Hypothesis testing at 0.05 significance level. Mann Whitney U-test (SPSS, 2023).

The Mann- Whitney U test was conducted to determine whether there is a statistically significant difference in CO2 emissions per passenger between the inland passenger vessels and the actual calculated carbon dioxide emissions from the main engines of large passenger vessels which were defined in the study on a customer-by-customer basis by hourly consumption at 85% main engine effect. The results indicate a significant difference between the groups at 0.05 significance level [U = 0, p< .001]. The null hypothesis was rejected, and it was concluded that there is a statistically significant difference between

the customer-specific carbon dioxide emissions of inland and international passenger vessels at significance level p<.05.

"The P-value expresses the probability that the sum of the ranks of the group will differ by the amount or more from the expected value observed in the sample, assuming the null hypothesis holds. The lower the p-value, the more support there is for the alternative hypothesis." (Akin menetelmäblogi, 2012: U-testi)

6.2 The dependence of fuel consumption on the number of passengers according to the Spearman correlation test

The correlation between the studied variables (the ratio of the number of passengers to the fuel consumption of the vessels) was tested using the Spearman correlation coefficient. The aim of the study was to test whether the variables are interdependent in order to understand the reasons for the factors affecting fuel consumption. If no correlation takes place, it can be concluded that for a large ocean-going vessel, fuel consumption is better correlated with other factors. In domestic traffic, a moderate correlation was discovered between the variables.

The dependence between x (number of passengers) and y (fuel consumption) was measured using the Spearman correlation test. The choice of the test was influenced by the fact that unlike the Pearson correlation coefficient, for example, the Spearman correlation coefficient does not have a normal distribution requirement for values. Both correlation tests are, however, suitable for measuring interval scale variables.

The Spearman correlation coefficient gets a value between -1 and 1. When it converges at the value of 1, there is a positive dependence between the variables. When it converges at the value of -1, the dependence is negative according to the Spearman correlation coefficient (Kananen 2011, p.108-111, 2011). The values of the variables must be discrete. If the continuity deviates

at some value, Spearman's ordinal correlation coefficient can be determined to calculate the averages of the numbers, as has been done in this study (Kananen 2011, p.108-111, 2011).

The correlation between number of passengers and fuel consumption in large ocean-going passenger vessels (2730-6687 pax)

Correlation		
	Consumption litres/hour	Total number of passengers
Spearman's rho	0.414	0.414
Sig. (2-tailed)	0.125	0.125
N	15	15

Table 3: There is no statistical significance between consumption and the number of passengers on ocean-going passenger ships (SPSS-statistics programme).

The number of passengers and fuel consumption in ocean going passenger vessels as variables showed that there is no correlation between the two at 0.05 significance level ($r = .414$, $p = .125$.). Hence, the number of passengers does not explain the fuel consumption of the ocean-going vessels studied (Kananen 2011, 109) or the differences in fuel consumption between ships ($n = 15$).

In general, the magnitude of engine power is influenced by the hydrodynamics of the vessel: its design and propulsion system connection, the traffic area and energy efficiency in different sea conditions are important keywords (Meriläinen 2017, 8–44).

The study also does not consider the power generation of large ships or the potential role of shaft generators in power generation at sea. Ocean-going

vessels are very different in design from domestic vessels, as the numerous services and machinery require considerable space and extra weight.

The correlation between number of passengers and fuel consumption in Finnish inland passenger vessels (18-220 pax)

Correlation		
	Consumption litres/hour	Total number of passengers
Spearman's rho	0.696	0.696
Sig. (2-tailed)	0.004	0.004
N	15	15

Table 4: There is moderate statistical significance between consumption and the number of passengers on inland passenger ships (SPSS-statistics programme).

The number of passengers and fuel consumption in large vessels as variables showed that there is a moderate correlation between the two on Finnish domestic passenger vessels at 0.05 and 0.01 significance levels ($r = .696$, $p = .004$), (Kananen 2011, 109). In contrast to the ocean-going vessels, a correlation between fuel consumption and number of passengers was found among fifteen observation units ($n = 15$).

The number of passengers on a vessel explains fuel consumption when looking at domestic vessels, their full passenger capacity and fuel consumption.

In domestic transport, vessel size is often constructed very straightforwardly in relation to the number of passengers. However, there are statistical exceptions even in the domestic market. A very traditional passenger vessel may not carry as many passengers as a modern mainland-to-island vessel. There is a wide variety of passenger vessels in Finnish waters, with very different hydrodynamic characteristics.

6.3 Establishing the correlation between number of passengers and fuel consumption

The study showed that there is a correlation between the total number of registered passengers and fuel consumption of a ship in the vessels sailing inland. As passenger capacity increases, so does fuel consumption.
An increase in the number of passengers requires increases in space, and thus a correspondingly larger ship size also consumes more fuel.
In international shipping, it cannot be seen as quite so straightforward. The number of passengers certainly has an impact, but on a large vessel the algorithms need to be considered on a much larger scale.

6.4 Determining fuel consumption in the reference groups

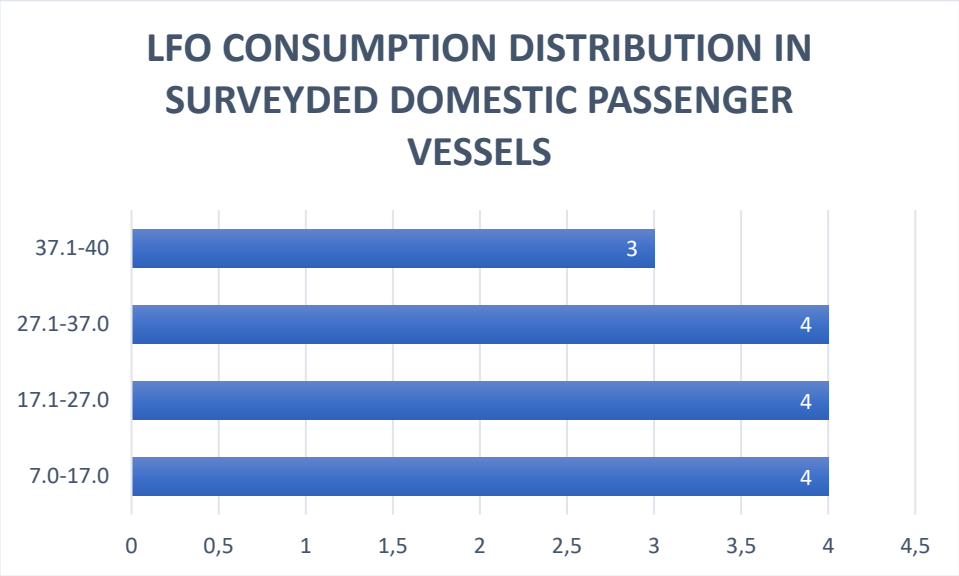
The tables show the hourly fuel consumption of the main engines of the studied vessels. For domestic transport, the figures also take into account the consumption of auxiliary engines. In order to avoid inaccuracy, the consumption figures for auxiliary machinery were not calculated for ocean-going cruise ships, where the variation in electric load is more significant than on domestic vessels due to diesel-electric propulsion systems, port calls and various passenger activities, for example. The statistics show that the range of variation in domestic consumption is relatively larger than for ocean-going vessels.

For ocean-going vessels, the most consuming vessel consumes almost three times as much as the least consuming one, while for domestic transport the difference between the least and most consuming vessels is almost six times greater.

In domestic transport, the vessels studied somewhat differ in their design and hydrodynamic characteristics: the smallest vessels are more like water buses while the largest vessels are miniature passenger vessels in terms of design, shape, layout and technology. In domestic transport, passenger vessels have also been built from towed vessels, for example, so the design and therefore

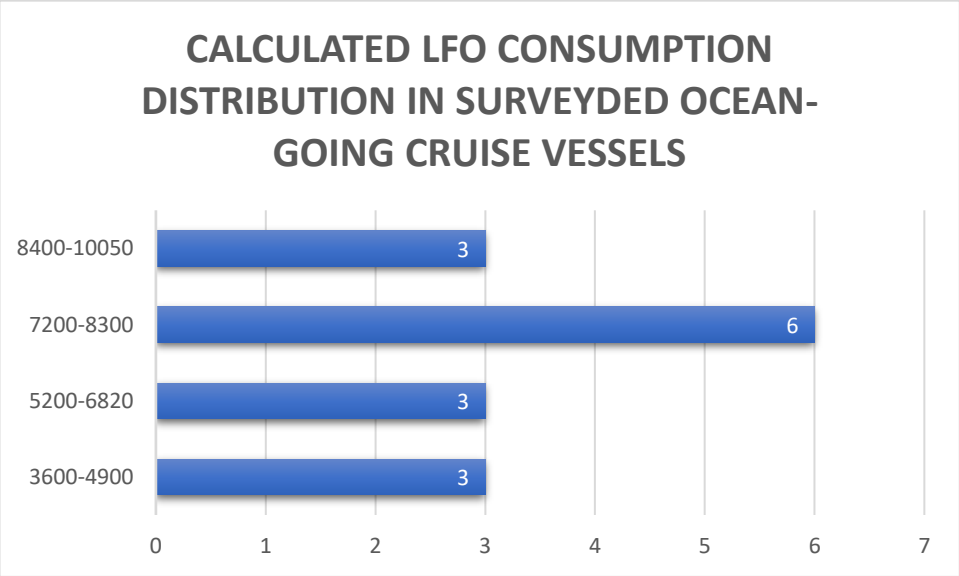
fuel consumption is relatively different from a lightweight water bus. The vessel traffic areas in Finland (Finnish Domestic traffic area 1, 2 and 3) also impose different requirements on vessel design. 1 covers inland waterways and islands while 3 already represents open sea traffic.

However, the traffic areas often overlap and vessels operating in inland waterways are very often also suitable for the domestic III traffic area.



n=15 Average Consumption= 24.75 litres LFO/ hour. Median Consumption= 26.98 litres LFO/ hour

Graph 1: Fuel Consumption distribution in domestic passenger vessels by litres/hour, range 7- 40 litres/hour



n= 15 Average Consumption= 7048.6 litres LFO/ hour. Median Consumption= 7339.15 litres LFO/ hour

Graph 2: Light Fuel Oil Consumption distribution in ocean-going passenger vessels by litres/hour. Range: 3669.3 litres -10045.1 litres/hour

6.5 Calculating fuel consumption and carbon footprint of ocean-going passenger ships (vessels of 2730 to 6687 passengers)

Data on the fuel consumption of vessels per unit were collected in a network environment by calculating the technical engine power according to the shipyards or types of aircraft, for example. The total power data of the main engines of 15 ocean-going cruise vessels were used in the calculation. The modelling was carried out only technically in accordance with the values given by the manufacturer. Hollenbach's resistance current calculation algorithm was not used in the calculation, nor when examining the efficiency of the machines or the diesel-electric azipod system included in all the studied vessels.

Collecting other technical data on the vessels was considered challenging in terms of availability. However, this has been taken into account in the research results, which are indicative. The commonly used technical formula for calculating consumption was used in the definition of consumption data. Consumption and emissions are determined with fuel oil so that it is possible to verify the comparison with the experimental group.

The efficiency of diesel is 0.35-0.45, but it was not considered necessary to determine in order to obtain technical consumption data, since the data are in any case based on the total power generated by the main engines. In addition to the ship's hull data, different weather conditions and speed have a significant impact on changes in the consumption control group. In statistical modelling, a conclusion was made about the consumption while the ship was passing, utilising 85% of the total power of the vessel. The impact of variable weather conditions and different driving speeds on fuel consumption was not determined in the study. However, their real impact on final consumption plays a significant role as theoretical models are established. However, the vessels have to do a lot of work in route selection when taking into account the currents and wind in the traffic area. Route planning is of great importance.

The impact of the number of passengers is also essential in order to calculate the carbon footprint per passenger. When looking at the vessels, only the share of passengers was calculated. When examining the number of passengers on board, the carbon footprint calculation per passenger was carried out only with the maximum number of passengers.

The study also takes into account the premise that passenger ships of both groups (domestic traffic and large passenger ships of international traffic) run on light fuel oil. The proportion of heavy fuel oil has not been estimated. In addition, the study has not defined the carbon footprint of new bio-based fuels, nor the calculation of new fuel alternatives in more detail. In addition to traditional fuel sources, new passenger ships also use scrubbers, LNG and battery technology (DNV, Alternative fuels insight). Shipping companies, as well as international pools and shipping organisations, are also carefully considering the use of new propulsion systems in passenger transport in addition to freight traffic. This study takes into account traditional diesel technology. The mass of fuel consumed per hour was determined by checking the SFOC values according to the ISO conditions of engines made by major manufacturers for merchant ships. The average value was estimated to be 170-200g/kWh. For ship-type machines, a reading of 170 g/kWh was achieved through interpolation for LFO (light fuel oil). In the review, the general machine types Wärtsilä 46 D and MAN 8L 48/60 four were considered for the main engines. The vessels also meet the specified emission standards of classification societies and the international contributions provided by legislation to the IMO vessels. These acts were not considered separately for the types of vessels (MAN Four stroke marine systems, 2022; Costa Mediterranea Ship Technologies, 2022).

During the study, the accuracy of the consumption of large vessels and refined theoretical consumption models were implemented using a common formula for calculating the consumption of marine fuel. For the formula, it's necessary to clarify the hourly fuel consumption of fuel quality in g/kWh from machine manufacturers' machine type manual. Total engine power from the vessel is

also required. The consumption is calculated using an 85% power load, so the result is multiplied by 0.85.

Consumption formula (which was used to determine the fuel consumption for ocean-going passenger ships)**:**

X= $P\ (tot) * SFOC * 0.85$

where:

X= Consumption

P (tot) = Total effect of main engine from the vessel (kW)

SFOC (g/kwh) = Mass of fuel consumed per hour / Power developed in KW. Determined from the equipment manufacturers' websites MAN and Wärtsilä according to commonly used marine engines. 170g/kWh

Density (ρ) calculated formula (Diesel density 850 kg/m3)

$$\rho = \frac{m}{v}$$

where:

ρ is the density

m is the mass

V is volume

From the formula above, the following equation can be formed:

$$V = \frac{m}{\rho}$$

from which the diesel volume in litres can be calculated by multiplying the diesel mass kg/m^3 per diesel density kg/m^3

CO2 emission/hour/passenger from ships propulsion formula:

It is known that 1 litre of diesel oil produces 2.68 kg of carbon dioxide when burned. Using previous formulas and factual data, the following equation can be constructed:

$\frac{Consumption\ (hour) \times 2{,}68}{max.number\ of\ passengers} = Co^2$ emission / hour/ passenger

The calculation above defines the hourly consumption of the large vessels in the study.

Example vessel: Main engine total effect 62,370 kW, number of passengers 6600 pax

Co^2 emissions from propulsion/hour:

$62{,}370 \times 170 \times 0{,}85 = 9012 \frac{kg}{hour}$ x 0.65 (calculated safety margin)

5877,8 kg equals about 6834 litres/ hour in 85% effect.

(Diesel density is 860 kg/m^3)

$CO^2\ emissions$/hour/ passenger:

$$\frac{6834 \times 2{,}68}{6600} = 2{,}77\ kg$$

= 2,77 kg CO2/ hour/ passenger

Example vessel 2: Main engine total effect 31,800 kW, max. passengers: 3300

Co^2 emissions from propulsion/hour:

$31{,}800 \times 170 \times 0{,}85 = 4595{,}1\ kg\ x\ 0{,}65$

= 2986,8 kg

2986,8 kg equals about 3473 litres/ hour in 85% effect

(Diesel density is 860 kg/m^3)

$CO^2\ emissions$/hour/ passenger:

$$\frac{3473 \times 2{,}68}{3300} = 2.82kg$$

= 2.82 kg CO2/hour/ passenger

The examples are models of how consumption and emissions were calculated for the fifteen ocean-going passenger ships under study. The vessels in the models were only examples, but the calculation was based on the same algorithms as for ocean-going vessels.

In the study, the possibility of error in the formula was estimated to be at 15-35% for the actual consumption of large ships, since the consumption of ships varies greatly from one type of vessel to another depending on their shapes and speeds driven, for example, and accurate consumption data cannot be

acquired without protected oil logbook data from the shipowner. The same possibility of error should be considered with carbon footprints. However, the vessels studied in the statistics are based on vessels with a total consumption of 100-200 MT per day (Sinha 2021) and their data do not apply to specified luxury cruise ships. However, for vessels consuming 100-200 MT per day and domestic vessels operating in Finland, the comparison is completely valid.

A similar calculation was performed for ships in domestic traffic, which found that the consumption data calculated with the formula differed by 1.35 % from the actual measured consumption data of the ships. Using Hollenbach's formula for calculating the resistance current is a significant innovation since it considers the water resistance and structure of the ship better, for example. In the future, calculation will continue to develop as regulations increase. Therefore a new, more extensive study that would also consider emission effects could offer insights on the still missing issues.

6.6 Technical determination of fuel consumption of domestic passenger vessels

Four shipping companies operating in different parts of Finland responded to a survey that collected data on fuel consumption and other technical factors of ships that belong to shipping companies. The quantitative survey was refined with open interviews regarding the technical data of the vessels and the operations of organisations. Responses to the survey were received from the owners, technical directors or shipowners of the shipping companies. The shipowners responded to the survey independently by email. Clarifications to the survey were given over the phone or in an appointment when necessary. For each of the 15 ships, separate responses were obtained.

The respondents to the survey were chosen using a snowball sample. It was desired to involve even more shipping companies in the study, but unfortunately a sample was obtained from only four due to the busy schedules of the companies. The ships surveyed represent approximately 9 percentage points

of the domestic passenger ships operating in Finland. The vessels included in the study operate domestically in either sea or lake areas and form a wide coverage in terms of gross tonnes. The GT of the smallest ship was 20 and the GT of the largest one was 250.

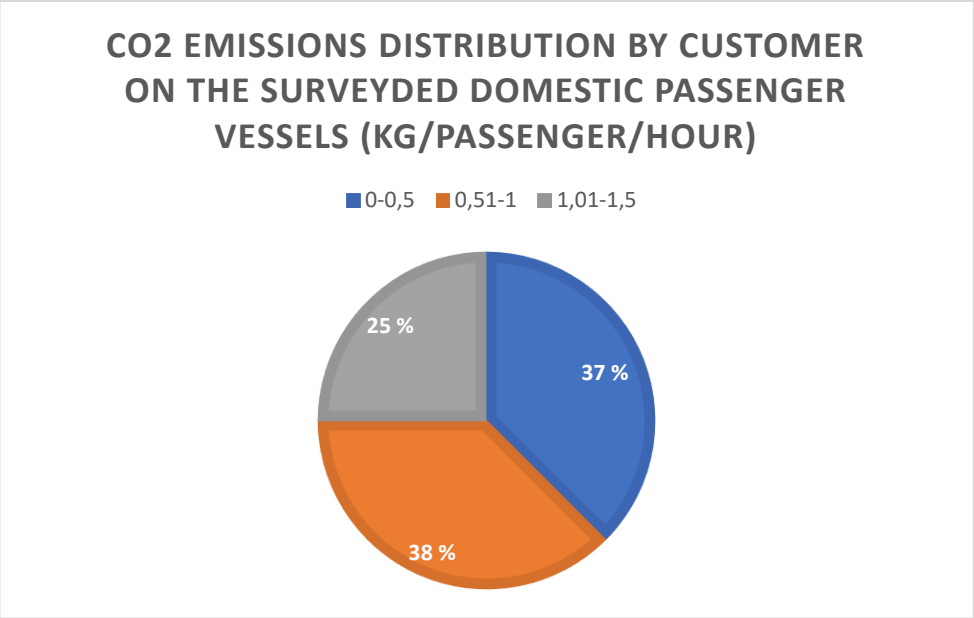
6.7 Customer-specific carbon dioxide emissions from domestic passenger vessels

The table graph from group 1 describes the fifteen different domestic transport vessels used in the study. The carbon footprint of each vessel was determined by customer basis in relation to the consumption with 85% effect. The average carbon dioxide emission rate per customer for specified domestic vessels is 0.667 kg CO2 / customer at full passenger capacity.

The carbon footprint is determined through a survey for shipping companies. Shipowners were asked to provide responses on the hourly consumption of each vessel and total number of passengers for the calculation.

The hourly consumption of the vessels in the group is multiplied by 2.68, which is the calculated amount of CO2 produced by a diesel engine burning one litre of fuel.
Once the carbon footprint of the total consumption is obtained, it is divided by the total number of passengers.

If a vessel carries half of its total passenger capacity, the carbon footprint of the vessel is in turn roughly 1.5 times the figures shown in the table using this calculation model. The number of passengers on the vessels in the test group ranges from 18 to 220. The total consumption value has been used in the calculation, which includes the combined consumption of both main and auxiliary machinery measured as a whole.



n = 15. Average: 0.667 kg CO2/ passenger/ hour. Median: 0.596 kg CO2/ passenger/ hour

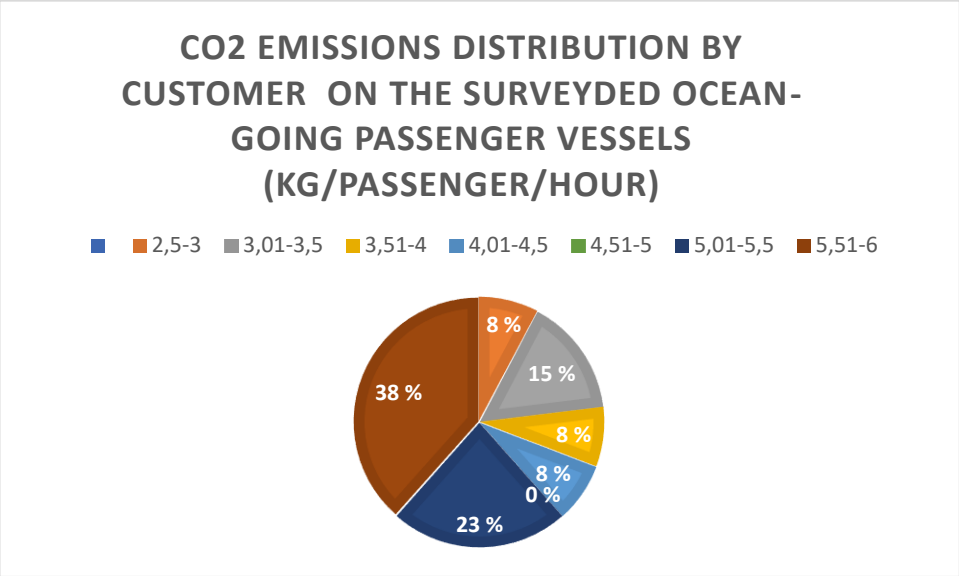
Graph 3: Carbon dioxide emissions from domestic transport fuel consumption per customer per hour

6.8 Customer-specific carbon dioxide emissions from specified ocean-going passenger vessels

The graph formulated from group 2 describes the fifteen (15) ships engaged in international voyages whose revenue consists exclusively of passenger transport and cruise-related passenger services.

The carbon footprint of each vessel was determined by customer basis in relation to the consumption with 85% calculated effect of the vessel. The carbon footprint is determined through a survey for shipping companies.
The hourly consumption of the vessels in the group is multiplied by 2.68, which is the calculated amount of CO2 produced by a diesel engine burning one litre of fuel. Once the carbon footprint of the total consumption is obtained, it is divided by the total number of passengers.
If a vessel carries half of its total passenger capacity, the carbon footprint per vessel is in turn roughly 1.5 times the figures shown in the table using this

calculation model. The number of passengers on the vessels in the test group ranges from 18 to 220.



n = 15. Average: 4.918 kg CO2/ passenger/ hour. Median: 5.13 kg CO2/ passenger/ hour

Graph 4: Carbon dioxide emissions from the fuel consumption of ocean-going cruise vessels per customer per hour.

7. SOURCES OF CARBON FOOTPRINT OF VESSEL OPERATIONS IN DOMESTIC VESSELS

Based on domestic and foreign passenger vessel traffic, it would make no sense to conduct a comparative study of other carbon footprint sources as the comparison would not provide reliable research results based on different traffic areas and technical regulations. The research focuses on monitoring other emissions from domestic passenger ships and is a qualitative part of a comprehensive research. The traffic area, flag state and classification society of a ship and the international regulations for IMO ships alone form such a broad set of rules that even carrying out a comparison of other carbon footprints of the same vessel type does not meet the requirements for the researched data. The impact of international regulations and the ISO standards is considerable in international traffic. The renewal of spare parts must be carried out in accordance with the requirements of the classification institutes based on the maintenance program, and the characteristics of the spare parts themselves are also precisely regulated. A shipping company cannot really influence these factors in international traffic, so the measurement of their effects should be carried out mainly through the combined effect of manufacturers and classification societies.

In addition, when comparing the technical characteristics and equipment of vessels in domestic traffic, challenges can be identified in their regulations in order to make a scientifically reliable comparison. Domestic vessels are subject to the IMO Non-SOLAS Directive, which was adopted as part of the domestic legislative collection in 2009 for vessels over 24 metres long which operate at least in the domestic II sea area. In Finnish inland waterways and coastal traffic area I, instead of the Non-SOLAS Directive, the requirements of the current technical regulations for passenger ships operating in domestic traffic area I apply. The requirements for vessels under 24 metres long differ from other points of the regulations depending on their technical characteristics

and equipment in both sea and lake areas (Law on the technical safety of a vessel, 2009).

7.1 Starting points for emission calculations for domestic passenger ship industry

The development of an environmental management system in the domestic passenger shipping industry is driven by the interests of international tourism organisations and corporate governance. From the owner-management side, the message is passed on to the board and the operational management of the company. As noted, emission accounting starts with the inclusion of environmental protection in the corporate strategy of company management, as well as in domestic passenger shipping companies. A company's strategy defines what environmental protection means for the company in the long term. The aim of including environmental protection in the strategy is to make the overall operations of the company more environmentally friendly. Based on the strategy, before calculating emissions the current situation of the shipowner must be examined and environmental objectives and values set by defining an environmental clause in subcontracts, for example. Once the goals have been set, an environmental team can be set up within the company. The aim is to make the awarded subcontracts and purchased products more environmentally friendly. For example, the company may require the subcontractor to comply with its own environmental protection programme, or the wholesaler may commit to supporting responsible producers. The responsibility of the shipping company is removed when the subcontractor has a certificate of its environmental commitment. However, it would not make sense for a company to independently establish quality or environmental certificates, but to rely on certificates that have been established over a long period of time and are generally recognised, such as those mentioned in this thesis.

7.2 Particle emissions of light fuel oil used in Finnish domestic passenger vessels

The Finnish company Neste Oil refines fuel oil on which product information is based on. There are small differences in the products from different manufacturers, but all the products are in accordance with the EN ISO standards that are effective in the field, meaning that the technical differences of the products were not seen as problematic for the reliability of the study.

Harmful organic compounds belonging to the category of polyaromatic hydrocarbons are created when carbon-containing materials burn incompletely. Compounds are found, among other things, in fuels, foods and air (Measurlabs 2022).

Sulphur dioxide (SO_2) is defined as an acidic gas, the harms of which have been studied specifically for both human health and ecosystems. The gas is produced as a combustion product of sulphur-containing fuels (Finnish Meteorological Institute, 2022).

Carbon residue is the amount of coke left after hydrocarbon is distilled. The two most common measures of carbon residue are the Ramsbottom (RCR) and Conradson carbon (CCR) methods. Both use units of weight % (McKinsey & Company 2022). The values appearing in the study are implemented with CCR measurement.

The definition of ash content in brief is that it indicates the unburned component that remains after a sample of furnace oil has been burned. The ash content in oil products is usually low: typically between 0.03% and 0.07% by weight. Some oils may have a higher weight percentage of ash content (Sciencedirect 2022).

Nitrogen oxides differ from other combustion-derived air pollutants with the fact that, as a result of burning fuel, combustible nitrogen is also formed from nitrogen in the air. Thus, the combustion temperature essentially affects its generation. When burning, mainly nitrogen oxide (nitrogen monoxide, NO) and a bit of nitrogen dioxide (NO2) are produced, of which nitrogen dioxide is harmful to health (Duodecim Terveyskirjasto, 2020). With modern exhaust gas recycling techniques, nitrogen oxides produced as a by-product have been reduced. The vast majority of diesel engines on ships of various sizes are equipped with a turbocharger, and many other technologies for exhaust gas circulation are also being developed. The turbocharger is a very old invention which was patented in 1905 (Turbotukku 2022).

Polyaromaatit Polyaromater Polyaromatics	% (m/m)	-	8.0	EN 12916
Rikki Svavelhalt Sulphur content	mg/kg	-	10.0	EN ISO 20846 EN ISO 20884
Hiiltojäännös 10 % pohjasta Kokstal av 10 % återstod Carbon residue on 10 % distillation residue	% (m/m)	-	0.30	EN ISO 10370
Tuhka Askhalt Ash content	% (m/m)	-	0.010	EN ISO 6245

Table 5: Product information on the content of Finnish fuel oil (Neste Oil, 2022).

The maximum mass percent of polyaromatics is eight (8) percent, which means that if a vessel's average consumption is 25,654 litres/ hour, its unit of weight is 22,800 grams (one litre of fuel oil equals 0,89 kg).

If the mass percent is 0,08, the calculation will be as follows:

% m/m = $\frac{grams\ of\ solute}{100\ g\ of\ solution}$ x 100

$= \frac{8\ g}{100 g}$ X 100 = 8

If the consumption is 25,654 litres (22,800g/hours), the mass percent concentration is 1,824g in 22,800 grams and 1,8 kg in 22,8 kg: *"the solution's mass percent concentration is given by the number of parts of solute you get in 100 parts of solution, which is made up of solute and solvent."* (Socratic 2016).

Carbon residue with 10% distillation residue:

The carbon residue concentration with a 10 % mass percent is 68,4 grams in 22,800 grams and 0,0684 kilograms in 22,8 kilograms

Ash content:

The mass percent concentration of the ash content is 22,8 grams in 22,800 grams and 0,0228 kilograms in 22,8 kilograms

Sulphur Content:

The sulphur content is 10 mg/kg. In 22,8 kg the sulphur content is 228 mg is 0,0001 %

7.3 Estimation of exhaust gas emissions of inland vessels excluding CO2 emissions

According to Zhang Fan et al., exhaust gas emissions can be calculated using two different methods. Emissions can be taken into account either by calculating them according to the ship's consumption data or engine power and time of use (kWh). In the study, it was estimated that the ship's average consumption data would perhaps be a more practical way of calculating the actual emission since the power requirement must take into account the consumption caused by e.g. arriving at the pier in more detail, and with current technology, this is not very easily implemented. An error in the consumption data is assessed on a ship-by-ship basis due to the variable engine rotation speeds of the investigated vessels. Most of the investigated ships were equipped with high-speed engines, but medium-speed engines were also represented (Zhang Fan et al. 2016, 7).

7.4 The average particle emissions of Finnish inland passenger vessels

Table 6: Average pollutants emissions from the tested vessels of the PROMOVAN programme and from the 2011 study along various trips (g/km)

Vessel	Cargo	Power kW	Fuel kg/km	CO_2 kg/km	NOx g/km	PM g/km	CO g/km	THC g/km
Passenger boat	-	2x 160	1.4	4.7	88	0.8	122	19.4
Freyssinet barge *	0 t	2x 160	-	4.7	79	1.1	12	-
Self-prop. barge	670 t	2x 970	13.6	42.6	873	6.1	205	11.2
Pusher tug	2715 t	2x 920	9.8	30.1	726	7.0	396	56.1
Pusher 1 *	3090 t	2x 660	*8.4*	32.3	322	3.3	35	-
Pusher 2 *	4000 t	2x 735	*11.8*	53.8	458	12.5	257	-
Pusher 3 *	2800 t	2x 750	*15.1*	57.7	427	3.2	77	-

* Vessels of "Port de Paris - VNF" study in 2011. The figures for fuel are the usual consumption given by the pilots and not data from test measurements

Table 6: Average emissions of the tested vessels from the PROMOVAN programme and the 2011 study through various trips (Pillot et al. 2016, 218).

The determination of direct emissions from ships without measurement at the end of the vessel exhaust funnel is only indicative. In the thesis, the Port de Paris VNF study of 2011, which determined exhaust gas emissions for tugboats and small passenger ships, was used as an indicative measurement method. The engine power and fuel consumption of the passenger ship in the example were very similar to the ships determined in the thesis. The average consumption mentioned in the table was 1.4 kg/kg, while the corresponding figure in the thesis was 1.38 kg/kg. In the Port de Paris VNF study, the engine power of the passenger ship was 320 kw (2*160kW), while the average engine power of Finnish ships was 337 kw. In the Port de Paris VND study, the calculation of the different sub-data of the emissions are also mentioned in more detail, which helped reach the final result. However, a critical aspect concerning the research should be that the emission data from each ship are completely unique due to the fuel already used, the structure of the ships and the characteristics of the machine (slow-medium-speed or high-speed) and whether the exhaust gas is recycled in the machine. Today, however, the ISO standard, for example, determines the limit values with which the fuels must comply. As a rough conclusion, it can be stated that the table corresponds with the average domestic passenger ship from which measurements were made in the study (Pillot et al. 2016, 218).

Based on the interview material, in domestic traffic, ships are generally connected to the shore power grid if their harbour visit exceeds 30 minutes, which means that the electricity produced by the ship's own generator is only used during the cruise and 30 minutes before and after the cruise. The consumption of the generator is taken into account in the total consumption. Emissions from onshore electricity production have been deliberately ignored in the study, as they were estimated to vary a lot between different parts of Finland. In addition, shipping companies have relatively little influence over emissions from the electricity network.

7.5 Greenhouse gas emissions from domestic passenger vessels

Direct emissions
- Ship operations (fuel, driving style, drive optimisation, route choices, real-time fuel consumption data)
- Company cars
- Emissions from operational company activities
- Ship heating (in an oil boiler is used)
-Waste and garbage (solid and oily waste, oily rags, filters, oil)
- Grey and black water, ballast water (typically not used in domestic passenger vessels)
- Business travel and crew changes
- Use of detergents
- Use of coat paints
Travelling with an auxiliary boat
- Disposable containers, ordering new clothes for restaurant workers etc., toilet and kitchen towels

Indirect emissions
Raw materials for restaurants (local food, sustainable food)
Spare parts, paints
Procurements for docking
Office supplies
Coffee etc. for meetings
Port services (washes, water, food waste, ballast water)
Sub-contractor emissions (buses, cars, trucks, tools)
Equipment purchases (e.g., emission category or energy class)

Other indirect emissions
Emissions from land stream production
Office heating, ship heating (if electric)
Computers for remote-access meetings (cloud services, datacenter archives)
Office or port-area lighting
Waste and garbage (depends on the availability of onshore recycling facilities for ship generated waste.

Direct emissions from domestic passenger ships consist of office and ship operations and waste from cruises and dockings. Indirect emissions are caused by bus transport between main and partner companies, procurement, food and spare parts. In the study, the role of environmentally friendly infrastructure managed by the city or port was found to be a significant part in reducing the indirect emissions of a company.

7.6 More cruises, more carbon dioxide accumulation

The traffic areas of vessels differ substantially based on their geographical location alone: whether it is on the lake, in the inner archipelago or in open sea areas. In Finland, there are also domestic transport entrepreneurs that offer river cruises. The ships travel at different speeds with variable numbers of customers and ship structures, which is why the cruise-specific carbon footprint and emissions also vary substantially between ships and itineraries. Some of the itineraries have more specific challenges in scheduling, while on charter cruises, for example, customers may enjoy a peaceful journey. Some ships leave the pier a few dozen times a day, while some have only a few departures a day depending on the ship's route and traffic. For this reason, the purpose of the study is to provide a basis for the calculation of emissions, and not exact answers to each section since it is not entirely possible due to the scope of the business, but should instead be carried out on a ship and shipping company-specific basis, for example.

7.7 Requirements for spare parts

On domestic passenger ships, based on interviews, the most common consumables to be renewed include various filters, belts and impellers, which, in general, must be replaced annually based on operating hours. During the season, ships have an average of 2-3 oil changes depending on the engine usage hours of the surveyed vessels.

Otherwise, based on the interviews, it can be estimated that a third of the items to be renovated can be reused with the help of circular economy, and recycling is taken into account as comprehensively as possible in the restoration of old ships. New materials that cannot be replaced by utilising old materials, account for two thirds of the total. The figure was achieved by examining the share of material procurement costs in the total repair costs of vessels.

Based on interviews, an average of 50 litres of paint is used for ship renovations per vessel each year. The amount includes all annual painting projects from primer to top coat. The median value of the age distribution among the domestic ships in the study is 36 years and the average age of domestic vessels 38,6 years. The average age of the passenger vessels of the EU Member State fleet is 28 years (European Maritime Safety Report 2022, 11).
The conversion and renewal of ships with new construction materials has prevailed in shipping among passenger ships, for example, increasingly in accordance with the principles of the life cycle model (Elo 2022, 32-36).

Some of the vessels of the interviewed shipping companies have undergone or are in the process of undergoing significant modifications of machine renewal and reorganisation of premises. Based on the interview data, technical and interior upgrades can increase the life cycle of ships for decades to come. It is not possible to come up with a general plan for extending the life cycle of ships, as vessels differ enormously from each other. The building materials of the vessels are commonly steel, aluminium and wood. Vessels of any building material can last for several decades if properly maintained. The different traffic areas of ships and the salinity of the water impose different requirements on the maintenance of the hull.

7.8 Food and waste emissions and recruitments

In addition to spare parts, the qualitative part of the study and the qualitative interview dealt with food and waste. Quantitative generalisations cannot be made from the qualitative shares due to the small sample size.
In the qualitative part, however, the issue is examined as a phenomenon, so the research was carried out in this respect precisely in accordance with the principles of qualitative research by coding the basic principles that are generally repeated in the interviews. All shipping companies answered that the origin of their food was 80-90% domestic in relation to the revenue from the restaurants. The maximum distance for importing food reported in the responses was

250 km. Three companies stated their average import distance to be significantly lower: only 0-30 km. During the sailing season, the amount of food waste is 2-10% of the weight of the food served, based on the responses of three shipping companies. All the interviewed companies spoke strongly in favour of local food and local products. The cruises aim to offer fresh ingredients of the season. Cruise operations in domestic traffic enable the availability of fresher raw materials since the transportation of food to the home port is easily scheduled, and ships can be replenished even multiple times a week if necessary.

In addition, the traffic area of the ships offers some indication of the amount of waste generated. For example, when moving to island destinations, a part of the waste is formed by the customers' snacks, but on restaurant ships, the customers' meals exclusively consist of the food and snacks served on board. All of the shipping companies also mentioned that the amount of waste from à la carte meals differs significantly from waste generated from buffet tables. In general, less waste is generated from à la carte than buffet dining. The cruises also vary significantly: on some charter and dinner cruises, dining is an important part of the cruise experience, while on shorter sightseeing cruises, mainly cafeteria services are used on board. The traffic can also have connect-line service to an island destination where, in addition to the scenery, cafe services are available.

7.9 Other waste

According to the interviews, waste can be divided into three categories: mixed waste, cardboard waste, oily waste and electrical waste. The amount of oily waste, including oils and filters, forms an average of 114 kg per ship per sailing season. On average, the waste recycling rate is 50%.

As waste management on the continent develops, even mixed waste can be sorted better in the future. Mixed waste was defined as unsorted waste. Domestic passenger ships typically call at ports several times a day. The black, bilge and in most cases grey water that the ship generates is sucked into the pipelines of cities after cruises, so the emission load they produce was not

defined in the study, regardless of the fact that it may still be significant in international transport. Ballast water facilities are generally not used to any significant extent on domestic passenger ships. Ballast water is occasionally needed to lower shallow bridges, but it is also used for tap water, which is pumped ashore. In international traffic, it is important to take wastewater into account, as the regulations still vary a lot in each flag state and the regulations regarding international sea areas still allow the discharge of wastewater directly into the sea.

7.10 The views of interviewed domestic passenger vessel companies on emission reductions

The interviewed domestic shipping companies listed the emissions from their operations, which showed that a lot of work has been done in the companies to consider different ways of reducing emissions. Some emissions were beyond the control of the companies, but the interviewees saw that a wide range of choices could still be made for the environment. During the study, different ways to reduce emissions were listed. Some are more suitable for one shipowner than another depending on the form and scale of their operations.

7.11 General means of reducing emissions

To reduce direct emissions, it was found that it could be done by operating ships in the most economical and low-emission way possible by connecting the ship to shore power and using bio-based diesel whenever possible. Operational route choices and transport scheduling are also at the heart of emission reduction. Renewable, domestic light fuel oil can be introduced on domestic vessels, which the manufacturer claims to be made from 100% recycled materials, reducing greenhouse gas emissions by 90% (Neste 2023, Neste MY Renewable fuel oil).

The development of waste sorting together with the development of waste disposal points and washing ships with ecological cleaning products are steps that shipowners have already taken. In all the interviewed companies, black sewage and bilge water is pumped into the city sewer and in most of them grey water is also discharged into the sewerage system. On ships and company sites, efforts have been made to sort waste and to encourage the waste recipient to offer better recycling options. Once recycling is in place in the company, it is important that the whole recycling chain on the mainland works as well. Other ways of reducing emissions identified by businesses include quitting the use of disposable containers for which there is a charge, switching to laundry service laundering instead of buying new clothes, and switching to cloth hand towels in toilets. When purchasing equipment, companies can also make low-consumption or low-emission choices by looking at the energy classes of products. However, the challenge with many of these choices is product availability in a short timeframe.

During the study, it became clear that committed staff and the continuous development of sustainable practices are efforts that shipowners have already made. Setting up an environmental team is also a step towards a more environmentally friendly and sustainable way of doing business. Shipowners have already used the circular economy and recycled spare parts, for example, to a significant extent. The owners can further reduce emissions by, for instance, switching to cars that use renewable diesel, requiring the use of EURO 6 emission class service vehicles, and by offering extensive recycling opportunities for waste sorting. In recycling, it is essential that different types of waste correspond to each other according to the readiness levels of the waste stations. Electricity companies can offer different packaging with the promise of environmental value or carbon neutrality. A company is able to influence its indirect emissions to some extent through the choice of electricity company. Therefore, cost-effective renewable electricity will play a key role in the future.

Skilful training, commitment, long-term action and continuous improvement are also at the core of corporate responsibility work. In seasonal work, it is important to familiarise employees with safety aspects and company values in a

comprehensive way, and to commit them to being a part of the work community so that they might choose the same employer for future sailing seasons as well.

8. RESULTS AND CONCLUSIONS

At the beginning of the study, the most common sources of emissions in domestic passenger ship traffic were identified as the research problem, on the basis of which research questions were determined as the objective of the study: What kinds of emission sources exist on domestic passenger ships?

When assessing the reliability of the survey, the relatively good response rate to the qualitative questions on domestic transport can be noted. Half of the respondents answered questions from different geographical areas. The representation of the survey in relation to the population was found to be moderate and the limitations of the population are explained for both comparative groups of the survey: domestic passenger vessels and ocean-going passenger vessels. In terms of validity, the study was found to have successfully addressed the research problem. The study has met the general validity criteria required for a study based on the calculation formulae, the legal provisions and the content of the questionnaire. By testing the questionnaire, the survey team found it to be effective in relation to the research problem. In the interviews, the groups were asked for their opinion on the questionnaire.

Based on the research problem, four research questions were prepared. The thesis report has been compiled by following the framework based on the research questions. The research report clarified the determination of emission sources according to the GHG protocol and the ISO standard. In addition, the criteria for awarding an eco-label were examined. Comparing the emissions of large passenger ships and domestic passenger ships was done by comparing their customer-specific carbon footprints based on fuel consumption. The study can be used as part of a GHG protocol or ISO standard in order to determine the baseline for emission calculations, and to provide tourists with an overview of the environmental impacts of domestic travel when choosing from different holiday options, for example.

The study found that when current restrictions are excluded, the carbon footprint load of domestic passenger ships is significantly lower than that of the ships with a passenger capacity of 2730-6687 mentioned in the study, and the results achieved statistical significance.
The research report clarifies the limitations of generalisation so that the results of the study can only be used when comparing passenger ships with fuel consumption from 100MT to 200MT/day.

For domestic passenger ships, other direct and indirect emissions were determined from the data encoded according to the qualitative part of the study - the main characteristics of the emissions. The literature review and the previous research results also defined other exhaust emissions and their estimated share in the average vessel type in addition to carbon footprint emissions from domestic traffic.

The study would require further investigation in order to obtain precise exhaust emissions from ships when measured directly. However, the research group did not have a metre in use that would affect the calculation of emissions, so the study had to be done on a computational basis.

In the future, domestic passenger shipping companies will be able to use this thesis to map their total company-specific emissions in terms of CO2 equivalents. The thesis is also suitable as a basis for the introduction of an environmental protection system and a quality system for business. In Finland, the Finnish Meteorological Institute is contributing to the calculation of emissions from ships. The study found that in the future it will be relevant to distinguish international and domestic traffic in order for the emissions to be determined on a vessel-by-vessel basis for domestic traffic as well when modelling emissions using a different formula. In the future it should also be important to distinguish domestic vessels and vessels going abroad so that the formula based on their sailing routes could also be distinguished in addition to data based on the AIS, since there is no studied certainty about the suitability of the Hollenbach method for inland waterway vessels. Another problem is that the Finnish

emission model is still under development for non-EU ships (differences between IMO and EU regulations), (Jalkanen 2022, Email).

Ships not equipped with AIS transponders due to size or traffic area should also have a means of mapping emissions. The thesis has explained the starting points for the calculation per shipping company and mapped the carbon dioxide emissions of ships in general. For domestic transport, an attempt has also been made to determine a model for other tailpipe emissions in addition to CO2 emissions through calculation. The sample size is quantitatively small but geographically large. In Finland, vessels have been selected from four different geographical regions and vessels operating in the oceans have been selected by random sampling, checking that they are still in service and that their propulsion is conventional. The samples taken provide a general picture of the situation in addition to the source data. Qualitative interviews with domestic shipping companies were also carried out to provide an overall picture of other emission sources. Further research is needed to calculate the total emissions. For a more detailed analysis, emissions need to be measured through appropriate measurement methods on board ships such as exhaust emissions and CO2 calculations for spare parts and raw materials from suppliers, for example, which the companies will use to provide a company-specific overall emission rate. In the future, digitalisation is likely to make big developments and more applications for calculating emissions will enter the market. A real-time overview of total emissions will be more readily available to companies. The interviews found that domestic shipping companies are investing in local food and the circular economy as much as possible in the replacement of spare parts for ships. In annual ship maintenance, oils, filters, belts and paints generally cause most of the expenditure. Through quantitative research, the thesis was able to argue that the domestic tourism industry is already an ecological choice in terms of CO2 emissions when compared to the reference group of vessels that mainly operate outside the Baltic Sea and when the service is used by as many customers as possible. The average carbon footprint per customer for the tested vessels was 0.667 kg/customer/hour, compared to 4.919 kg/customer/hour for the reference group of

passenger vessels. For domestic passenger vessels, a moderate correlation was found between maximum customer numbers and fuel consumption, whereas no such correlation was found for the vessels in the reference group.

The sample size was small for a quantitative study, which was taken into account in the statistical analysis by using non-parametric methods to test both the correlation and the hypothesis of statistically significant differences in fuel consumption between the groups.

A study can be considered valid when it is in line with its boundary conditions. This study has verified its calculation formula, findings and their generation. The calculation of fuel consumption was based on the commonly used formula of ships running at 85% power. Consumption data for large marine engines have been verified by checking the websites of equipment manufacturers and the chief marine engineer, and fuel data from the supplier's product catalogue and safety instructions. For domestic and oceanic transport, consumption and emissions have been determined with light fuel oil to allow comparison between vessels. However, light fuel oil is restricted in some areas, which the study has taken into account. The emission coefficient for heavy fuel oil is 3.2 thousand kilograms per one thousand kilograms of HFO fuel, while the corresponding figure for light fuel oil is 3.17 thousand kilograms per thousand kilograms of fuel oil (Statistics Sweden, Emission factors used in the estimations of emissions from combustion, 2018). The figures allow an equivalent classification of carbon dioxide emissions. The results were calculated by subtracting 35% from the calculated consumption of ocean-going vessels in order to obtain a correct safety margin. The same formula was used to calculate the consumption of domestic transport, and it was found that the result was at most 35% higher than the measured consumption, which led to 35% being deducted from the consumption of all calculated ocean-going passenger vessels.

Both groups used in the comparison were quite small, so the samples accounted for 7.8% of the population (191 vessels) of domestic passenger ship traffic and 3.8% of the population (341 vessels) of ocean-going traffic. However, the sample is representative: the observation units have been selected

randomly from both groups and no vessel defined in the frame of reference has been omitted on a discretionary basis. In a larger study, the entire population of both vessel groups could be determined as measurable fuel, which would require significantly more resources from the research team.

There is only little information available on the subject, and the research group would need to go through a lot of modelling in addition to the literature review. However, the ongoing research provides important basic principles for a wider range of research in the future as well as starting points for emissions calculations. As the study also provides situational awareness, it can be used in examining different vessel types and shipping companies. The need for research on new fuels is increasing, and information on the current situation of traditional vessels is needed for the mapping of new, more environmentally friendly alternatives. In other words, the life cycle of fuel types for domestic vessels should also be examined - which fuel suitable for transport would be the most ecological from production to emissions in terms of emission values? Electricity has also been studied in terms of inland waterway transport, but it would also be useful to investigate the suitability and emissions of biogas in domestic passenger shipping, for example. When it comes to vehicles, research results show that renewable diesel can achieve lower CO2 values with a life cycle model than methane (Kumpulainen 2011).

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APPENDIXES 1 (2)

HIILIJALANJÄLKIEN KARTOITTAMINEN KOTIMAAN MATKUSTAJA-ALUSLIIKENTEESSÄ

KYSELY KOTIMAANLIIKENTEESSÄ OLEVILLE VARUSTAMOILLE/ RESEARCH FOR FINNISH WATERWAY SHIPPING COMPANIES

Varustamon nimi:

YLEINEN OSUUS/GENERAL:

Alusten lukumäärä varustamossa/ Number of vessels:

Tiedot yhtiön aluksista, aluskohtaisesti eriteltyinä:

GT:

Vuosimalli/ model year:

Käyttövoimalaatu/Fuel:

Ajettava Nopeus/Speed:

Koneiden lukumäärä: Pääkoneet: Apukoneet: Kattilat:

Koneiden käyntitunnit ajokuukausina/ kuukausi: pääkoneet: apukoneet: kattilat:

Koneiden yhteinen tuntikulutus/ Fuel comsumption per hour:

Kulutus purjehduskauden aikana/ Fuel consumption per sailing period:

Matkustajakapasiteetti max/ number of passengers:

Keskimääräinen kuukausittainen matkustajamäärä aluksella/ average montly number of passengers:

Purjehduskauden pituus aluksella(kk)/lenght of sailing season (months):

Ajettava mailimäärä purjehduskauden aikana/ sea miles during sailing period:

APPENDIXES 2 (2)

Liikennöinti, valitse oikeat vaihtoehdot/ Traffic, choose right opinions: Tilausliikenne/Charter, reittiliikenne/Route traffic, liikenne pelkästään sisävesillä/Only in-land traffic,/Only sea, archipelago traffic: Ainoastaan meri-ja saaristoliikennettä/ liikenne sisävesillä ja merialueella/ inland and seatraffic, pelkästään matkustajakuljetuksia/ only passenger transport/ matkustaja-ja rahtikuljetuksia/ both passengers and cargo transport

RAVINTOLA/RESTAURANT: *Osuudessa voi jo käyttää olemassa olevia tietoja, mikäli niitä on jo olemassa.

Raaka-aineiden keskimääräinen tuontimatka/ Average distance for raw materials: (kysymystä voi purkaa myös pääraaka-aineiden kotimaisuusasteella, mikäli vastaus on vaikea antaa):

Raaka-aineiden painomäärä purjehduskauden aikana/ The amount of rawmaterials during sailing period:

Ruokajätteiden määrä purjehduskauden aikana/ The amount of food waste during sailing period:

Purjehduskaudella käytettävät yleisimmät raaka-aineet ja niiden osuus kokonaisuudessa käytettävistä raaka-aineista/ the most common raw materials used during the sailing season and their share of the total raw materials:

JÄTEMÄÄRÄ/ KUUKAUSI/ ASIAKAS:

Jätteiden kierrätysaste kokonaisjätemäärästä/ the recycling amout of wastes:

Jätteiden tyypit yleisesti sekä jätemäärät (sekajäte, pahvi ja kartonkijäte sekä öljyinen jäte) / the types of carbage and the amount of wastes/ sailing period:

TELAKOINTI/ ALUSTEN KUNNOSTUKSET:

Käytetty maalien litramäärä/ purjehduskausi/ the amount of paint during the sailing period:

Varaosat/ Tarvikkeet/ Remontit, rungonrakenteet (konehuone, matkustajatilat, navigointijärjestelmät), täysi uusimistarve purjehduskausittain: Varaosien määrä/ materiaali/ vuosi…. (spare parts, accessories, hull structures (full need for renewal during the sailing season)

- Kysymystä voi lähteä purkamaan kiertotalouden ajatusmallilla eli varaosien määrä, joka aluksissa keskimäärin vuosittain korjataan ja käytetään uudestaan suhteessa kokonaan uusiin varaosiin. Onko vanhat hävitettävät varaosat kierrätysmahdollisia ja miltä osin?