Interreg

Co-funded by the European Union

Central Baltic Programme

REISFER

REDUCING CO_2 EMISSIONS IN ISLAND FERRY TRAFFIC

Elias Joki-Korpela, Minna-Liina Ojala and Lauri Ojala

D.1.2.2

The Business Environment for Island Ferry Services in the Central Baltic Region

– Possibilities and Preconditions to Engage in CO_2 Reduction

UNIVERSITY OF TURKU

September 2025

Deliverable Information Sheet

Version	Final
Grant Agreement Number	CB0300186
Project Acronym	REISFER
Project Title	Reducing CO2 emissions in island ferry traffic
Project Duration	36 months
Deliverable Number	1.2.2
Deliverable Title	The Business Environment for Island Ferry Services in the Central Baltic Region – Possibilities and Preconditions to Engage in CO_2 Reduction
Deliverable Dissemination Level	Public
Work Package	1/2
Lead Partner	Tallinn University of Technology
Authors	Elias Joki-Korpela, Minna-Liina Ojala and Lauri Ojala
Official Due Date	30 September 2025
Delivery Date	30 September 2025

List of Acronyms

BBAB	Blidösundsbolaget AB, a ferry operator in the Stockholm County
CBR	Central Baltic (Sea) Region
CO_2	Carbon Dioxide
ESF	The Estonian State Fleet
EU	European Union
EU ETS	EU Emissions Trading System
GHG	Greenhouse Gases
GNSS	Global Navigation Satellite System
GoA	The Government of Åland
GT	Gross tonnage
HFO	Heavy Fuel Oil
HSL	Helsingin seudun liikenne, a joint municipal authority organizing and procuring public transport in the Helsinki metropolitan area
HVO	Hydrotreated Vegetable Oil
IMO	International Maritime Organization
Island ferry	A ferry operating on a route that is not part of public road network, typically linking islands in the archipelago to a mainland port and/or to some other islands
LNG	Liquefied Natural Gas
MDO	Marine Diesel Oil
Road ferry	A ferry operating on a route that is part of public road network. These ferries typically carry 10 to 100+ vehicles and have capacity to take passengers
Ro-Pax (ferry)	A roll-on/roll-off (Ro-Ro) ferry that can take both passengers and vehicles
SMEs	Small and Medium-sized enterprises

Keywords List

- Island ferry services
- Carbon emissions
- Decarbonization
- The Baltic Sea
- Central Baltic Region

Disclaimer

This document reflects the views of the author(s) and does not necessarily reflect the views or policy of the Programme authorities. Whilst efforts have been made to ensure the accuracy and completeness of this document, the Programme authority is not responsible for any use that may be made of the information it contains nor for any errors or omissions, however caused.

Table of Contents

List of Figures

List of Tables

1 About REISFER project and this report

1.1 REISFER as part of Interreg Central Baltic Programme

As part of the Interreg Central Baltic Programme, the 3-year REISFER project (2024–2027) aims to significantly reduce the carbon footprint of island ferry transport, which plays a vital role in connecting mainland areas with islands across the Central Baltic Region (CBR) (Figure 1).

The primary objective of the REISFER project is to achieve a 10–20% reduction in CO_2 emissions on selected ferry routes by introducing a combination of technological and operational innovations.

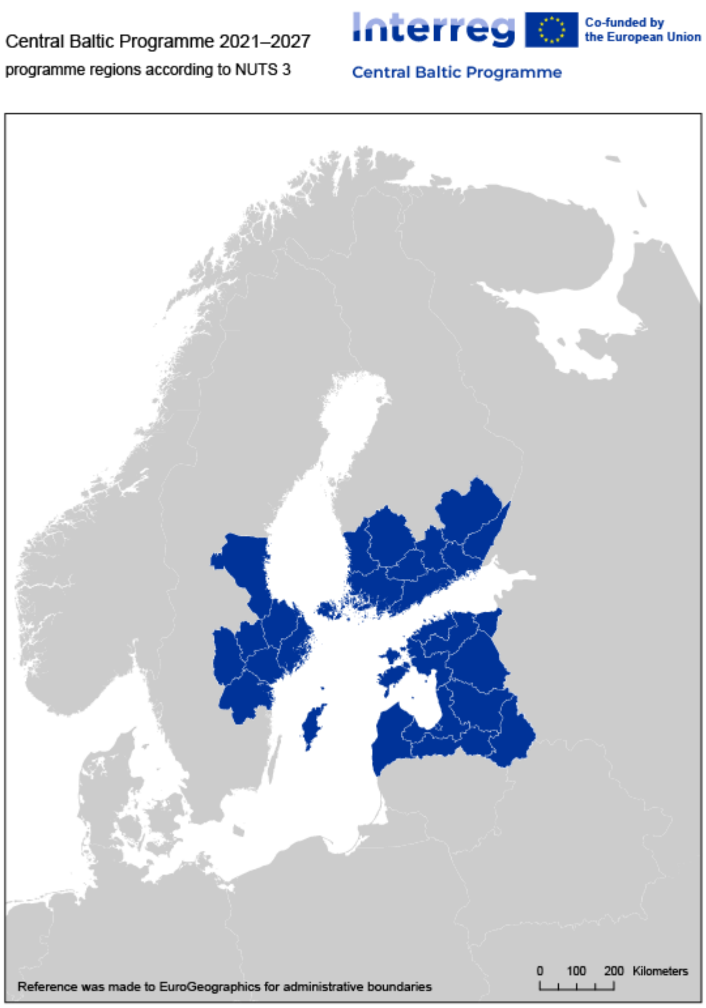

Figure 1: Participating regions in the Central Baltic Programme 2021–2027

The project's work plan is divided into two work packages (WPs), each focused on delivering outcomes that contribute to lowering CO_2 emissions in key ferry transport areas:

1. **WP 1 – CO_2 reduction possibilities and potential in CBR island ferry traffic**
2. WP 2 – CO_2 emission abatement methods and technologies on ferries

This report falls under the WP 1 in the REISFER project.

1.2 Purpose of the report

The Baltic Sea, as one of world's busiest maritime areas, features a dense network of ferry routes connecting countries, islands and mainland ports. These ferry services are essential for both passenger and cargo transport, particularly in heavily trafficked areas like the Gulf of Finland and the northern Baltic Proper.

Ferry services are considered the backbone of transport in the Baltic region, with major routes experiencing constant, year-round demand. This includes large car-passenger vessels in cross-border routes, largest of which can take well over 2,000 passengers and hundreds of cars and trucks or trailers. On routes between Finland and Estonia, Finland and Sweden and Sweden and Estonia, these large-scale services carry over 15 million passengers, over 2 million cars and over 1 million trucks and trailers per year. In addition, ports in Gotland handle close to 2 million passengers.

This report focuses on a less known, but equally important domestic and local road and island ferry services with smaller vessels in the Central Baltic region, namely those between islands and/or the mainland along the coastline or in inland lakes.

The definition of coastal or inland ferry services may vary, so it is important to provide a coherent typology for these. For Central Baltic Region, five sub-markets are distinguished in Figure 2, which is based on the governance type and nature of the service, not on vessels' technical specifications.

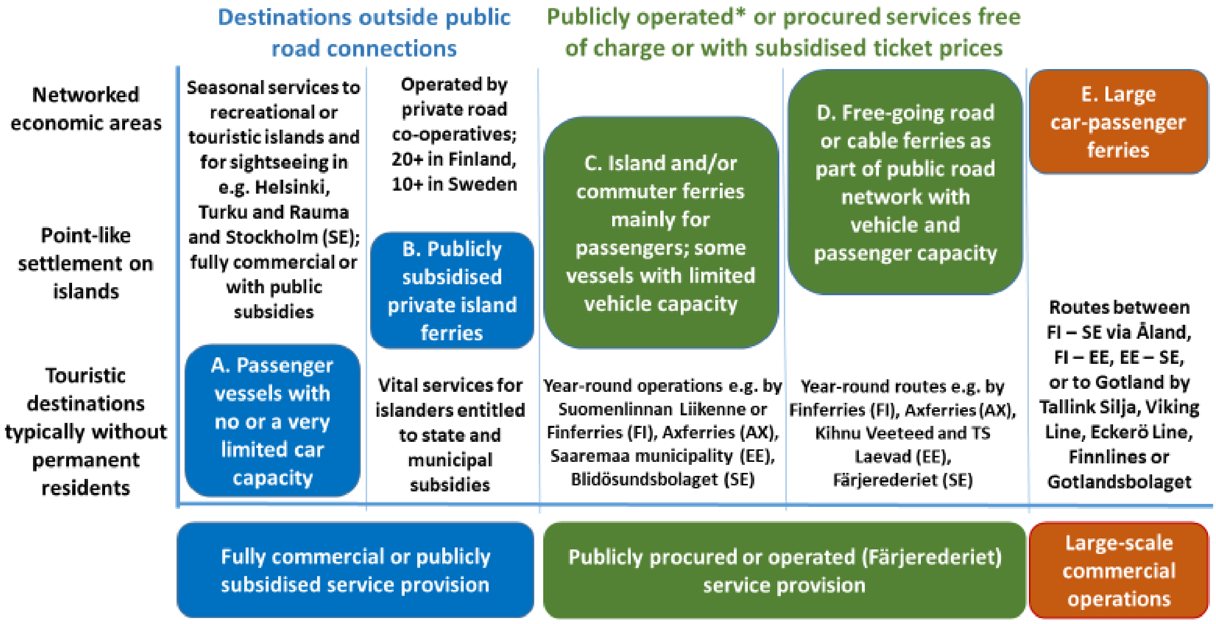

Figure 2: Categorisation of ferry services especially in the Central Baltic Region (Ojala et al., 2025)

While REISFER report D.1.2.1 (Ojala et al., 2025) offered a cross-border analysis of the scale and governance structures of ferry services in the Central Baltic Region, this report builds on those findings by providing further insights into additional factors influencing island ferry operations.

The purpose of this report is to provide an overview of the preconditions and opportunities that the business environment offers for reducing CO_2 emissions in island ferry transport specifically in the Central Baltic Region. The report begins by outlining the available strategies and technological measures for emission reduction in this sector.

It then presents a general overview of the physical and natural environment of the Central Baltic Region, followed by an examination of the socio-cultural, technological, political, and economic conditions characterizing each of the studied sub-regions: Estonia, mainland Finland, the Åland Islands, and Sweden.

This report does not seek to provide an exhaustive or highly detailed analysis of each individual factor or region. Instead, its aim is to offer a general-level understanding of the various contextual elements that shape and influence island and road ferry operations across the Central Baltic region.

2 Introduction

The European Union (EU) and its individual Member States have set ambitious emission reduction targets for the current and coming decades—and island ferry traffic is no exception. Reducing environmental impact is becoming increasingly important for both the companies providing ferry services and the authorities responsible for procuring, subsidising, and regulating the sector. In the Central Baltic Sea Region, cutting CO_2 emissions is rapidly emerging as a key priority for professionals engaged in island ferry operations.

As efforts to reduce emissions in the transport sector accelerate, it becomes increasingly important to evaluate the current state and near-term opportunities for emission reductions in the island ferry industry—both in 2025 and in the coming years. While extensive research has been conducted on long-term decarbonisation strategies for maritime transport, this report focuses specifically on the short- to medium-term possibilities within the island ferry service sector, and geographically within the Central Baltic Sea Region. It does not cover emission reduction strategies beyond the 2030s or address other segments of the maritime industry.

There are essentially two primary ways for maritime vessels to reduce greenhouse gas emissions: by decreasing fuel and energy consumption, or by switching to lower-emission fuels or electricity.

One of the most prominent pathways for reducing emissions in ferry transport is the installation of rechargeable batteries onboard vessels, enabling the use of shore-side renewable electricity to power voyages with zero direct emissions. Implementing this solution requires investment in charging infrastructure, which can be difficult and very costly especially in remote islands. Decision-making on electric grids and charging infrastructure often depends on public authorities taking the initiative. Ferry operators must either invest in new battery-powered vessels or retrofit existing vessels with battery systems to take advantage of shore power.

In addition to battery-electric solutions, various alternative energy sources are emerging for maritime transport. According to the International Maritime Organization (IMO), industry experts estimate that by 2030, up to 15% of the global shipping fleet could be powered by alternative fuels. This means vessels would no longer rely on conventional fuels such as heavy fuel oil (HFO), marine diesel oil (MDO), or electricity alone.

The alternative fuels considered in this report include ammonia, biofuels, hydrogen, methanol, e-fuels, and liquefied natural gas (LNG). While LNG is still a fossil fuel, it can offer substantial CO_2 emission reductions—ranging from 15% to 30%—depending on vessel type and implementation method.

Emission reduction strategies are not implemented in isolation. Their success is influenced by a wide range of contextual factors, including the availability of infrastructure, economic incentives, customer behaviour, and variability in weather conditions. To accurately assess the feasibility and potential impact of emission reduction measures in island ferry traffic, it is essential to understand the broader business environment in which these strategies operate.

The research questions (RQ) this study answers are:

1. What emission reduction measures are feasible for island ferry operators?
2. What are the main elements in island ferry business environment like in each sub-market of the Central Baltic region?

RQ1 is explored in Chapter 3, which introduces the current operational and technical methods available for reducing emissions in ferry traffic. These primarily include ferry electrification, a potential shift to alternative fuels, and operational methods such as slow steaming and voyage optimisation. This study does not examine these methods in depth, but rather assesses their applicability and usefulness in the context of island ferry transport.

RQ2 is addressed in Chapters 4–8, which provide an overview of the business environments in Estonia, mainland Finland, the Åland Islands, and Stockholm County in Sweden, along with the preconditions and opportunities they offer for emission reduction in the Central Baltic Region.

A business environment refers to all factors that influence a business or organisation. It is commonly analysed using the PESTEL framework, which includes Political, Economic, Socio-cultural, Technological, Environmental, and Legal elements. Given the scope of this report, these elements are presented at a general level as follows:

- **The physical and natural environment** provides the foundation and boundaries that define what kind of ferries and routes can be utilised, where and how
- **The socio-cultural environment** provides information on the characteristics and behaviour of people in certain market. In this report, the focus is on population and tourism.
- **The technological environment** refers to the current level of vessel technology in use and availability of the necessary supply and infrastructure for electricity and alternative fuels in each region
- **The legal and political environment** encompasses international and national laws that regulate and guide island ferry transport
- **The economic and competitive environment** refers to the economic preconditions and incentives that service providers in the island ferry traffic industry face in making environmentally friendly investments.

Each element of the framework shapes the conditions under which ferry operators and authorities make decisions. By providing a general overview of these elements, this report helps to identify both the constraints and opportunities that exist in each sub-region.

3 Emission reduction methods in shipping

The mission to reduce ferry emissions can essentially be approached from two primary directions: operational optimization and alternative energy solutions.

The first approach focuses on improving operational efficiency, through methods such as eco-driving and voyage optimization. These strategies aim to reduce fuel consumption and can often be implemented without major technological modifications to existing vessels. Their key advantage lies in cost-effectiveness and immediate applicability. These fuel-saving strategies are examined in more detail in Subchapter 3.1.

The second approach involves addressing the source of emissions: the fuel itself. By replacing fossil fuels with cleaner alternatives, or eliminating fuel use altogether through electrification and battery-powered propulsion, it is possible to achieve zero operational emissions. Here, operational emissions refer to those generated during vessel operation, as opposed to lifecycle emissions, which encompass all emissions from fuel production to vessel decommissioning.

When evaluating alternative fuels and electrification, it is essential to consider lifecycle emissions. While some energy sources may produce no emissions during operation, their production can result in significant environmental impacts, potentially creating a misleading impression of being entirely emission-free. Despite the clear environmental benefits, challenges such as high costs, limited fuel availability, and technological constraints can complicate the transition. These issues are discussed in Subchapter 3.2.

A key concept in the technological development of ferries is retrofitting—the process of upgrading an existing vessel with new technologies. This can range from small enhancements to comprehensive conversions, such as shifting from conventional fuel systems to battery-electric propulsion. Alternatively, operators may opt to replace older vessels entirely. Modern ferries are typically designed with greater energy efficiency, making fleet renewal an effective long-term strategy for emission reduction.

A summary of the emission reduction methods explored in this study is presented in Table 1.

Table 1: Emission reduction methods in island ferry traffic

Reducing fuel consumption	
Eco-driving	Reducing and optimising driving speeds and avoiding idle running of engines to reduce fuel consumption.
Voyage optimisation	Optimising routes and schedules to minimise total driving distance and/or engine hours leading to lower fuel consumption and emissions.
Energy systems of vessels	Efficient heating and cooling systems to save energy, installing energy efficient lighting systems such as LEDs.
Blasting and painting	Appropriate coating of vessels with antifouling paints to lower or preserve low water resistance, which results in lower need to use energy and fuel.
Replacing the use of traditional fuels with electricity and batteries or alternative fuels	
Electrification of ferries	Batteries are installed onboard vessels and used as the power source of the ferry. The batteries are recharged in ports with electricity from the grid, similarly to bunkering.
Hydrogen and ammonia	Hydrogen and ammonia can be used to power vessels with a fuel cell. The fuel cell will create electricity that is used to power the vessel.
Biofuels, HVO	Biofuels are fuels produced from biomass and typically function similarly to fossil fuels. HVO is the most prominent biofuel in ferry traffic as HVO is essentially a renewable version of marine diesel.
Methanol	Methanol is an industrial alcohol that can serve as a sustainable marine fuel. While it is a liquid, it is not a drop-in fuel and requires modifications to existing engines and infrastructure.
LNG	Liquefied Natural Gas (LNG) can be used as fuel and the use of LNG will lower emissions but not eliminate them. LNG is a fossil fuel and therefore cannot achieve carbon neutrality.
E-fuels	E-fuels are synthetic fuels meant to mimic existing fossil fuels. E-fuels are a promising option from an environmental perspective but still years away from large-scale implementation.

3.1 Reducing fuel consumption

3.1.1 Eco-driving

Eco-driving—operating a vessel as fuel-efficiently as possible—is one of the simplest methods for reducing emissions. A key component of eco-driving is slow steaming, which involves sailing at reduced speeds. Since slower speeds require less energy, this directly decreases CO_2 emissions per nautical mile. However, the downside is longer travel times, which can reduce convenience for passengers and users. Despite this, slow steaming remains a low-cost, immediately available strategy for emission reduction. Ultimately, adjusting vessel speed represents a trade-off between faster service and lower environmental impact.

Beyond slow steaming, vessels can be operated more fuel-efficiently by optimizing routes and timing to take advantage of environmental conditions such as currents and tides. While slow steaming offers a straightforward approach, ferry crews can also be trained in more advanced eco-driving techniques. These methods help reduce fuel consumption and contribute to moderate emission reductions. One of the key benefits of eco-driving is cost efficiency—using less fuel not only lowers emissions but also reduces operating expenses for ferry operators and contracting authorities.

3.1.2 Voyage optimisation

Voyage optimization is an operational strategy designed to minimize fuel consumption and emissions by optimizing routes and schedules. This may involve selecting shorter or more efficient routes, reducing the frequency of underutilized voyages, or concentrating operations during peak travel times—daily, weekly, or seasonally. Schedule optimization is especially relevant in the context of island ferries in the Central Baltic Region, where some services may run with very few passengers solely because they are part of a fixed timetable. Additionally, voyage optimization can include weather-based routing, although this approach is typically more applicable to long-distance, open-sea travel.

In densely populated archipelagos, the hub-and-spoke model presents a promising approach for streamlining ferry operations. This model designates a central "hub" island with direct connections to the mainland, while smaller surrounding islands—the "spokes"—are served via connections to the hub.

For instance, in Southwest Finland, where the current island ferry network is highly complex, implementing a version of the hub-and-spoke model could enhance efficiency, particularly during off-peak seasons. Figure 3 illustrates how this model could be applied in the context of island ferry services.

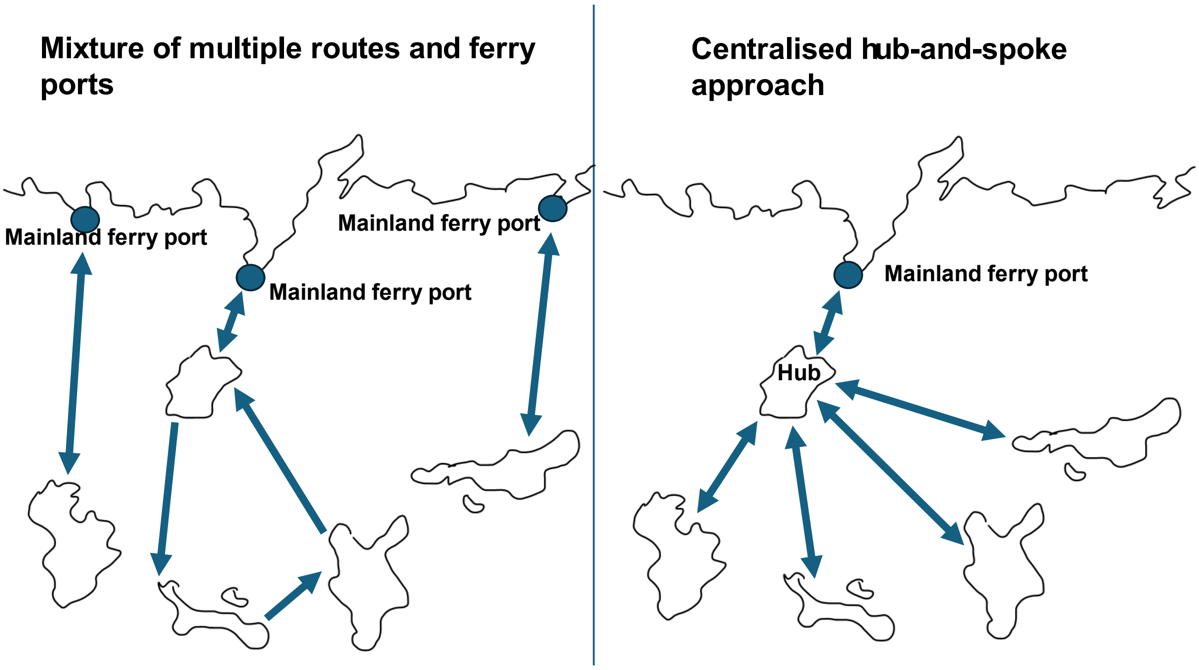

Figure 3: Example of the hub-and-spoke model in island ferry traffic (Figure by Joki-Korpela)

3.1.3 Energy systems

A ferry requires energy not only for propulsion but also for powering a range of onboard systems. Passenger ferries, in particular, consume energy for heating, cooling, lighting, and other amenities—functions typically supported by electricity generated from the vessel's engine. Installing energy-efficient systems can substantially lower the overall energy demand of these operations, resulting in reduced fuel consumption. As such, improving energy efficiency serves as an indirect yet impactful method for cutting emissions and operational costs.

Even when vessels operate on clean energy sources, reducing energy use translates into cost savings. For example, ferry operators in the REISFER project have begun replacing conventional lighting with energy-efficient LED systems to decrease the energy required for onboard lighting.

3.1.4 Hull maintenance – blasting and painting

The condition of a vessel's hull plays a significant role in its overall energy consumption. A smooth and well-maintained hull reduces hydrodynamic resistance, which in turn lowers the amount of force—and fuel—required to propel the vessel. Regular maintenance, including surface cleaning, blasting, and the application of specialized coatings, is essential for preserving hull efficiency and minimizing fuel use.

Table 2: An indicative listing of bans on antifouling compounds or substances in shipping. Compiled from several sources (IMO, EU, HELCOM)

Compound / substance	Authority / Convention	Ban details / Scope	Effective date
Tributyltin (TBT) and all organotin compounds used in antifouling paints	IMO — International Convention on the Control of Harmful Anti-Fouling Systems on Ships ("AFS Convention")	Ships are prohibited from applying or reapplying antifouling systems containing organotins, or having them on hulls without a barrier to stop leaching.	The Convention entered into force September 17, 2008.
Organotin paints for pleasure boats under 25 m and fish net cages / underwater structures	HELCOM (Baltic Sea regional agreement under the Helsinki Convention)	Recommendation to ban use and retail sale of organotin-containing antifouling paints in the Baltic Sea area, for pleasure boats and fish cage nets; later recommendations expand scope.	HELCOM Recommendation 20/4 adopted 23 March 1999. Full independence from organotins follow via IMO's AFS Convention in 2008.
Cybutryne	HELCOM, EU	Use of cybutryne (a biocide) is restricted/prohibited under EU biocides regulation / Commission Implementing Decision. HELCOM Recommendation 42-43/11 (2025) notes ban on cybutryne for certain uses (under biocidal product regulations in EU).	
Copper-based biocidal antifouling paints	EU (concern rather than full ban)	Not universally banned, but under scrutiny: their toxicity to non-target marine organisms is of concern. Studies and EU bodies are exploring less toxic and biocide-free alternatives. Not explicitly banned in all applications, but could be subject to restriction depending on specific product and use.	

However, environmental concerns arise from the use of certain toxic hull coatings. Some traditional marine paints contain harmful substances that leach into the surrounding waters over time, posing significant risks to marine ecosystems. To support responsible and sustainable vessel maintenance, the use of such toxic coatings should be avoided entirely in favor of environmentally friendly alternatives. Some of the toxic substances, such as Tributyltin (TBT), are also prohibited by IMO (See Table 2).

3.2 Electrification and alternative fuels

3.2.1 Electrification of ferries

Electrification of maritime vessels refers to replacing traditional fuel entirely with batteries and electricity as the vessel's primary energy source. In hybrid systems, electric motors operate alongside conventional combustion engines, allowing both to be used as needed. Full electrification results in a battery-powered ferry that produces zero emissions during operation, as no combustion of any fuel takes place.

While the International Maritime Organization (IMO) and the European Union (EU) have implemented emission reduction regulations for the shipping industry, these are primarily targeted at larger vessels in international trade. In contrast, small island ferries, which typically fall below 500 gross tons and operate on domestic routes, are governed by national regulations rather than international frameworks.

Moreover, the IMO and EU employ different methodologies for calculating emissions. The IMO uses a tank-to-wake (TtW) approach, which accounts only for emissions generated during onboard fuel combustion. The EU, by contrast, applies a well-to-wake (WtW) approach, encompassing the entire fuel lifecycle—from extraction and production to transportation and eventual combustion—offering a more comprehensive assessment of greenhouse gas emissions.

Although switching to batteries eliminates operational CO_2 emissions, it does not eliminate lifecycle emissions associated with the production of electricity and batteries. This makes the source of electricity critical when evaluating total emissions under a WtW framework. If battery-powered ferries are charged using fossil-based electricity (e.g., coal), the emissions are merely shifted in time and space rather than reduced.

The true environmental benefit of battery-powered ferries is realized when they operate using renewable electricity, such as wind, solar, hydro, or emission-free nuclear power. These sources can make the operation nearly carbon-free. Still, it must be acknowledged that battery manufacturing is not an emission-free process and may involve significant lifecycle emissions. Therefore, while batteries combined with clean energy can significantly reduce emissions, they do not eliminate them entirely.

From an operator’s perspective, transitioning to electric propulsion requires either:

- Purchasing new battery-electric ferries, or
- Retrofitting existing vessels with battery systems and supporting technologies.

However, electrification is not a universal solution. Batteries are heavy, require space, and are dependent on a reliable charging infrastructure, which introduces logistical and technical constraints—particularly in maritime environments. Electrification is best suited to short routes and lightweight vessels, which generally makes it well-aligned with island ferry traffic.

Yet, some island routes in the Central Baltic Region, for example, are relatively long and connect remote islands, making the establishment of charging infrastructure both difficult and expensive.

Just like traditional ferries rely on fuel and bunkering stations, electric ferries depend on an uninterrupted power supply and shore-side charging infrastructure. This includes:

- The charging station at the ferry terminal, and
- A stable connection to the local electricity grid.

Setting up this infrastructure typically requires collaboration with local authorities, grid operators, and sometimes national regulators. It is often a time-consuming and bureaucratic process, but an essential step. Without adequate charging infrastructure along a route, operating a battery-electric ferry is not feasible.

In conclusion, charging infrastructure is a critical enabler of ferry electrification. Its availability—combined with route characteristics, vessel type, and access to renewable energy—will determine the feasibility and success of emission reduction through electrification in the island ferry sector.

Despite its limitations, electrification is emerging as a key trend in the ferry transport industry, with several authorities in the Central Baltic Region increasingly leaning toward this solution. According to CleanTechnica, up to 70% of new ferry orders are now electric, reflecting a broader shift toward sustainable maritime transport. In neighbouring Norway, electric ferries have already become the industry standard, positioning the country as a global frontrunner in this field.

However, the growing popularity of electrification does not imply that all island ferries in the Central Baltic Region can or should be electrified. The feasibility of electric ferries is highly route-specific, depending on factors such as distance, port infrastructure, and financial capacity. Nevertheless, on routes where electrification is technically and economically viable, transitioning to battery-electric vessels offers an effective means to eliminate operational emissions.

3.2.2 Hydrogen and Ammonia

Hydrogen is a chemical element with the potential to serve as a zero-emission energy source. In maritime applications, hydrogen must be converted into electricity using a fuel cell, making hydrogen-powered vessels a form of electrified transport. Unlike battery-powered vessels, hydrogen vessels can generate electricity during operation, enabling longer range and continuous energy supply. While hydrogen is often cited as a promising energy carrier for the future, significant challenges related to its production, storage, transport, and safety remain.

Hydrogen fuel can be produced in several ways, with vast differences in environmental impact and cost.

Green hydrogen, produced via electrolysis using renewable electricity, is low- or zero-emission but expensive.

Grey hydrogen, produced from fossil fuels (e.g. natural gas), is significantly cheaper, but results in considerable CO_2 emissions.

Given that the main incentive for adopting hydrogen is emission reduction, relying on grey hydrogen would be counterproductive. On the other hand, switching to green hydrogen would increase fuel costs considerably. (Hossain Bhuiyan & Siddique, 2025)

Hydrogen can be stored either as a compressed gas or as a liquid:

- Compressed hydrogen gas requires large-volume tanks, which take up substantial onboard space—especially problematic on small vessels like ferries.
- Liquefied hydrogen must be stored at extremely low temperatures (−253 °C), requiring specialized cryogenic tanks and infrastructure.

While hydrogen performs reliably in cold conditions and offers high energy density, its storage and handling remain logistically complex, particularly in maritime use. (Hossain Bhuiyan & Siddique, 2025)

Ammonia (NH_3), a compound of nitrogen and hydrogen, can also be used as a marine fuel. Compared to hydrogen, ammonia is:

- Easier to store and transport, making it more logistically suitable for maritime uses.
- Potentially used as a hydrogen carrier, meaning it could be transported and converted back into hydrogen before use.

However, ammonia poses its own serious drawbacks—most notably its toxicity. Even small amounts can be harmful to humans, raising significant safety concerns. (Sarkar et al., 2025)

Both hydrogen and ammonia are highly flammable, and hydrogen in particular is prone to leaks due to its low molecular weight and extremely low flashpoint.

Any malfunction, leak, or human error in storage or handling can result in serious accidents, underscoring the need for rigorous safety protocols and risk mitigation strategies.

Despite their theoretical promise, hydrogen and ammonia are not yet practical fuels for island ferry traffic in the Central Baltic Region, especially in the short term:

- The space required for hydrogen tanks makes it challenging to retrofit small ferries.
- Safety risks associated with flammable and toxic materials increase operational complexity.
- Most critically, the infrastructure for production, bunkering, and distribution is lacking.

As of 2024, only 0.2% of the planned hydrogen infrastructure in the Nordic countries is operational. In the Baltic States, the Baltic Hydrogen Group is developing a regional hydrogen supply network, but full functionality is not expected until the 2030s. (Nordic Energy Research, 2024)

Hydrogen and ammonia offer high energy density and zero operational CO_2 emissions, making them promising long-term solutions for decarbonizing maritime transport. However, due to their current technical, logistical, and economic constraints, they are not yet viable for island ferry operations in the Central Baltic Region. Their successful adoption will depend on the development of infrastructure, cost reduction, and robust safety frameworks.

3.2.3 Biofuels - HVO

Biofuels are a broad category of fuels derived from renewable biological sources, such as biomass, vegetable oils, or bio-waste. Like fossil fuels, they are burned in internal combustion engines to produce power. Among these, Hydrotreated Vegetable Oil (HVO)—also known as renewable diesel—emerges as one of the most suitable biofuels for island ferry operations in the Central Baltic Region.

HVO is a liquid biofuel that closely resembles traditional marine diesel, making it compatible with most existing diesel-powered marine engines. This compatibility significantly simplifies the transition from fossil fuels:

- Existing vessels and bunkering systems can often be used without modification.
- HVO shares similar storage, transport, and refuelling characteristics with fossil diesel.

In optimal cases, no technical retrofit is required—only a switch in fuel type, allowing for a relatively fast and low-barrier transition. Compared to electrification, hydrogen, or ammonia, HVO is a practically implementable solution in the short term.

Although burning HVO still produces CO_2, the overall lifecycle emissions are substantially lower than those of fossil diesel:

- Emission reductions of up to 80% are possible, depending on feedstock, production methods, and supply chain factors.
- HVO is typically produced from waste-based sources, such as used cooking oil or animal fats, making it both renewable and sustainable.

While not a zero-emission solution, biofuels like HVO offer significant environmental benefits through reduced operational emissions and the use of non-fossil, circular production inputs.

Biofuels generally face fewer infrastructure limitations than other alternative fuels. However, supply remains a key challenge:

- Current global HVO production is insufficient to meet large-scale maritime demand.
- Production capacity is constrained by the availability of bio-waste, which is influenced by other industries.

That said, the island ferry sector is relatively small, and existing production capacity in the Central Baltic Region—from leading Nordic biofuels suppliers such as Neste and UPM (Finland) and Preem AB (Sweden)—is theoretically sufficient to meet current demand for HVO in island ferry operations.

A dedicated HVO supply network for ferry ports would need to be established, but the outlook is promising:

- All three major producers have committed to significantly increasing production by 2030–2035, signalling strong long-term feasibility for a regional HVO transition.

One of the main barriers to adoption is cost:

- HVO is currently more expensive than fossil diesel.
- In publicly procured ferry services, this cost difference is often absorbed by the contracting authority, not the operator.

This underscores the need for political will and policy support to facilitate a transition to HVO:

- Procurement criteria must be updated to favour low-emission fuels.
- Budgetary planning must account for the higher short-term fuel costs in exchange for long-term environmental benefits.

Encouragingly, HVO is already in regular use on publicly procured routes in Stockholm County, Sweden, demonstrating its practical viability.

Among the various emission-reducing fuel alternatives, HVO stands out for its practicality, compatibility, and readiness:

- It requires no major technological upgrades for vessels or ports.
- It offers meaningful emission reductions.
- Its adoption is feasible in the near term, especially with public sector backing.

While biofuels are not a long-term net-zero solution, HVO presents a highly implementable option for rapidly reducing the carbon footprint of island ferry transport in the Central Baltic Region.

3.2.4 Methanol

Methanol, also known as methyl alcohol, is an industrial, undrinkable form of alcohol with significant potential as an environmentally sustainable marine fuel. While the combustion of methanol does produce some CO_2 emissions, its lifecycle emissions can be close to zero, depending on the production methods. Like hydrogen and ammonia, the carbon footprint of methanol is largely determined by how it is produced.

Some production processes rely on natural gas, resulting in carbon emissions. However, green methanol—also known as bio-methanol—can be produced using biomass and renewable electricity, effectively capturing more carbon than it emits, and thus achieving near carbon-neutrality. Importantly, green methanol is also comparatively cost-effective to produce when compared to many other alternative fuels, making it a promising candidate for the future of low-emission ferry transport (Methanol Institute, 2023).

Unlike hydrogen and ammonia, which are primarily used in fuel cells to generate electricity, methanol is a combustible liquid fuel. This means it powers internal combustion engines, albeit requiring specially designed or modified engines. Traditional fossil fuel engines cannot run on methanol without significant retrofitting or replacement.

A major logistical advantage of methanol is its physical state:

- Stored and transported as a liquid, methanol does not require pressurised tanks or cryogenic storage, unlike hydrogen or liquefied natural gas (LNG).
- This makes methanol easier to integrate into existing fuel supply chains and bunkering infrastructure originally built for fossil fuels (Rao et al., 2025).

Methanol holds several advantages that make it a realistic medium- to long-term fuel solution for island ferry services:

- High global availability – methanol is already one of the most commonly produced industrial chemicals in the world.
- Significant emission reduction potential, particularly when green methanol is used.
- Cost-effectiveness compared to other low-carbon alternatives such as hydrogen or ammonia.
- Compatibility with existing bunkering systems, reducing the need for costly infrastructure upgrades.

These characteristics place methanol's applicability for island ferry services somewhere between moderate and high, especially in regions like the Central Baltic, where infrastructure is already under strain from electrification and other energy transitions.

Despite its promise, methanol faces two main challenges in the context of Central Baltic island ferry traffic:

1. Lack of methanol supply at ports: Methanol is currently not available at most island ferry terminals. Without bunkering infrastructure, ferry operators have little incentive to invest in compatible vessels.
2. Need for engine retrofits or replacements: Converting vessels to run on methanol is technically feasible but represents a substantial capital investment, particularly for smaller or publicly contracted operators.

To overcome these obstacles:

- Political support and strategic investment will be needed to establish bunkering infrastructure at key ferry ports.
- Public authorities could take the lead in coordinating supply chains, offering financial incentives, or including methanol compatibility in procurement criteria.
- Once infrastructure is in place, ferry operators can begin retrofitting or acquiring vessels with methanol-compatible engines, enabling a cost-effective and lower-emission fuel transition.

Methanol offers a balanced pathway toward decarbonising island ferry operations—combining moderate infrastructure requirements with high emissions reduction potential. Its logistical compatibility, cost efficiency, and scalability make it an appealing alternative to more technically complex or infrastructure-intensive solutions. However, public-sector leadership will be essential to kickstart the transition by establishing a reliable and accessible methanol supply network.

3.2.5 LNG

Liquefied Natural Gas (LNG) is an alternative marine fuel that, while cleaner than traditional options like Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO), is still a fossil fuel. Composed primarily of methane, LNG must be stored at cryogenic temperatures below –162°C to remain in liquid form. This low temperature requirement, combined with the hazards associated with methane leaks, creates logistical and safety challenges for handling, storing, and bunkering LNG in maritime operations.

LNG does not eliminate carbon dioxide (CO_2) emissions, but it can reduce them by approximately 25% per nautical mile when compared to HFO or MDO. In addition to CO_2 reductions, LNG produces very low levels of sulphur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM), which makes it significantly cleaner than traditional fuels in terms of air pollution.

An even more environmentally friendly variant is BioLNG, a renewable form of LNG derived from biomass, similar in concept to HVO (Hydrotreated Vegetable Oil). While BioLNG can achieve further lifecycle emission reductions, it still falls short of true carbon neutrality.

Despite these improvements, LNG is not a zero-emission solution, and it is typically considered a transitional fuel rather than a long-term decarbonisation strategy for the shipping industry. One significant issue with LNG is leakage, or so-called methane slips, of the gas in connection to bunkering and storage, which can yield to considerable emissions (See e.g. Comer et al. 2024).

LNG is a mature and relatively cost-effective fuel option compared to many other alternative fuels. Several ferry-type vessels using LNG are already in operation across Europe, including:

- Smaller ferries operating on LNG in Norway, and
- Larger Ro-Pax vessels, such as those used by TS Laevad OÜ in Estonia, or on the Vaasa (FI) – Umeå (SE) route in the Baltic Sea.

While LNG bunkering facilities are not yet widespread in smaller island ferry ports, LNG is commercially available and reasonably priced, making it a viable short- to medium-term option where infrastructure exists or can be developed.

However, LNG is not a drop-in fuel. Traditional marine engines cannot run on LNG without extensive modifications. Shifting to LNG requires:

- Retrofitting vessels with specialised cryogenic storage and fuel systems, or
- Procuring new LNG-compatible vessels, both of which involve significant capital investment.

The European natural gas landscape has changed dramatically due to the ongoing war in Ukraine. Europe, previously reliant on Russian pipeline gas, is now investing heavily in LNG infrastructure to diversify energy sources. Countries such as Germany, Poland, and Finland have accelerated development of LNG terminals and supply chains, enhancing the availability of LNG across the continent.

One of LNG's advantages over conventional natural gas is its transport flexibility: LNG can be shipped by sea, whereas gas in its traditional form requires fixed pipelines. This logistical advantage increases LNG's availability and future potential, with European LNG capacity expected to grow substantially by 2030.

Despite its benefits, LNG presents several limitations for use in island ferry traffic:

- Emission reduction potential is moderate, insufficient for meeting zero-carbon targets.
- LNG requires retrofitting or replacement of vessels, as it is incompatible with traditional fuel systems.
- Cryogenic storage systems are expensive and technologically complex.
- Fuel handling safety concerns exist due to LNG's flammability and extremely low temperatures.

These factors, combined with its fossil origin, have led to LNG being positioned more as a bridge fuel—helping to reduce emissions in the near term while alternative zero-emission technologies like hydrogen, electricity, or e-fuels are developed and scaled.

LNG can offer a realistic path to cleaner ferry operations in the short to medium term, especially on routes where:

- Electrification is not feasible,
- HVO or methanol supply is limited, and
- Infrastructure for LNG is available or planned.

However, due to its limited emissions reduction potential, incompatibility with legacy engines, and fossil fuel classification, LNG should not be viewed as a long-term solution for decarbonising island ferry traffic in the Central Baltic Region. Instead, it serves best as a transitional option on the way to sustainable, zero-emission maritime transport.

3.2.6 E-fuels

Electrofuels (e-fuels) refer to a category of synthetically produced fuels designed to be low- or zero-emission alternatives to conventional fossil fuels. Unlike other alternative fuels, e-fuels are defined not by their chemical composition, but by their production process, which involves combining renewable electricity with captured carbon dioxide (CO_2) or other feedstocks to create energy-dense fuels.

There is no single e-fuel, as the term encompasses a variety of synthetic fuels, such as:

- E-diesel (synthetic diesel),
- E-methanol,
- E-ammonia,
- E-kerosene, and others.

Many of these fuels mirror the properties of their fossil-derived counterparts but are created through renewable and potentially carbon-neutral processes. Their primary advantage is that they can often be used with existing fuel infrastructure and combustion engines, minimizing the need for radical system overhauls.

E-fuels are generally produced through advanced technological methods, including:

- Electrolysis: Using renewable electricity to split water (H_2O) into hydrogen (H_2) and oxygen (O_2),
- Direct Air Capture (DAC) or carbon capture from industrial sources to obtain CO_2,
- Synthesis: Combining H_2 and CO_2 (or nitrogen for e-ammonia) through chemical processes such as Fischer-Tropsch synthesis or methanation to produce hydrocarbon-based or hydrogen-based fuels.

This process allows for the recycling of atmospheric or industrial CO_2, theoretically achieving net-zero lifecycle emissions, depending on the energy and inputs used.

Benefits of E-Fuels in maritime applications include the following:

- Compatibility: Many e-fuels are drop-in replacements for fossil fuels, usable in existing engines with minimal or no retrofitting.
- Scalability: They offer a technologically flexible path for long-distance maritime transport, where electrification is not feasible.
- Zero/low lifecycle emissions: When produced using renewable electricity and captured carbon, e-fuels can be carbon-neutral or even carbon-negative in lifecycle assessments.
- Energy storage: E-fuels act as a chemical energy storage solution, which is especially valuable in integrating variable renewable energy sources like wind and solar into transport.

Challenges and limitations of E-Fuels in maritime applications include the following:

- High energy demand: The production of e-fuels is energy-intensive, often requiring 2–6 times more energy than using renewable electricity directly (e.g., in battery-powered systems).
- Cost: E-fuels are currently significantly more expensive than fossil fuels or even other alternative fuels due to complex production and low current volumes.
- Infrastructure: Although e-fuels can use existing bunkering systems, production and distribution infrastructure is still under development, especially in the maritime sector.

In the context of the Central Baltic region, island ferry traffic, e-fuels could provide a long-term solution for decarbonisation, especially for:

- Longer routes where battery-electric ferries are not feasible,
- Remote locations where green hydrogen or renewable electricity infrastructure is limited,
- Operators seeking drop-in alternatives that require minimal engine modifications.

However, short-term deployment remains limited due to the high cost and low availability. Investments in pilot projects, public-private partnerships, and supportive policy frameworks will be essential to make e-fuels a viable option for the island ferry sector in the 2030s and beyond.

E-fuels are, in theory, an ideal solution for decarbonising maritime transport, including island ferry services. They offer the potential to eliminate CO_2 emissions without requiring major modifications to existing vessel technology or bunkering infrastructure. This compatibility makes them particularly appealing for operators looking to transition away from fossil fuels without significant capital investment in new vessels or ports.

However, practical challenges currently limit their adoption. E-fuels remain very expensive, and production capacity is insufficient to support wide-scale deployment. Most synthetic fuel technologies are still in early stages, and their production, distribution, and commercial use are several years away from maturity. As with many emerging technologies, initial costs are high, and scaling up to economically viable levels will take time.

Despite these limitations, e-fuel projects are progressing across Northern Europe. A number of facilities are in the planning or construction phase, signalling both market interest and long-term potential. These developments underline the promise of e-fuels but also reinforce that they are not yet a short-term solution.

For the island ferry industry in the Central Baltic Region, investment in e-fuels should be seen as a long-term strategy, with realistic implementation timelines likely falling in the 2030s. In the meantime, other alternative fuels and emission-reduction strategies are expected to play a more prominent role.

3.2.7 Summary of electrification and alternative fuels

Replacing traditional fuels with electricity and batteries or alternative fuels is an effective way to eliminate emissions, but it is expensive and has certain limitations. Electrification offers many advantages, including cost-efficient operation, zero emissions, and a vessel that runs more smoothly and quietly compared to those with fossil fuel engines. The difficulty and cost of implementation are the limiting factors for battery powered vessels

Alternative fuels, on the other hand, tend to be expensive to use but are less constrained by the need to establish an entirely new supply network. HVO, in particular, is both readily available and technically suitable for diesel-powered ferries, but the rise in fuel costs is a limiting factor.

It is also important to recognize that not all alternative energy sources have the same environmental impact. LNG and HVO, for instance, only reduce the amount of emissions rather than eliminate them completely. However, sustainably produced biofuels can achieve much greater emission reductions than LNG. Table 3 illustrates how various alternative fuels compare to fossil fuels in terms of emissions.

Table 3: Exemplification of the prevalence of lifecycle emissions of HFO, MGO, LNG, e-methanol, e-methane and e-diesel (EMSA, 2024: 32)

	HFO, MGO*	LNG*	E-methanol	E-methane	E-diesel
Life cycle GHG emissions					
N_2O	Present	Present	Present		
CH_4	Low	Present at Otto engines	Not present	Present in Otto cycle engines	Not present
CO_2	Present	Present	Mainly from manufacturing production systems.		
H_2 (indirect)	Not present	Not present	From venting and purging for electrolysers.		
Air pollutant emissions					
SO_X	Present	Not present (limited to pilot fuel)	Not present (limited to pilot fuel)	Not present (limited to pilot fuel)	Not present
NO_X	Needs SCR for ECA	Otto engines meet ECA requirements without SCR, diesel engines do not	Reduced compared to HFO/MGO, but needs SCR for ECA	Otto engines meet ECA requirements without SCR, diesel engines do not	Needs SCR for ECA
Direct particulate matter	Present	Reduced	Likely reduction compared to HFO/MGO		Present
Carbon monoxide and hydrocarbons	Present	Present or increased	Present or increased (for Otto cycle engines, CO emissions are higher)		Present
VOCs and PAHs	Present	Reduced	Not present		

The more experimental alternative fuels—such as hydrogen, ammonia, methanol, and e-fuels— stand out for their potential to completely eliminate CO_2 emissions. Each of these fuels has unique applications, production capacities, and technical challenges, but they all currently face the same obstacle: the lack of an established supply network. Setting up bunkering stations for these fuels is equivalent to building charging infrastructure for electric ferries; without bunkering or charging, the vessels cannot operate. Many alternative fuels are also difficult to adopt from a technical perspective. Hydrogen, ammonia, and methanol are not drop-in fuels, which means that they require designated vessels either through retrofitting or procurement. Some e-fuels, however, are drop-in fuels – a strong incentive for their development– but they are not yet widely available.

Hybrid vessels are another option. Typically, a hybrid vessel combines electric and fossil fuel-based propulsion, allowing operators to benefit from batteries without being overly dependent on charging infrastructure. The emission reduction achieved by a hybrid vessel depends on how much the vessel uses each propulsion. Furthermore, a hybrid vessel can also utilize alternative fuels, potentially making it a zero-emission vessel regardless of the propulsion source. The main drawback of a hybrid is that accommodating two energy sources increases both the vessel's weight and technical complexity. Overall, hybrid vessels are a practical solution for routes where full electrification is not feasible.

4 Physical and natural environments of the region

The Baltic Sea is a semi-enclosed, brackish, and relatively shallow body of water covering 392,000 km², with an average depth of just 54 metres. Its physical geography, along with regional climate and weather conditions—especially in the archipelago areas—form the foundation for human activity and directly influence the types of ferries and routes that can be used. Additionally, factors such as sea depth, wind, waves, seasonal ice coverage, and ice structure affect navigation, fuel consumption, scheduling, and vessel speed in maritime transport.

The area of interest in this report includes the Stockholm Archipelago, the Åland Islands, the Archipelago Sea, the Gulf of Finland, and coastal Estonia, including the islands of Hiiumaa and Saaremaa (Figure 4), as well as Finnish lakes within the Central Baltic Region and Lake Peipus in Estonia.

A nearly continuous belt of tens of thousands of islands and islets stretches from the Stockholm Archipelago through the Sea of Åland to the Turku Archipelago, forming a region of complex topography and bathymetry. The inner archipelago zones are typically characterized by large islands separated by narrow, shallow straits. These gradually transition into dense clusters of smaller islands and sheltered waters, eventually giving way to the more open and deeper areas of the outer archipelago.

The average depth of the Archipelago Sea is approximately 23 meters, while the Sea of Åland reaches an average depth of 75 meters. Notably, along the fault line between Åland and Sweden, depths of up to 300 meters are reached closer to the shoreline, which is more than anywhere else in the Baltic Sea.

In the Gulf of Finland, there are over 15,000 islands, and the transition from the inner to the outer archipelago is more abrupt compared to other areas. Rocky shores, underwater reefs, and canyons are also characteristic features of the region. The average depth is 37 meters, with the western parts being deeper as the seabed gradually becomes shallower toward the east. The deepest point, reaching 123 meters, is located off the north-western coast of Estonia.

Together, the western coast of mainland Estonia and the islands of Saaremaa, Hiiumaa, and Muhu enclose the Väinameri sea area, which is characterized by its shallow waters, where the average depth is less than 10 metres. The deepest part, reaching 22 metres, is located between Muhu and the mainland. In contrast, the outer coasts of Saaremaa and Hiiumaa are deeper and less sheltered.

Figure 4: Map of the archipelago and sea areas (adapted from Räisänen, CC BY-SA 3.0)

As Figure 5 illustrates, the region experiences significant seasonal variation in weather conditions due to its northern latitude and the combined influence of both temperate marine and subarctic continental climate zones. Westerly winds are the most common and tend to be strongest during autumn and winter, while summer is typically characterized by weaker overall wind intensity.

In summer, average sea temperatures range from 13 to 20 °C, whereas in winter, they drop to between 0 and 5 °C. Over recent decades, both surface water and air temperatures have increased. At the same time, winter and spring precipitation appears to have risen. In the past, the Gulf of Finland was typically covered by ice during the winter months. Today, however, the sea remains largely ice-free, with only the more sheltered areas of the archipelago usually retaining ice cover.

While open deep-water routes can enhance fuel efficiency under calm conditions due to reduced bottom friction, they are also more exposed to strong winds and waves. Such conditions increase engine load and fuel consumption. During storms, greater water depth can amplify wave energy, requiring vessels to exert additional power to maintain stability and course. In winter, these areas are often affected by fragmented drift ice, which demands continuous monitoring and careful navigation (See Bratkov et al., 2025).

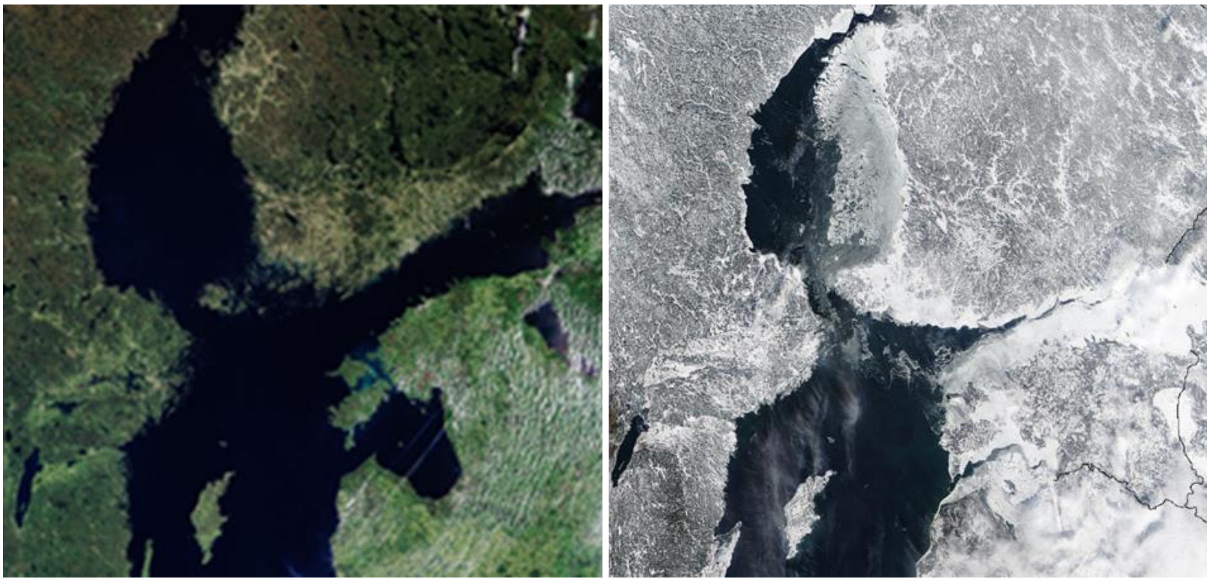

Figure 5: The Baltic Sea seen from Copernicus Sentinel-3 satellite in May 2021 (left; source: ESA), and in February 2003 seen from Terra Satellite (right; source: NASA)

More sheltered coastal routes, including inland lakes, are generally less affected by wind and wave conditions. However, during winter, these areas are more prone to developing uniform level ice, which increases engine power requirements and fuel consumption, and may result in slower transit times. Routes with multiple stops in complex archipelago environments—such as those around Åland—can experience rapidly changing ice conditions over short distances, requiring frequent navigational adjustments and contributing to further delays.

The Baltic Sea is a unique and sensitive marine environment, home to complex ecosystems and several endangered species. Despite the establishment of national parks and UNESCO World Heritage Sites (such as the Suomenlinna fortress island outside Helsinki), biodiversity loss remains a significant concern across all coastal regions. Eutrophication—driven by excessive nutrient inputs—is the primary threat to the sea's ecosystems. However, efforts to reduce greenhouse gas (GHG) emissions and minimize the risk of oil spills also help alleviate environmental pressures and contribute to the overall protection of the marine environment.

To ensure efficient and sustainable ferry transport, operators must adapt to evolving local and global conditions in the physical and natural environment. Maintaining reliable service across the Central Baltic Region calls for investments in advanced vessel technologies, optimized route planning, and the implementation of innovative emission reduction measures.

5 Estonia

5.1 Population and tourism

Estonia has a population of nearly 1.4 million, of whom over 30% live in the capital city of Tallinn by the Gulf of Finland (Statistics Estonia, 2025a). When the over 2,000 islands are included, the country has about 3,800 km of coastline. The inhabited Estonian archipelago comprises the three main islands – Saaremaa, Hiiumaa, and Muhu – and 17 smaller islands (Figure 7). Approximately 41,000 people inhabit these islands; Saaremaa is the most populous, with over 30,000 residents, followed by Hiiumaa (8,300 residents) and Muhu (1,600 residents). The smaller islands have tens or hundreds of residents, or fewer.

Following the concentration of islands and population, ferry services are also focused on the west coast. The routes between Saaremaa and Hiiumaa and to the mainland had over 2.5 million passengers in 2024 (Kornel, 2025). The island ferries connecting the islands of Saaremaa and Hiiumaa with the mainland can carry up to 700 passengers and 150 vehicles. In 2024, over 1.2 million vehicles were transported to and from the three main islands (TS Laevad OÜ, 2025).

Figure 6 shows examples of island ferries used in Estonia.

Figure 6: Ferry Soela in winter (left; photo by Kihnu Veeteed AS), and ferry to Saaremaa (right; photo by [Draceane](), [CC BY-SA 4.0]())

In addition to the permanent residents, many Estonians have a second home in the archipelago. Remote work, as well as seasonal and multilocational living, have become increasingly common in Estonia, particularly since the Covid-19 pandemic (Raagmaa, 2023). Together with domestic and foreign tourists, seasonal residents form a considerable share of the passengers of island ferry services. However, both the occupancy of summer cottages and the arrival of tourists are highly seasonal.

Both inbound and domestic tourism have nevertheless been growing steadily. The number of accommodated foreign tourists grew from 1.4 million in 2008 to almost 2.3 million in 2019 (Statistics Estonia, 2025b). The number dropped following the pandemic, but reached over 1.8 million in 2024. The number of domestic visitors registered in accommodations was 0.9 million in 2008 and reached 1.5 million in 2019. More recently, in 2024, the number was over 1.7 million.

Figure 7: Map of main inhabited islands and ferry lines in Estonia (Figure by Ojala, M-L)

As inbound tourism is a key determinant of economic growth, the government aims to increase international tourism (Republic of Estonia, 2025). Promoting nature, sustainable travel, and easy multi-modal transportation are part of the strategy, aligning well with decarbonisation and other developments in the island ferry sector. Although Estonia's population is decreasing, the increase in both international and domestic tourism, as well as lifestyle changes toward multilocational living, continues to maintain and increase the demand for ferry services.

5.2 Legal and political environment

As a member of both the European Union and the International Maritime Organization (IMO), Estonia is subject to a range of EU and international maritime regulations. These include participation in the EU Emissions Trading System (EU ETS) and compliance with IMO regulations on sulphur oxide (SOx) and nitrogen oxide (NOx) emissions. In addition to these obligations, the Estonian government has shown strong political commitment to reducing CO_2

emissions in maritime transport. This is reflected in initiatives such as the Ministry of Climate's procurement of green ferries and Tallinn's designation as a TEN-T core port, which requires the Port of Tallinn to provide shore-power infrastructure for vessels by 2030.

At the national level, Estonia currently has minimal regulation specifically targeting CO_2 emissions from island ferries. In public procurement processes for ferry services, emission levels are not yet a determining factor. Furthermore, due to the relatively small size and capacity of these vessels, the EU ETS does not apply to most Estonian island ferries. As a result, the current legal and political environment remains relatively permissive regarding CO_2 emissions from the perspective of island ferry operators. However, this situation is expected to change, as environmental regulations are likely to become increasingly stringent in the near future.

5.3 Technological environment

The structure of the Estonian island ferry market has created a technological environment largely controlled by the public sector. The Estonian State Fleet (ESF), a public body operating under the Ministry of Climate, is responsible for owning and procuring ferries and other maritime vessels. Currently, the majority of Estonian island ferries are state-owned through the ESF, which will also oversee the acquisition of new vessels in the future.

AS Saarte Liinid is a state-owned company responsible for operating Estonia's small ferry ports. It operates under the Ministry of Climate, which holds 100% of its shares. Island ferry services, although provided by private companies, are publicly procured by the Estonian Ministry of Regional Affairs and Agriculture, as well as by several municipalities and regional authorities.

The largest ferry operator in the country, TS Laevad OÜ, is a subsidiary of the Port of Tallinn, which is itself majority-owned (67%) by the Estonian state. Through these institutions and ownership structures, the technological and operational environment of Estonia's island ferry transport remains firmly under state control.

The procurement of new, environmentally friendly vessels for Estonia's island ferry services is advancing steadily. However, uneven development of the supporting infrastructure continues to hinder the most innovative initiatives.

For example, the Estonian State Fleet (ESF) procured an electric hydrogen–battery hybrid vessel scheduled to enter service in late 2026. Yet the hydrogen system was later removed when it became clear that the technical readiness of shipyards, the broader supply chain, and the absence of local hydrogen bunkering infrastructure do not yet support hydrogen-powered passenger ferries. In its revised configuration, the vessel's primary energy source will be shore-charged batteries, supplemented by biofuel-fired internal combustion engines to provide auxiliary or peak power—particularly during winter operations in heavy ice conditions.

Despite this adjustment, the project highlights ESF's commitment to adopting cutting-edge, zero-emission technologies as the enabling infrastructure matures.

The Baltic states—Estonia, Latvia, and Lithuania—have nevertheless witnessed a growing interest in hydrogen as a sustainable energy solution. The Baltic Hydrogen Group, a consortium of companies across the region, is actively working to develop the infrastructure and supply chain for green hydrogen. If hydrogen supply and bunkering infrastructure are established at Estonia's island ferry ports, both authorities and operators will be in a more realistic position to consider a transition to hydrogen-powered vessels.

AS Saarte Liinid, the state-owned operator of small ferry ports, has recently launched an initiative to establish charging infrastructure across the island ferry network. At present, Estonia lacks sufficient charging capacity to support widespread use of battery-powered ferries; however, this initiative aims to change that. The objective is to install charging stations at the majority of island ferry ports, enabling the operation of battery-electric and hybrid vessels by 2027.

Currently, there is no large-scale use of hydrotreated vegetable oil (HVO) as a marine fuel in Estonia. Based on the present situation and ongoing developments, Estonia's island ferry sector appears to be moving primarily toward electricity, battery technologies, and hydrogen as key solutions for reducing ferry traffic emissions.

5.4 Economic and competitive environment

The intensity of competition in the Estonian island ferry market is relatively low, and smaller operators typically lack the financial capacity to make significant sustainability-related investments. In contrast, the state-owned TS Laevad OÜ possesses considerably greater economic and administrative resources, enabling it to invest in environmentally sustainable technologies.

However, the market structure limits direct competition: TS Laevad OÜ operates only the two highest-volume routes—those connecting the islands of Saaremaa and Hiiumaa to the mainland—while smaller ferry routes are operated by private companies under public contracts. In some cases, these contracts include the use of state-owned vessels, further highlighting the strong role of the public sector in shaping the market.

The governance and market structure of Estonia's island ferry sector positions smaller operators under indirect but significant control by public authorities. These operators typically rely heavily on revenue from public service contracts, which limits their financial capacity for large-scale investments. When the public sector is responsible for both funding and providing the vessels, it follows logically that it should also carry the responsibility for major investments—such as retrofitting vessels with clean technologies or developing infrastructure for alternative fuels and shore power.

Table 4: Estonian island ferry operators, their turnover, personnel, and vessels in 2023. Source: Ojala et al., 2025.

Service provider	Turnover (Million EUR)	Personnel	Vessels
TS Laevad OÜ	36.7	140	5
Kihnu Veeteed AS	6.6	49	7
Tuule Liinid OÜ	1.7	20	4
Spinnaker OÜ	0.6	4	4
Saaremaa Vald (municipality)	-	-	2

In contrast, under full-service contracts where operators own and operate their own vessels, smaller-scale sustainability investments may be more economically viable. Examples include eco-driving training or upgrading onboard systems for more energy-efficient heating, cooling, and lighting.

Table 4 provides an overview of Estonia's island ferry operators in 2023.

6 Mainland Finland

6.1 Population and tourism

The Finnish population is highly concentrated in coastal areas. Helsinki metropolitan region by the Gulf of Finland, for instance, is home to over 1.2 million people. When the urban centres are excluded, the actual archipelago areas have approximately 130,000 residents, accounting for 2,4% percent of the whole Finnish population (Rannanpää et al., 2025).

Finland has more than 200,000 islands, and 1,050 of them are permanently inhabited (Rannanpää et al., 2023). The most populous islands are connected to the mainland with a bridge – or even a subway system in Helsinki. The smaller islands are accessed with ferry services and private vessels. About 470 of the inhabited islands are without fixed road connections, and these islands are home to approximately 8,800 people.

The maintenance and accessibility of archipelago areas relies on well-functioning transport connections, and road and island ferries are essential modes of transport in the Finnish archipelago. Figure 8 shows examples of these ferries. Route availability and passenger volumes reflect the distribution of permanent and seasonal populations as well as tourism activity, with the Archipelago Sea standing out as the busiest area (See Figure 9).

Figure 8: Island ferry to Suomenlinna (left; adapted from Lenz, CC0 1.0), and Finferries' Elektra, a hybrid road ferry (right; adapted from Ek, CC BY-SA 4.0)

The Archipelago Sea has over 24,000 islands, covering 24% of total island land area in Finland, and hosts approximately 30,000 residents and over 32,000 seasonal houses. The largest municipalities are Parainen and Kemiönsaari, with a combined permanent population of approximately 22,000 people. With its unique nature and designation as a UNESCO Biosphere

Reserve, the Archipelago Sea is also a popular tourist destination. The Archipelago Trails, for example, attract an estimated 50,000 visitors annually.

Similarly, the busiest road ferry routes in Finland are in the Archipelago Sea: the Pargas–Nauvo ferry transported 566,000 vehicles in 2023, and Nauvo–Korppoo served approximately 280,000 vehicles (Rannanpää et al., 2025).

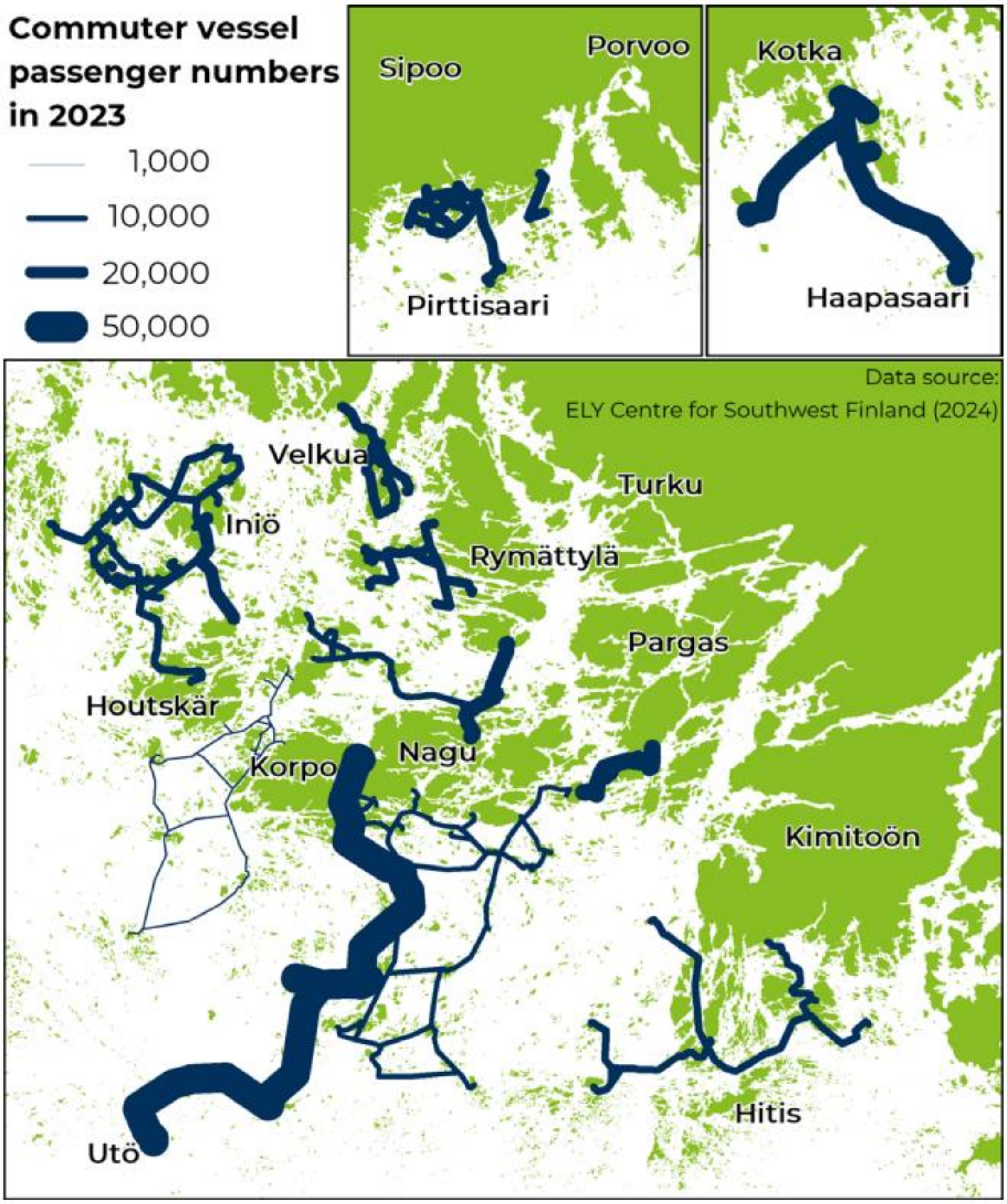

Figure 9: Commuter ferry routes and passenger numbers in Southern Finland (Rannanpää et al., 2025)

The Gulf of Finland contains approximately 15,000 islands. While the permanent coastal population is concentrated in the Helsinki metropolitan area and smaller cities such as Kotka, Porvoo, and Hanko, the more rural islands are primarily characterized by tourism and seasonal habitation. The most popular ferry route connects mainland Helsinki with the fortress island of Suomenlinna. This island is home to about 800 permanent residents, but as a UNESCO World Heritage Site, it attracts tens of thousands of visitors each month: in 2024, Suomenlinna ferries carried over 2 million passengers (SLL, 2025).

While permanent residence in the Finnish archipelago is declining and aging, the number of second homes continues to grow. Approximately 20,300 islands are used for leisure housing, with over 150,000 second homes located in archipelago areas (Rannanpää et al., 2023). Second-home occupancy is highly seasonal. This seasonality of island residence is further amplified by tourism, which is largely focused in the summer months.

The archipelago's rich cultural and natural heritage is widely recognised as a sales appeal for tourism, but the development has been fragmented and much of the potential unutilised. Therefore, "Archipelago and Coastal Area" is designated and developed as one of the main tourism areas in Finland (Visit Finland, 2019; 2025a). In 2019, tourists spent over 7.4 million nights in this region, with foreign visitors accounting for 15% of the total. The travel restrictions imposed during the Covid-19 pandemic led to a significant decline in these figures; however, the tourism industry has been recovering to pre-pandemic levels (Visit Finland, 2025b).

6.2 Legal and political environment

For mainland Finland, the key legal instrument regarding island ferry traffic is the Finnish Archipelago Act[1]. This act refers to island ferry services only and dictates all Finnish citizens permanently living on Finnish islands must be provided a costless public transport connection to a mainland port. It means that any rerouting or rescheduling efforts regarding island ferry traffic services must not contradict the Archipelago Act and the right to transportation services the law grants to permanent citizens of Finnish islands. The Ministry of Agriculture and Forestry of Finland is currently working on an update to the Archipelago Act, but this is unlikely to have major consequences to how island ferry services in Mainland Finland are arranged.

So far public procurement of Finnish island ferry services has been mainly price based. However, Finnish authorities are now planning to bring environmental criteria into future tenders, which highlights the political pressure ferry operators face to reduce CO_2 emission levels. The legal and political environment regarding island ferry traffic emissions in Finland is slowly, but inevitably, shifting towards increased environmental regulation.

[1] Finlex, 1981/494 (saaristolaki, skärgårdslagen)

Finland has set an ambitious goal of reaching carbon neutrality by 2035, which requires emission reduction across all industries including the transport sector. As significant emission reduction is required, even the small-scale transport like island ferries will be affected by the 2035 goal. Finnish island ferry operators should expect increasing environmental regulation and emphasis on emission reduction methods in public procurement within the next 10 years.

6.3 Technological environment

The technological environment for island ferry operations in mainland Finland is currently undergoing a transition. Historically, the sector has depended on aging vessels powered by conventional fossil fuels. However, reducing emissions is becoming a growing priority, and electrification is increasingly seen as a viable solution—at least for specific routes. The state-owned ferry operator Finferries, which controls approximately 85% of the market, has already electrified several of its ferries and has publicly committed to further reducing greenhouse gas emissions. Given Finferries' dominant market position and demonstrated success in implementing electrification, other operators may feel compelled to follow suit to stay competitive. Notably, Finferries also emphasizes eco-driving training as part of its environmental initiatives.

The potential for electrifying Finnish island ferry routes is largely dependent on route characteristics. In general, road ferries—which typically operate short crossings—are more suitable for electrification. In contrast, longer island ferry routes, which can involve several hours of travel across open sea to remote islands, present significant challenges. For these routes, full electrification is likely to be unfeasible, mainly due to the impracticality and high cost of building adequate charging infrastructure in remote locations. As a result, while electrification offers promising environmental benefits, it is not a one-size-fits-all solution for Finland's diverse island ferry network.

In addition to Finferries, the City of Helsinki operates several island ferry routes though Suomenlinnan Liikenne Oy, a subsidiary of the public transport concern. It has recently increased its use of HVO (hydrotreated vegetable oil). One of Finferries' vessels, Kökar, operates for Suomenlinnan Liikenne Oy in Helsinki and runs on HVO. Furthermore, some larger Ro-Pax ferries operating between Helsinki and Tallinn are also beginning to adopt HVO, signalling a growing trend of bunkering biofuels in the capital.

Operators and authorities in mainland Finland are well-positioned to transition to HVO, especially given that major Finnish companies like Neste and UPM are among the leading global producers of renewable fuels. In the northern Baltic Sea, a bio-LNG/LNG-powered ferry also connects Vaasa, Finland, and Umeå, Sweden—further demonstrating the region's openness to alternative fuels.

Mainland Finland benefits from favourable conditions for transitioning to environmentally friendly energy sources. The country already has established access to multiple sustainable options, including HVO, LNG, and green electricity. Among ferry operators, Finferries has taken a leadership role in pioneering both electrification and HVO adoption in island ferry traffic. However, Finland currently lacks the large-scale supply and charging infrastructure required to enable a wider systemic transition.

This infrastructural challenge is partly geographical. Unlike countries with a centralized ferry hub—such as Sweden's Stockholm—Finland's ferry routes are widely dispersed across the country. The absence of a centralized ferry network limits economies of scale and complicates coordinated infrastructure investments. As such, the responsibility for shaping the technological trajectory of the sector does not rest with ferry operators alone. Public authorities will play a crucial role in steering the future of sustainable ferry transport in Finland through strategic investment, procurement policies, and infrastructure development.

6.4 Economic and competitive environment

The level of competition in the island ferry market in mainland Finland is very low, with the state-owned company Finferries serving as the clear market leader. Its market share by revenue in the island ferry services is over 90%, and it's share in road ferry services is about 75% in late 2025.

This is not necessarily the intended outcome even for Finferries itself, as it has been the result of a number of separate events largely outside the company's influence. The main events considering island ferry services in mainland Finland during the 2020s are presented in a chronological order below. During the same period, no significant changes have taken place in the road ferry markets or operations in mainland Finland.

1. **Increase in budget allocation due to VAT adjustment:**

Starting from the beginning of 2023, the government budget for island ferry services has been calculated without including value-added tax (VAT), while the numerical value in the budget has remained largely the same.

Impact: This increased the annual net budget by approximately EUR 3 million, representing about a 25% rise compared to the 2022 level. The current budget is around EUR 20 million, of which approximately 90% is allocated to procuring ferry services, while the remaining funds are used for land-side infrastructure projects, such as quay renovations and floating ramps.

2. **Maximum contract duration for island ferry services extended to 15 years:**

With the approval of the Ministry of Finance, the maximum duration for publicly procured archipelago ferry service contracts was extended from 5 to 15 years in 2023. This change has a significant impact on how tenders are planned and executed.

The first 15-year contracts have been signed for the Utö route (2027–2049) in the Archipelago Sea and the Porvoo–Sipoo route east of Helsinki in the Gulf of Finland.

The tendering for the southern route between Parainen and Nauvo in the Archipelago Sea in winter 2026 will also make use of this opportunity.

Impact: Longer contract periods increase the willingness to invest and support long-term commitment to ferry operations, but at the same time, they limit competition over the long run.

3. **Finferries acquired Saariston Meritie Oy's operations:**

In 2023, Saariston Meritie Oy, a privately held firm, sold the operations and vessels for the Utö, Hiittinen, and Rymättylä routes in the Archipelago Sea to Finferries. This was done upon approval of the tendering authority, the ELY Centre of Southwest Finland (Centre for Economic Development, Transport and the Environment)

As of autumn 2025, Saariston Meritie Oy operates only one route in Åland (the so-called Tvärgående linjen).

Impact: Following these acquisitions, Finferries now operates virtually all the main archipelago island ferry routes on mainland Finland.

4. **Bankruptcy of EW Finland Oy (a subsidiary of Nordic Jetline Finland Oy):**

EW Finland Oy operated the ferry service in the Porvoo archipelago in the Gulf of Finland, declared bankruptcy along its parent company and abruptly ceased operations in summer 2024.

The ELY Centre (Centre for Economic Development, Transport and the Environment) organized an emergency replacement operator (Sibbo skärgårdstrafik) for the route.

Impact: The immediate impact for was substantial for the islands in the Porvoo region, which is a relatively small route by number of passengers and operated by smaller craft.

5. **Establishment of the AxFerries joint venture in Åland:**

Following Nordic Jetline's bankruptcy, the Government of Åland established a 50/50 joint venture with Finferries in autumn 2024.

The new company, AxFerries Ab, began operating the majority of Åland's archipelago ferry routes in 2025, including Åva–Osnäs, Föglö Line, Southern Line, and Hummelvik–Torsholma.

In the coming years, the ferries currently owned by the Government of Åland are also expected to be transferred to AxFerries' ownership.

Impact: Although this arrangement concerns Åland, Finferries' role as a key nationwide ferry operator is further strengthened.

Economically, both island ferry and road ferry services face a challenging operating environment, evidenced by several service providers having gone bankrupt or voluntarily terminated their public contracts due to financial constraints.

As a result, most ferry routes are now operated by the state-owned company. While this development has reduced competition and led to a decline in the number of small, locally based operators—which is not necessarily an ideal outcome—it also means that ferry service providers now have greater financial capacity to invest in technological upgrades and sustainability measures.

Since island ferry services in mainland Finland are primarily publicly procured and mostly free of charge for passengers, the economic viability of the sector is closely tied to public funding and the political decisions that guide it. Notably, the level of national public funding allocated to island ferry services decreased slightly between 2024 and 2025, which may impact future development and investment capacity within the industry.

Table 5 lists the main island and road ferry operators currently active in mainland Finland.

Table 5: Island and road ferry operators serving mainland Finland, their turnover, personnel, and vessels in 2023. Source: Ojala et al., 2025.

Company	Turnover (Million EUR)	Personnel	Vessels
Finferries corporation	51.7	280	91
Suomen Saaristovarustamo Oy (Finferries)	13.3	49	15
Kuljetus Savolainen Oy	7.1	30	10
Suomenlinnan Liikenne Oy	5.6	21	3
Kymen Saaristoliikenne Oy	2.7	3	2
Archipelago Lines Oy	2.4	13	1
Sundqvist Investments Oy Ab / Östern	1.3	7	1
Sibbo Skärgårdstrafik Ab	-	-	-

In Helsinki, the public transport authority HSL is planning to raise ticket prices in 2026 in response to increasing operational costs and the need to fund new infrastructure projects. This has intensified the political debate on the issue, in which ticket prices of the few ferry lines in the HSL system are purely marginal.

At the national level, the incumbent Finnish government is pursuing a policy of reduced public spending, which may have broader implications for the island ferry sector.

Should public funding for island ferry traffic be reduced, it could delay or scale back major publicly funded infrastructure projects, such as the deployment of charging infrastructure for electrified ferries along the Finnish coastline. As a result, the transition to cleaner ferry technologies may face slower implementation timelines, despite growing environmental and political interest in lowering emissions from the maritime transport sector.

7 Stockholm County

7.1 Population and tourism

Stockholm County comprises 26 municipalities, of which only five are landlocked, and is home to approximately 2.5 million residents. The Stockholm Archipelago consists of roughly 30,000 islands, of which around 200 are inhabited (Länsstyrelsen Stockholm, 2019). Even the City of Stockholm itself spans multiple islands, interconnected by bridges, a subway system, and a well-developed ferry network (See Figures 10, 11).

Figure 10: Ferry terminal Strömkajen in Stockholm (left; photo by Bulach, CC BY-SA 4.0), an archipelago ferry en route in Stockholm archipelago (right; photo by Blidösundsbolaget AB)

As a major travel destination, Stockholm attracts millions of tourists annually. In 2024, accommodations in Stockholm County recorded nearly 8.4 million tourist arrivals—an increase of approximately 32% compared to 2014. July and August remain the busiest months, while January and February see the lowest visitor numbers. In 2024, about 32% of tourists were international, with the remaining 68% being Swedish residents (Swedish Agency for Economic and Regional Growth, 2025). Notably, approximately 20% of tourists visit the archipelago during their stay (Visit Stockholm, 2023).

The public transport system includes four ferry commuter routes in central Stockholm, which carried over 4.8 million passengers in 2022. The archipelago ferries, operating across a broader area from Arholma in the north to Landsort in the south (Figure 11), served around 1.5 million passengers—an average of 4,100 boardings per day (SL, 2023). In addition, ten road ferry routes connect several of the largest islands to the mainland within Stockholm County (Färjerederiet, 2024).

Approximately 9,000 residents live on islands in Stockholm County that lack a bridge connection to the mainland (SCB, 2023). While most of these islands are served by road ferries, several inhabited islands have neither a road ferry nor a bridge. Instead, the islands are accessed by archipelago ferries, taxi boats, or private vessels.

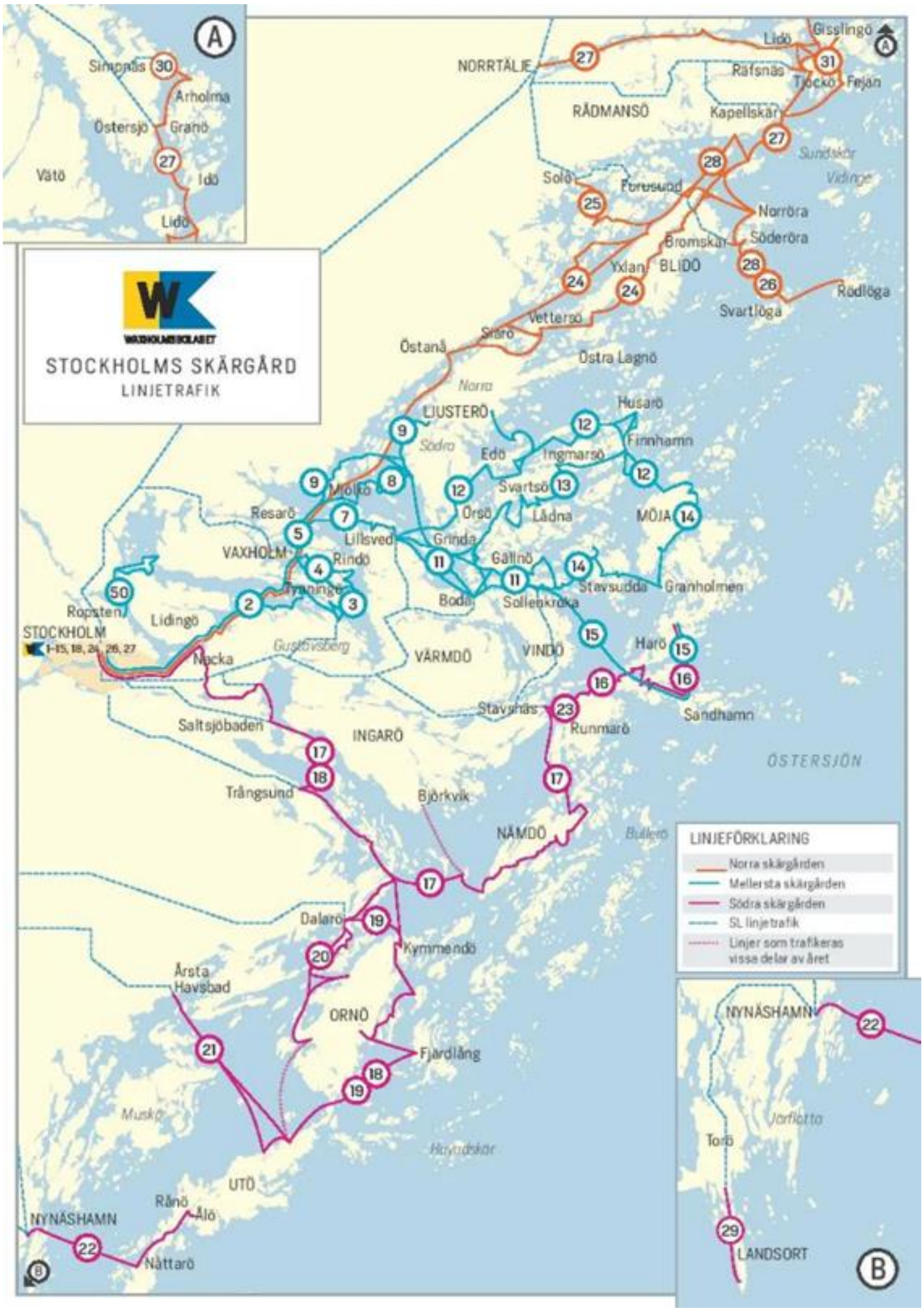

Figure 11: Stockholm's archipelago map with ferry routes (Skärgårdstrafiken 2020)

Fourteen of these islands with limited access have been designated as Core Islands (kärnöar) and prioritized in regional planning as service hubs for surrounding islands and tourism. The regional standard for Core Islands includes daily, year-round ferry access. At present, these islands are home to approximately 1,500 permanent residents. However, the regional aim is to strengthen infrastructure and services, thereby increasing their capacity for both permanent settlement and business development (Region Stockholm, 2025).

Most Core Islands are also included in another regional development initiative: the Stockholm Archipelago Trail, launched in 2024. This trail covers 20 islands and offers 270 km of hiking routes, all accessible via the public ferry network. To promote sustainable tourism and reduce seasonal dependency, the autumn period has been branded as the “magic season” for the trail. The trail remains open year-round, though winter ferry connections and available services are more limited (Stockholm Archipelago Trail, 2025).

7.2 Legal and political environment

Sweden is subject to the same EU and IMO regulations as Estonia and Finland. Previously, the public procurement of island ferry services has been price-focused, but the procuring authority will consider environmental criteria in the future.

Authorities in Stockholm County have demonstrated a strong will to reduce emissions from the public transport services they provide by arranging charging infrastructure for not only island ferries, but also for larger ferries, such as those heading to Gotland, Finland, and Estonia. These policies are in line with Sweden’s national emission reduction goal of reaching net zero GHG emissions by 2045.

The regional governing body of the Stockholm County is called Region Stockholm, which is responsible for healthcare, public transport, culture and regional development within the county. Island ferry traffic is a part of the county’s public transport network and one of Region Stockholm’s main responsibilities. The Core Islands, which are being developed according to the hub-and-spoke model, are one example how regional planning directly shapes how the island ferry transport is organised.

Region Stockholm owns a shipowner company Waxholms Ångfartygs AB (also known as Waxholmsbolaget, WÅAB) and procures ferry services from private companies. The role of WÅAB is to own vessels and govern contracted operators, not to operate the vessels itself. WÅAB has a fleet of 25 vessels, which are not enough for the high demand of island ferry services in the Stockholm County. Thus, Region Stockholm is also procuring ferry services from companies operating their own vessels.

7.3 Technological environment

The technological environment in Stockholm County is currently slightly more advanced in terms of emission reduction when compared to other regions in this study. HVO is commonly used by island ferries in Stockholm County, and a supply network for ferries is in place. The main issue is cost, as the fossil option, Diesel MK1 (a mixture of fossil and biodiesel), can be purchased at roughly half the price of HVO. Island ferries in Stockholm County are predominantly HVO-compatible, which means the technological preconditions exist for a complete biofuel transition.

There are also a few electric ferries and hybrids operating in Stockholm County. Blidösundsbolaget AB (BBAB) is the largest ferry operator in the region and leading the way regarding electrification. BBAB recently converted a 50-year-old vessel, M/S Silverö, from fossil fuels to fully electric. The old engine and all fuel-powered appliances and systems were removed, and the vessel is now fully powered by batteries, emitting zero emissions in operation. This project serves as an example of what is possible, but also highlights regional limitations. M/S Silverö was selected due to being a lightweight and suitable vessel for retrofitting, and it operates a route that provides access to sufficient shoreside power for charging in Vaxholm island.

In the City of Stockholm, a first of its kind electric hydrofoil ferry is in operation (Figure 12). The Candela P-12 shuttle, Nova, is a fully electric passenger ferry serving commuter traffic. The cutting-edge hydrofoil technology lifts the vessel above water and allows it to drive faster, use less energy and create less sound or wake when compared to a traditional ferry.

Figure 12: Candela hydrofoil shuttle Nova in SL traffic in Stockholm (Photo by Oberger, CC BY-SA 4.0)

Stockholm County faces similar issues to those on the mainland Finland regarding electrification, as the ferries need to cover a vast archipelago. For the broader electrification of Stockholm County's ferries, a more extensive network of charging stations would need to be established. The strategic locations of the City of Stockholm and Vaxholm, for instance, where many of the region's ferry routes lead, is an advantage, but the archipelago is too large for ferries to make voyages far into the islands and back without recharging (See Figure 11).

The local authority, Region Stockholm, will play a key role in allowing or setting up sufficient charging infrastructure across the archipelago. The technology and know-how to convert a vessel to use batteries exist, albeit at an expensive cost to the operator.

7.4 Economic and competitive environment

The economic and competitive environment for island ferry services in Stockholm County can be described as robust and dynamic, particularly when compared to other regions within the Central Baltic. The market is competitive, with multiple operators actively involved in providing services, and financially capable of investing in environmentally sustainable technologies, including the electrification of vessels.

Table 6 lists the key island ferry operators active in Stockholm County.

Table 6: Island ferry operators in Stockholm County, their turnover, personnel, and vessels in 2023. Source: Ojala et al., 2025.

Company	Turnover in SEK Million	Turnover in EUR Million (1 SEK = 0.087 EUR)	Personnel	Vessels
Blidösundsbolaget AB	483.7	42.1	227	38
Rederi AB Ballerina	169.2	14.8	94	17
Madam Rederi AB	39.2	3.4	18	5
Djurgårdens Färjetrafik AB	31.4	2.7	22	6
Ingmarsö Sjötjänst AB	24.3	2.3	4	2

Unlike regions such as mainland Finland—where a single dominant operator (Finferries) holds a significant market share—Stockholm County does not have a monopolistic market structure. Although Blidösundsbolaget AB (BBAB) is currently the market leader, several other companies operate in the region, ensuring healthy competition in public tenders.

One notable competitor is Ballerina Rederi AB, a well-established company that possesses the operational capacity and financial resources to compete effectively with BBAB for contracts. The presence of multiple capable operators contributes to an innovative business environment, fostering progress in sustainable ferry operations.

8 Åland Islands

8.1 Population and tourism

The Åland Islands is a self-governing and demilitarised province of Finland. This sparsely populated and geographically diverse archipelago consists of approximately 6,760 islands (1,556 km²) and has a population of 30,650. Around 60 of the islands are permanently inhabited (ÅSUB, 2025a). The main island, Fasta Åland, is home to 93% of the population and includes the capital city, Mariehamn (population approx. 11,800), along with nine other municipalities.

The six island municipalities – Brändö, Föglö, Kumlinge, Kökar, Sottunga, and Vårdö – have a combined population of close to 2,000 (See Figure 14). Approximately 30% of the 8,500 summer cottages are located on these islands, with the remainder situated on Fasta Åland (ÅSUB, 2024a).

Figure 13: M/S Viggen and passengers (left; adapted from: Koistinen, CC BY 3.0), and Töftö cable ferry line (right; adapted from: Matti, CC BY 3.0)

Tourism is Åland's largest export industry and makes a significant contribution to the local economy. It employs 20% of the private sector workforce and relies heavily on maritime transport, including both large car-passenger ferries and smaller inter-island ferries. In 2023, tourist-generated land-based consumption was estimated at EUR 107 million, rising to over EUR 700 million when sea-based tourism is included (ÅSUB 2024,b).

Recent statistics show approximately 1.3 million annual inbound tourists, although this figure includes cruise passengers who do not disembark in Åland. Accommodation data – covering hotels, guest houses, cottages, and campsites – provides a more realistic view: in 2024, nearly 200,000 guests arrived, staying an average of two nights. Tourism is highly seasonal, with about 4,000 monthly arrivals in winter, over 33,000 in June and August, and nearly 60,000 in

July. More than half of the guests were from Finland, while about one-third were from Sweden. Fewer than 40,000 passengers arrived or departed via Mariehamn Airport, underscoring the importance of maritime transport (ÅSUB, 2025b).

The dispersed population, mosaic-like geography, and strong tourism industry make island ferry services vital for Åland. Ferries connect the smaller islands to Fasta Åland and also provide links to the Turku Archipelago in Finland (See Figure 14). There are four main free-moving ferry routes – the Northern Line, Cross Line, Southern Line, and Föglö Line – which served 422,000 passengers and 248,000 vehicles in 2024. Additionally, six shorter cable ferry routes carried nearly 570,000 passengers and 380,000 vehicles (ÅSUB, 2025b). Figure 13 shows examples of a free-moving ferry and a cable ferry in the Åland Islands.

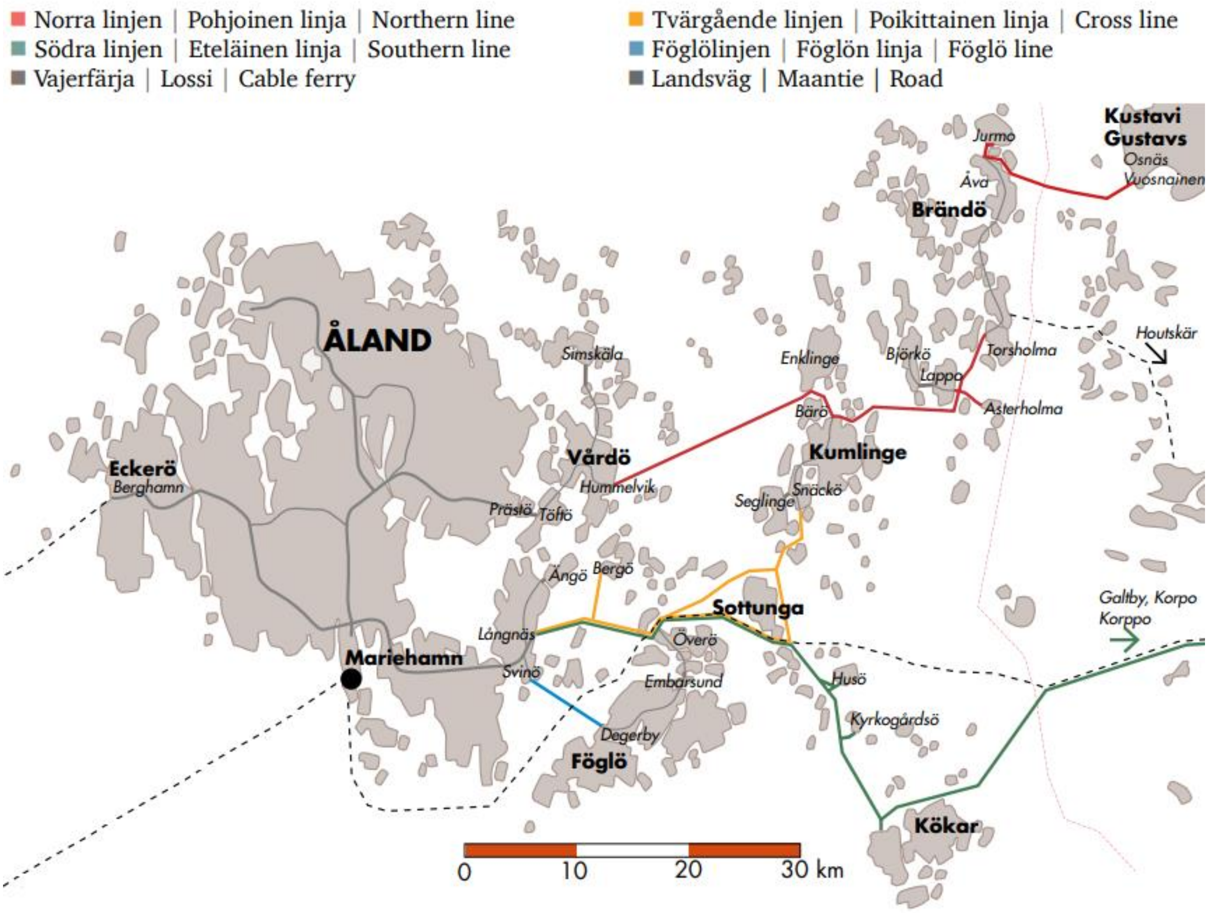

Figure 14: Map of the main ferry lines in Åland Islands (Government of Åland)

In addition to tourism, shipping and ferry services, as well as the processing of agricultural and fish products are key economic sectors in Åland. These industries are partially dependent on reliable ferry services. The Government of Åland is currently planning a large-scale offshore wind farm, Sunnanvind, north of the region. The aim is to make wind energy a new pillar of the regional economy and a significant energy source (Government of Åland, 2025).

8.2 Legal and political environment

The legal and political environment in the Åland Islands is mostly impacted by the incumbent regional government. The Finnish Archipelago Act does not apply to Åland and due to its autonomous position, the regional government decides on policies concerning island ferry services. Åland Islands is the only Finnish region with a regional autonomy. This decision dates back to a treaty signed by the League of Nations in 1920.

The Government of Åland (GoA) may change with each election, potentially leading to shifts in certain guiding policies. However, the overall importance of ferry services to the island region remains consistently high, as reliable ferry connections are essential for the citizens of Åland, regardless of political affiliation.

8.3 Technological environment

The technological environment of island ferry traffic in the Åland Islands is currently defined by an aging fleet, with many vessels expected to be replaced or retrofitted with new technologies in the coming years. A pivotal moment came in 2024, when a key ferry operator suddenly went bankrupt while operating older vessels powered by traditional fuels. In response, the Government of Åland (GoA) recognized the urgent need for renewal and has committed to modernizing the region's ferry fleet.

Given the vital role of ferry services and the significance of the archipelago environment to local residents, the GoA has clearly set its course toward electrification. This transition is already underway, with the government launching a tender for a new electric cable ferry.

Regarding the technological environment for island ferry traffic in the Åland Islands, a significant initiative is currently in the planning and feasibility study phase. The project, known as Mega Green Port (Mega Grön Hamn in Swedish), involves key stakeholders such as OX2—a renewable energy developer—and the Bank of Åland (Ålandsbanken), among others.

The project's ambitious goal is to transform the Port of Långnäs on the east side of the mainland Åland into a Nordic hub for green energy. As a central hub for the region's ferry traffic, Långnäs plays a vital role in connectivity, and its development into a green port would pave the way for adopting zero-emission alternative fuels such as hydrogen, e-fuels, and green electricity.

If implemented, the Mega Green Port would create highly favorable conditions for the Åland Islands' ferry traffic to transition toward emission-free operations. However, no final investment decision has been made, and even in the best-case scenario, the port would still be several years from being operational. Nonetheless, the fact that such a project is being seriously considered highlights Åland's strong commitment to a green energy transition and sustainable maritime transport.

8.4 Economic and competitive environment

The overall business environment for island ferry traffic in the Åland Islands experienced a major shift in 2024 with the establishment of AxFerries—a 50/50 joint venture between the Government of Åland (GoA) and Finferries Corporation. This development was prompted by an unexpected event in July 2024 in which the contracted ferry operator, Nordic Jetline, filed for bankruptcy and ceased operations virtually overnight. In response to the sudden service disruption, the GoA acted swiftly to secure continuity and long-term stability in ferry services by launching AxFerries, which was eventually formed in autumn 2024.

AxFerries now operates the majority of the former government-owned vessels and has quickly become a dominant player in the regional ferry market. Despite the strategic importance of ferry services for the region, the overall competitiveness of the market remains low. Table 7 below lists the island ferry operators currently active in the Åland Islands.

Table 7: Island ferry operators in the Åland Islands contracted by GoA, their turnover, personnel, and vessels in 2023. Source: Ojala et al., 2025.

Company	Turnover (Million EUR)	Personnel	Vessels
AxFerries Ab	n.a.	n.a.	7
Kuljetus Savolainen Oy	7.1	30	10
Kymen Saaristoliikenne Oy	2.7	3	2
Sundqvist Investments Oy Ab	1.3	7	1
Alandia Tug Ab	0.4	4	1

While there are still a few private operators running island ferry routes in Åland, AxFerries is expected to hold a highly advantageous position in future public tenders for ferry services. With the backing of both the GoA and Finferries, AxFerries benefits from substantial financial and operational resources, giving it a clear edge over its competitors. A key reason the GoA chose Finferries as a joint venture partner was the company's proven expertise in ferry electrification. This partnership indicates that both AxFerries and the GoA are positioning themselves for a technologically advanced and environmentally sustainable future in ferry transport.

9 Conclusion

Ongoing Transformations in Island Ferry Traffic in the Central Baltic Region

The operating environments of the island ferry traffic industry in the Central Baltic Region are undergoing substantial transformations, impacting the environmental, technological, and economic dimensions of ferry services. These changes are driven by both global climate imperatives and regional policy goals. In addition to these evolving conditions, navigational safety remains a constant and critical concern in maritime operations—including ferry services—requiring continuous attention and adaptation to ensure reliable and secure transport.

Navigational Safety and GNSS Interference

While navigational safety was not a focus of this report, it is important to note that the operational environment has deteriorated—particularly in the Gulf of Finland, but also across broader areas of the Baltic Sea—due to a sharp increase in GNSS (Global Navigation Satellite System) interference. This interference can involve spoofing, jamming, or other forms of signal manipulation, leading to serious disruptions in the functioning of equipment that relies on satellite navigation. As modern ferry operations increasingly depend on accurate GNSS data for positioning, timing, and route planning, these disruptions pose a growing risk to maritime safety and demand urgent attention from both operators and authorities. (See, for example, Estonian Transport Administration, 2025)

Climate Change and Policy Pressures

Human-induced global warming is changing the physical and natural environment to such a degree that rapid greenhouse gas (GHG) emission reductions and climate adaptation measures are essential across all sectors of society—including island ferry traffic.

Regional Differences and Shared Trends

Each sub-region—Estonia, mainland Finland, the Åland Islands, and Stockholm County—has its own distinct business environment. However, several overarching trends can be identified. Politically, both the Nordic countries and Estonia have set ambitious emission reduction targets. To meet these goals, the transport sector must shift to various forms of sustainable energy, and island ferry services are no exception. The current market structures, which are primarily based on the public procurement of cost-effective ferry services, are being challenged by the technological demands required to meet emission targets.

Demographic and Tourism Dynamics

While population in each sub-region are largely concentrated along the coasts, the permanent populations on islands—particularly in Sweden, Finland, and the Åland Islands—have been steadily aging and declining in recent decades. At the same time, however, the popularity of second homes and seasonal living has increased across all archipelago areas.

Tourism plays a central role in each region's economy. Increasing visitor numbers is a shared objective among national and local stakeholders. The archipelagos, with their rich cultural and natural heritage, are widely promoted as key tourism destinations. However, increased travel also contributes to higher emissions, prompting the development of sustainable tourism strategies such as extending the peak season and encouraging longer stays to reduce travel frequency.

The Technological Environment and Electrification

The technological environment has a pivotal role in defining the possibilities and preconditions for lowering emissions in island ferry traffic. This environment includes the current ferry fleet, the availability of alternative fuels, and existing infrastructure for charging electric vessels. Electrification is clearly emerging as a dominant trend. Each sub-region either operates battery-powered vessels already or has such vessels in the procurement pipeline. From an environmental perspective, electrification offers one of the most effective means to eliminate emissions. However, in practical terms, it is a complex and expensive undertaking. Transitioning a route to electric operations typically requires either the purchase of a new vessel or a technically demanding retrofitting of an existing one.

Charging Infrastructure as a Limiting Factor

Electrification also depends heavily on charging infrastructure, which imposes practical limitations on its implementation. Establishing charging stations on remote islands is often not feasible, thereby restricting the use of electric ferries to specific routes. Electrification must therefore be approached on a case-by-case basis, focusing on routes where the technology can be applied most effectively. Where applicable, battery-powered vessels can achieve near-zero CO_2 emissions.

Alternative Fuels and Regional Initiatives

In addition to electrification, several alternative fuels are available that can help reduce ferry traffic emissions. Hydrogen stands out as one of the cleanest options, offering zero operational emissions. However, it is technically challenging to adopt as a marine fuel. Estonia has taken a significant step in this direction with plans to introduce a hydrogen-electric hybrid ferry, demonstrating the feasibility of hydrogen in island ferry operations.

HVO (hydrotreated vegetable oil), also known as renewable diesel, is arguably the most accessible alternative fuel. It can directly replace diesel in existing engines and is already available across the Central Baltic Region, although Stockholm County remains the only area with a well-developed bunkering network. The future outlook for HVO is promising, with major Nordic petrochemical companies such as Preem, Neste, and UPM committed to expanding its production.

LNG (liquefied natural gas) is another alternative, although it only offers moderate emission reductions and is often considered a transitional rather than a long-term solution. Methanol and ammonia are also emerging marine fuels, though they have not yet been adopted in the region's island ferry industry. E-fuels represent a more advanced category of alternative fuels, and while they are not yet commercially available, the Åland Islands have expressed interest in their future deployment.

Operational Measures for Immediate Emission Reduction

There are also more immediate and cost-effective ways to achieve moderate emission reductions without a complete shift in energy sources. Any measure that lowers fuel consumption contributes directly to emission reduction in shipping and waterborne transport. Such measures include eco-driving practices, voyage optimization, adoption of energy-efficient onboard systems, and regular hull maintenance. Ferry operators across the Central Baltic Region are increasingly aware of these strategies and have already taken steps to harness their emission reduction potential.

Preconditions and Opportunities for Emission Reduction

Overall, the preconditions for reducing emissions from island ferry traffic in the Central Baltic Region are good. Several examples across the region demonstrate that the technical capabilities and know-how needed to achieve significant emission reductions—or even zero emissions—already exist. Political will to lower emissions is also strong, which supports the ongoing technological development.

Another positive aspect is the small scale of the island ferry traffic industry. The ferries are typically small and light and form only a small portion of the total number of vessels operating in the Baltic Sea. This means that, from the government's perspective, a relatively small investment could yield significant results in regional island ferry emission reduction.

Key Barriers: Geography, Costs, and Bureaucracy

Key challenges to reducing emissions include geographical constraints, limited financial resources, and bureaucracy. The geographical issue is related to the distance to remote islands that need regular ferry services as it limits the possibilities for electrification, and financial resources are limited in the public sector. Procuring new vessels, retrofitting existing vessels, and arranging supply networks and charging infrastructure for sustainable energy sources is expensive. High costs can limit implementation and force decision-makers to prioritize only certain routes.

The bureaucracy involved with the market structure of the industry (island ferry services are typically publicly procured) as well as with setting up charging stations, for instance, is an issue. Existing public contracts are typically designed for the use of fossil fuels, and it may take until the next tender for the situation to change. Similarly, establishing charging stations for electric ferries often requires an access to the power grid, which can involve lengthy administrative procedures.

References

Bratkov, V. – Kasepõld, K. – Aiken, D. (2025) Report on the Setup of the Island Ferry transport in the Central Baltic Region. *REISFER report D.1.1.1*.

Comer, B. – Beecken J. – Vermeulen R. – Sturrup E. – Paschinger, P. – Osipova, L. – Gore, K. – Delahaye, A. – Verhagen, V. – Knudsen, B. – Knudsen, J. –Verbeek, R. (2024) FUGITIVE AND UNBURNED METHANE EMISSIONS FROM SHIPS (FUMES), Characterizing methane emissions from LNG-fueled ships, International Council on Clean Transportation, available here.

EMSA (2024) *Synthetic Fuels for Shipping*. European Maritime Safety Agency, Lisbon.

Estonian Transport Administration (2025) Estonia and Finland warn ships in the Gulf of Finland about increased GNSS interference, June 17, 2025, available here.

Färjerederiet (2024) Färjerederiets årsrapport 2024.

Hossain Bhuiyan, M. – Siddique, Z. (2025) Hydrogen as an alternative fuel: A comprehensive review of challenges and opportunities in production, storage, and transportation, *International journal of hydrogen energy,* Vol. 102.

Kornel, A. (2025, March 20) Ferry traffic in Estonia [conference presentation], REISFER Island Ferry Summit, Helsinki, Finland.

Länsstyrelsen Stockholm (2019) Skärgårdsfakta – Grafiska kartor 2019.

Mayanti, B. – Hellström, M. – Katumwesigye, A. (2024) Assessing the decarbonization roadmap of a RoPax ferry, *Maritime Economics & Logistics,* Vol. 27.

Methanol Institute (2023), Marine Methanol: Future-Proof Shipping Fuel, <Marine_Methanol_Report_Methanol_Institute_May_2023.pdf> retrieved 7.8.2025.

Nordic Energy Research (2024) Nordic Hydrogen Valleys, <https://pub.norden.org/nordicenergyresearch2024-04/index.html>, retrieved 5.8.2025.

Ojala, L. – Joki-Korpela, E. – Ojala, M-L. (2025) Road and Island Ferry Traffic Governance and Markets in the Central Baltic Region. *REISFER report D.1.2.1*.

Raagmaa, G. (2023) Estonian population and regional development during the last 30 years—back to the small town? *Regional Science Policy & Practice,* Vol. 15.

Rannanpää, S. – Ahtinen, S-M. – Antikainen, J. – Heikkinen, B. – Hovi, S. –Sinerma, J. – Tolonen, S. (2023) Suomen saaristoalueet tilastojen kertomana. *Maa- ja metsätalousministeriön julkaisuja 2023:25 (Publications of the Ministry of Agriculture and Forestry 2023:25)*

Rannanpää, S. – Rautiainen, S. – Hirvonen, T. – Kahila P. (2025) Finland's Archipelago 2024: Current state of Finland's archipelago areas. *Publications of the Ministry of Agriculture and Forestry 2025:2.*

Rao, X. – Yuan, C. – Guo, Z. – Xu, Y. – Sheng, C. (2025) Methanol as an alternative fuel for marine engines: A comprehensive review of current state, opportunities, and challenges, *Renewable Energy,* Vol. 252.

Region Stockholm (2025) Kärnöar - statistik om befolkning, bebyggelse, sysselsättning och service.

Republic of Estonia (2025) Strategic focuses of tourism.

Sarkar, S. – Kundu, D. – Bej, S. – Murmu, N.C. – Banerjee, P. (2025) Is Ammonia the Fuel of Future? Direct Ammonia Fuel Cell (DAFC) as an Alternative Energy Infrastructure, *Small: Nanoscience & Nanotechnology journal*, Vol. 21.

Sæther, S.R. – Moe, E. (2021) A green maritime shift: Lessons from the electrification of ferries in Norway, *Energy Research & Social Science,* Vol. 81.

SCB (2023) Statistikdatabasen: Befolkning och bebyggelse på öar utan fastlandsförbindelse med bro. År 2010–2020. <www.statistikdatabasen.scb>.

SL (2023) Fakta om SL och länet 2022. Storstockholms Lokaltrafik.

SLL (2025) Suomenlinnan Liikenne Oy lukuina. Suomenlinnan Liikenne Oy.

Statistics Estonia (2025a) Population. Statistical database.

Statistics Estonia (2025b) Accommodated tourists and nights spent by country of residence. Statistical database.

Stockholm Archipelago Trail (2025) <https://stockholmarchipelagotrail.com/>.

Swedish Agency (The) for Economic and Regional Growth (2025) Statistik om turism. <https://tillvaxtverket.se/>

TS Laevad OÜ (2025) Our year in numbers. <https://www.praamid.ee/en/homepage/>. Retrieved in 20.9.2025.

Visit Stockholm (2023) Stockholm and our visitors.

Visit Finland (2019) Matkailuvuosi – matkailun suuralueet sekä maakunnat.

Visit Finland (2025a) Suomen matkailulliset myyntivaltit.

Visit Finland (2025b) Matkailun ennusteet.

ÅSUB (2025a) Åland in Figures 2025. Ålands statistik- och utredningsbyrå.

ÅSUB (2025b) ÅSUB's statistical databases. Ålands statistik- och utredningsbyrå.

ÅSUB (2024a) Statistical Yearbook of Åland 2024. Ålands statistik- och utredningsbyrå.

ÅSUB (2024b) Turismens samhällsekonomiska betydelse för Åland 2023. Ålands statistik- och utredningsbyrå. *ÅSUB rapportserie 2024:4.*