

Boatplan Stockholm 2025

Strategy for the transition of archipelago traffic



ElectriCITY & Green City Ferries

Summary:

Boatplan Stockholm 2025 is based on the guidelines that Region Stockholm has decided on for the transition of archipelago traffic in terms of climate, environment and attractive public transport. Boatplan Stockholm 2025 shows how a comprehensive approach can be taken to the questions that Region Stockholm wants answers to through the Transport Authority's investigations regarding the archipelago fleet's future structure, ownership and tonnage. The plan contains the following proposals:

1 Make full use of the new technology. Carbon fiber hulls, ASV-technique with air cushions that lift the vessel and reduce water resistance, new battery technology and new hydrogen technology make it possible to reduce energy consumption by up to 80 percent and radically reduce emissions.

2 Optimal operation through a new mix of vessels. The new fleet is built up by four main groups of vessels: new fast and emission-free vessels, vessels converted to hydrogen operation, new or rebuilt slow vessels with battery operation, historic and selected other vessels for peak-shaving with smart HVO, providing better average cabin factor.

3 The combination of new technology and new fleet makes the transition profitable. Such a new fleet will have significantly lower energy costs than continued operation with current vessels, which are planned to be converted to 100% HVO (Biodiesel) operation. Investments of SEK 1,500 million in new vessels/infrastructure are commercially viable.

4 New external and long-term financing. Region Stockholm has in its budget guidelines called for co-financing from external partners. Two strong players, Vattenfall and Infranode, are prepared to commit themselves long-term to securing this transition and the expanded public transport on water.

Table of Content

1.	Background to Boatplan Stockholm 2025	3
1.1	<i>Region Stockholm's Guidelines and Transport Authority's mission</i>	3
1.2	<i>Boatplan Stockholm 2025 – an approach to the transition</i>	3
2	Challenges: Climate/environment, public transport and economy	4
2.1	<i>Climate and environment</i>	4
2.2	<i>The role of boat traffic in public transport</i>	4
2.3	<i>The economy of the transition</i>	4
3	The new technology	5
3.1	<i>Use of carbon fiber makes the hull lighter and reduces energy use</i>	5
3.2	<i>New ASV design of the hull reduces resistance and energy use</i>	5
3.3	<i>Electric power instead of diesel operation eliminates emissions</i>	5
3.4	<i>Hydrogen operation eliminates emissions and has longer range.</i>	5
4	The new archipelago fleet	6
4.1	<i>New efficient, emission-free and standardized vessels (> 25 knots)</i>	6
4.2	<i>Selected vessels converted to hydrogen operation (< 12 knots)</i>	7
4.3	<i>New vessels or retrofitted to battery power (< 12 knots)</i>	7
4.4	<i>Historic and other vessels with HVO for peak-shaving</i>	7
4.5	<i>All in all, this basically means:</i>	7
5	The new economy	8
5.1	<i>Reduced energy costs</i>	8
5.2	<i>Increased capital costs</i>	8
5.3	<i>Business profitability</i>	9
6	The new funding	10
6.1	<i>A co-financing plan</i>	10
6.2	<i>More efficient infrastructure and increased competition in public tendering</i>	10
6.3	<i>Waxholmsbolaget's role in the new infrastructure</i>	11
7	Start of the transition towards 2025	12
7.1	<i>Electric drive plus HVO (Biodiesel)</i>	12
7.2	<i>Electrification of the ferries in Hammarby Sjöstad</i>	12
7.3	<i>Ropsten - Storholmen</i>	13
7.4	<i>Ålstäket - Stockholm</i>	13
7.5	<i>Ljusterö - Husarö</i>	13

1. Background to Boatplan Stockholm 2025

1.1 Region Stockholm's Guidelines and Transport Authority's mission

Boatplan Stockholm 2025 has been developed by the Innovation Platform ElectriCITY and the technology company Green City Ferries ¹. The plan is based on the guidelines decided by Region Stockholm for the conversion of archipelago traffic in terms of climate, environment and attractive public transport and where we would like to highlight the following points:

- Public transport should be a world leader and achieve high-level climate goals.
- Region Stockholm will retain the leadership in the green transition.
- Expanded waterborne public transport and smart routes that shorten travel times.
- Region Stockholm wants to use the opportunities of modern technology.
- Great potential to increase capacity and reduce costs if commuter traffic can be carried out with a more efficient and standardized tonnage.
- Possible co-financing with municipalities and/or external financiers.
- Available tonnage for commuter boat traffic until year end 2024/2025.

The Transport Authority has been assigned to work out a proposal for the modernization of the Archipelago Fleet.

- The “Maritime traffic investigation 1” is now completed. It reports a low cabin factor and proposes an alternative with smaller vessels
- An investigation regarding fleet ownership is ongoing.
- The “Maritime traffic investigation 2” is to be completed by 2021 with focus on energy-efficient tonnage

1.2 Boatplan Stockholm 2025 – an approach to the transition

Through Boatplan Stockholm 2025 we will show how a comprehensive approach can be made to the questions that Region Stockholm wants answers to through the Transport Authority's investigations.

Our starting point is that a transition must take the following into account:

- climate/environment, i.e. transition to renewable and emission-free fuels
- attractiveness in order to increase the use of traffic on water and reduce car traffic
- business profitability

¹ ElectriCITY is an innovation platform that promotes initiatives against climate change. It has about 60 companies and research institutions as members. Resident in Hammarby Sjöstad. Green City Ferries AB specializes in electric high-speed vessels. GCF was the first in the world to have a supercharged all-electric ferry six years ago. Three years ago, GCF launched the BB Green prototype, which is still the world's fastest electric passenger ferry with supercharging. The larger BB Green 24 is now launched.



2 Challenges: Climate/environment, public transport and economy

2.1 Climate and environment

The major challenge for Region Stockholm in terms of climate and environment comes from the use of diesel for the operation of the vessels.

Climate impact - carbon dioxide emissions. The archipelago fleet consumes 15 million liters of diesel per year and causes emissions of 40,000 tons of carbon dioxide per year, which represents 8% of shipping emissions in Sweden.

Environmental impact - nitrogen oxide emissions. Ordinary diesel and biodiesel (HVO) emit the same amount of nitrogen oxides and particulate matters. The archipelago fleet emits almost 500 tons of nitrogen oxides and 60 tons of particulate matters every year. Nitrogen oxides lead to acidification and overfertilization of watercourses. Nitrogen oxides and particulate matters are harmful to human health. According to the Swedish Environmental Protection Agency, these emissions in Sweden annually leads to the premature death of 7,600 people and also high health-care costs as a result.

2.2 The role of boat traffic in public transport

The challenge for Region Stockholm when it comes to the role of boat traffic in public transport is to achieve short travel times, frequent departures and comfortable trips to make boat traffic an attractive alternative to car commuting.

The number of passengers on the "Sjövägen" commuter boat line has steadily increased and now amounts to about one million passengers carried by some 10 vessels. The Ekerö line has also increased in popularity. Commuter services on water seem to have a future. It is a major challenge for Region Stockholm to implement what is stated in the politically decided guidelines to be "*world leader*", "*achieve high climate goals*", "*retaining the leadership in the green transition*" etc. The necessary transition is an excellent opportunity to also increase the role of boat traffic in public transport.

2.3 The economy of the transition

The challenge for Region Stockholm in terms of economy in archipelago traffic lies in the current aged fleet, which consists of some 60 vessels, the structure of the fleet leading to low cabin factor and an increase in energy costs of 67% if the entire fleet increases the use of HVO as fuel from 20% to 100%.



3 The new technology

Region Stockholm has stated in the guidelines for the conversion of archipelago traffic that it should be "world leader" and achieve "high climate goals". To achieve this, Region Stockholm wants to "use the opportunities of modern technology".

After decades of development, vessel technology as well as battery and fuel cell technology have reached the commercialization phase, while at the same time regulatory requirements for environmental and climate impacts have driven the development even further. We have taken into account Region Stockholm's guidelines and Boatplan Stockholm is based on four innovations, which are - or will be - commercially available during the period 2020 - 2025.:

3.1 Use of carbon fiber makes the hull lighter and reduces energy use

The use of carbon fiber reduces hull weight by 30% compared to an aluminum-built vessel. This material is now being used even where there are high demands on strength. So, for example, the Swedish Navy corvette Visby is built in carbon fiber.

3.2 New ASV design of the hull reduces resistance and energy use

ASV means Air Supported Vessel. A fan in the bow blows air into a cavity under the vessel, which levels and planes on the air cushion. The result is 40% lower energy consumption compared to catamarans. With an energy efficient hull, the wake wash becomes small and you can get dispensation to drive fast where there is otherwise speed limitation. This means shorter travel time and better use of the vessel.

3.3 Electric power instead of diesel operation eliminates emissions

The new battery technology makes it possible to charge fast enough to get a well-functioning traffic. Vessels in Boatplan Stockholm 2025 uses a newly developed battery system with LTO batteries² for short charging time (less than 10 minutes) and long life (more than 10 years). The BB Green 24 takes 147 passengers and has a range of 30 km.

3.4 Hydrogen operation eliminates emissions and has longer range.

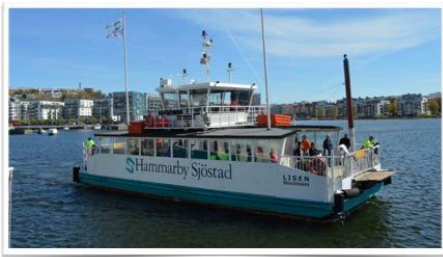
For longer distances than 30 km, batteries will be too heavy. Instead, hydrogen/fuel cells must be used. The development of fuel cells has now reached commercial maturity and can be used for longer distances. Already today, hydrogen operation is cheaper than diesel operation with HVO.

The carbon-fiber ASV hull, together with electric power, or hydrogen operation, means an energy saving of 80% (hydrogen 65%) compared to diesel-powered catamarans. At the same time, the new technology also means reduced maintenance. This significantly reduces operating costs. For more information see *Annex 1 The new technology*.

² Maritime LTO battery systems are developed by Stockholm-based Echandia, former sister company of Green City Ferries. The batteries were type approved by DNV-GL in February 2020.

The good circle: By reducing energy consumption, it will be possible to use batteries and thus reduce energy consumption further.

4 The new archipelago fleet



The current fleet, consisting of 62 vessels is old; the majority of vessels are 40 years or older. The cabin factor in the Archipelago Fleet is very low. “Maritime traffic investigation 1” showed that the fleet has a cabin factor of only 25 percent in July. This means a cabin factor of about 8 per cent over the year, indicating that the size of new high-speed boats can be significantly smaller and adapted to normal traffic. This also reduces the need for investments with lower capital costs as a result.

Against this background, we propose that the new archipelago fleet will be built up by four main groups, three of which use electricity/hydrogen and one consists of older historical vessels, which will be preserved and used for peak-shaving and operated with HVO:

- New efficient, emission-free and standardized vessels (> 25 knots)
- Selected vessels converted to hydrogen operation (<12 knots)
- New vessels or old retrofitted to battery power (<12 knots)
- Historic and some other vessels used for peak-shaving with HVO

4.1 New efficient, emission-free and standardized vessels (> 25 knots)

Most commuter vessels can be powered by battery because the distance normally allows for ³ this. The vessel is proposed to be the standard for high-speed vessels in

³ 2016 Green City Ferries launched the BB Green20 prototype, the world's fastest electric-powered vessel largely funded by the EU through FP7 and Horizon 2020.



the Archipelago. These ASV vessels consume much less energy than high-speed catamarans at 25 knots. A larger ASV vessel for 300 passengers will also be developed.

With these vessels, the Archipelago Fleet can become competitive against taking the car into town thanks to high frequency, short travel times, comfortable and emission-free travel. For the individual traveler, travel costs will be lower than today's mileage, congestion tax and parking, which costs almost amounts 4,000 SEK per month. (It will be significantly cheaper to take the boat and use SL's monthly pass.)

At the same time, it is important that there are connections to other means of transport at the piers and that there are charging possibilities. Therefore, hubs should be planned with charging possibilities before the route is established. There are some logical ones: Ropsten and Slussen on Baltic side and Munkbrohamnen and possibly Alvik on the Inland side.

4.2 Selected vessels converted to hydrogen operation (< 12 knots)

For longer distances, e.g. to Sandhamn, the vessels need to be equipped for hydrogen operation. Several of today's vessels, some 30 of them, still have a long time to serve. They are ice-going and are also used for goods transport and are suitable for hydrogen operation. However, in order to make the conversion into fuel cells and tanks for hydrogen operation economically reasonable, the power requirement needs to be reduced from 1500 kW to 500 kW, which means a speed reduction from 20 to 12 knots.

4.3 New vessels or retrofitted to battery power (< 12 knots)

In central Stockholm with speed restrictions there are shuttle services (Hammarby Sjöstad and Djurgården) and commuter services (Sjövägen and Ekerö). Even these heavy steel boats in shuttle traffic are well suited for being retrofitted to electric drive because they run so slowly. They consume only 20 - 30 kWh on one round. The three new vessels on Sjövägen are diesel electric and easily retrofitted to battery operation.

4.4 Historic and other vessels with HVO for peak-shaving

Peak-shaving is a concept for energy supply on larger vessels. It refers to cutting load peaks from e.g. bow thrusters. In the archipelago traffic there are peak loads in high season and some days of the week, when people are going out to the archipelago or back to Stockholm. The historic vessels and some other selected ones can be used as "peak shaving" vessels. They do not need to be retrofitted and can continue with HVO as fuel.

4.5 All in all, this basically means:

- Invest in 30 new energy-efficient vessels
- Keep 30 vessels and retrofit them
- Decommission 30 vessels

5 The new economy



Boatplan Stockholm 2025 aims to implement in a comprehensive way both the necessary transition and the urgent strengthening of maritime traffic as an alternative to road traffic. There are two factors that make it possible to carry out this conversion and reinforcement in an economically viable way:

- one factor is the new technology, which makes it possible to reduce energy costs by 65 - 80 %.
- the second is the new structure of the archipelago fleet – with both new electric and hydrogen-powered vessels and older vessels for peak-shaving. The archipelago fleet will have a structure that better responds to the varying demand for transport and thus provides a higher cabin factor.

5.1 Reduced energy costs

Our analysis of the archipelago fleet's economy is based on a thorough mapping of the entire fleet and of the costs of energy use for each vessel.

The starting point has been existing vessels in existing traffic. Each vessel has been tested against timetables and speed measurement made via the AIS system in order to estimate the current diesel consumption per vessel. Furthermore, all 25 vessels owned by Waxholmsbolaget have been checked against operational data for 2019 regarding operating hours and diesel consumption. The other 37 have been compared to similar vessels in Waxholmsbolaget's fleet and an estimate of the uptime, speed and diesel consumption has then been made. This has been done to estimate the fuel costs for the 62 vessels in the Archipelago Fleet.

5.2 Increased capital costs

The majority of the vessels are older than 40 years and need to be replaced by new vessels as shown in section 4 The new archipelago fleet. The focus of the investment is on the acquisition of standardized, energy-efficient high-speed vessels with batteries or hydrogen as energy source. The vessels cost SEK 40 -50 M each and the total investment will amount SEK 1,000 M. Investment in the retrofitting of existing speed-reduced or slow vessels and new acquisition of slow ones is estimated to amount SEK 400 M.



For the new high-speed electric vessels, pontoons with charging equipment are required and with installation they are estimated to cost about SEK 100 M. Hydrogen refueling can be done at a few strategically located places in the archipelago and these investments are expected to be made by those who supply the hydrogen.

The investment needs can be estimated at SEK 1,500 M as follows:

- 23 new fast emission-free vessels 1000 M
- 11 vessels converted to hydrogen operation 200 M
- 14 new or retrofitted slow vessels 200 M
- 12 Charging stations with pontoons 100 M

5.3 Business profitability

The economic impact of the transition to meet climate and environmental requirements while improving the competitiveness of maritime traffic against car traffic can be illustrated by the following comparison. The calculation focuses on the two factors relevant to a comparison between "business as usual", i.e. the current fleet that has to be operated 100% by HVO, and a new fleet of mainly electric and hydrogen powered vessels. The HVO option involves a cost increase of SEK 90 million – without making the traffic emission-free – while the transition to a new climate neutral and emission-free fleet is limited to SEK 60 million:

	Business as usual	Emission-free fleet
Current energy and capital costs	SEK 230 M	SEK 230 M
Increased/decreased energy costs	+90 MSEK	- SEK 70 m
Increased/decreased capital costs ⁴	SEK 0 m	+ SEK 130 m
Total energy and capital costs	SEK 320 M	SEK 290 M

This shows that the transition to a climate-neutral and emission-free fleet is commercially viable compared to the continued operation of the current fleet and the transition to 100% use of HVO.

⁴ The capital costs used are 10 % on invested capital, which in turn is based on 20 years of depreciation on vessels (5 % per annum) and 5 % interest. Powertrains and charging stations are depreciated over 10 years.



6 The new funding

A new, climate-neutral, emission-free and economically viable Archipelago fleet requires investments of approximately SEK 1,500 million. In Boatplan Stockholm we have taken up this idea of co-financing and have presented a business case for two companies that invest in sustainable infrastructure, Infranode and Vattenfall Network Solutions. They are in favor of an investment like this, provided that the right framework is developed.

6.1 A co-financing plan

Infranode invests capital on behalf of the leading institutional investors and pension funds KPA Pension, Fjärde AP-fonden, Folksam, LähiTapiola and EIB, with a focus on green investments and stable returns and low risk. Infranode has no interest in disposing of assets but prefers to own with an investment horizon of at least 20 years. Infranode's strategy is to share with others – with municipalities, county councils or private owners. Infranode makes minority or majority investments in new construction or infrastructure. The companies are interested in participating in long-term financing of the transition to a climate-neutral and emission-free Archipelago fleet.

Vattenfall Network Solutions has developed a functional solution to speed up the electrification of commuter vessels. The "Power as a Service" has been provided for 20 years for other industries. Now it also exists for shipping. Vattenfall takes full investment and ownership responsibility for electrical equipment, power train and batteries on vessels and charging stations on land. Furthermore, all responsibility for operation and maintenance of the electrical plant is taken and an agreement is signed with the customer for about ten years. For this, the shipowner or operator will pay a fixed monthly fee. If the vessel needs more charging power than the grid can deliver, for example in some places in the archipelago, you can have an additional battery on land that is charged when the vessel is out and discharged when the vessel arrives. In this way, the infrastructure investment is added as an operational cost, which does not burden the public investment budgets. Vattenfall also plans to offer functional solutions for hydrogen propulsion with fuel cells once the market has become more established.

6.2 More efficient infrastructure and increased competition in public tendering

This arrangement creates a financially strong Waxholmsbolaget that is given the role of owner of the fleet, while the shipping companies compete with each other for the operation and have the opportunity to rent the tonnage on equal terms.

This approach has several advantages. One advantage is that investments in new vessels can be carried out cost-effectively through a financially strong Waxholmsbolaget, which can procure new technologically advanced vessels at low capital costs, low residual value risk and a high degree of flexibility in terms of where the vessels are to be used.

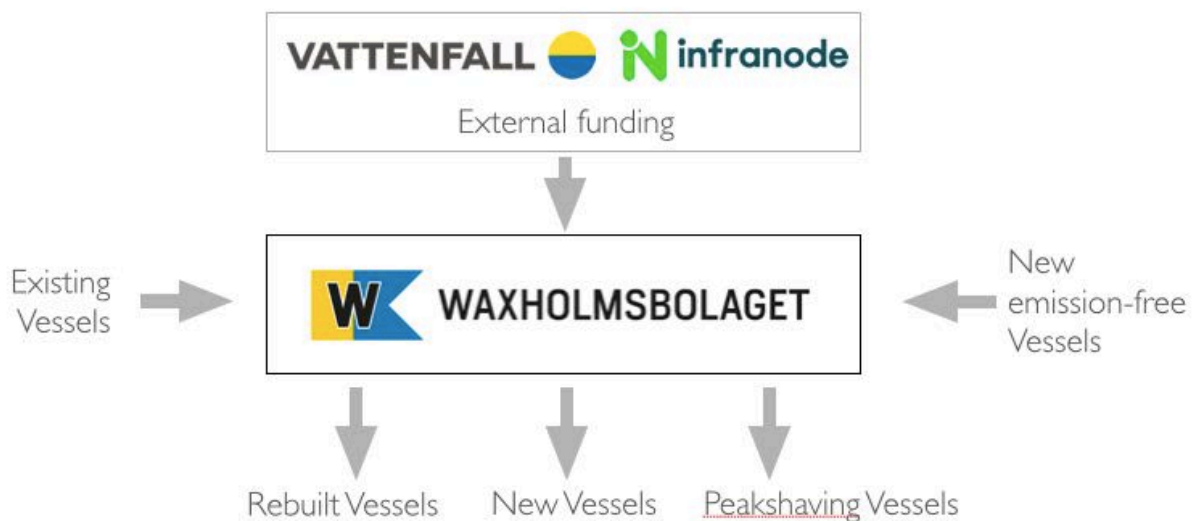


Another advantage is that competition between shipping companies can be maintained and even increased; shipping companies which do not have the financial resources to invest in new electric or hydrogen-powered vessels need not be eliminated but can compete when public tenders no longer requires the shipowner to own the vessels. This approach reduces the risk that only large players can participate in future procurements.

Procurement of vessels is thus separated from the procurement of traffic, which makes the processes easier and with the possibility of having a short-term rather than long-term contracts, while the long-term responsibility for the fleet is maintained.

6.3 Waxholmsbolaget's role in the new infrastructure

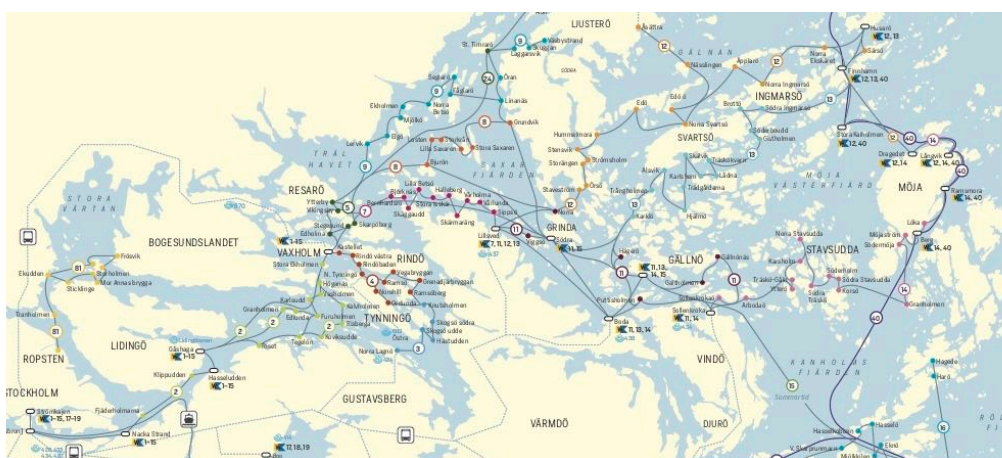
Waxholmsbolaget's main task will be to provide a climate- and environmentally friendly fleet of vessels that corresponds in the long term to the transport needs in the Archipelago. For this, the company purchases new emission-free vessels and also existing vessels that shall be retrofitted. Waxholmsbolaget's second task will be to optimize the fleet with respect mainly to costs for capital, operation, maintenance and cabin factor, which requires close cooperation with the Transport Authority.



7 Start of the transition towards 2025

Awareness of the climate change and environmental impacts has increased considerably in recent years. Continued diesel operation will face increasing public opinion and increased restrictions. EU President Ursula von der Leyen recently announced a € 750 billion investment to be used for rapid recovery after the Corona shutdown, focusing on climate and sustainability, particularly in the transport sector and Europe's Green Deal. In particular, it mentions the focus on the production and use of modern and environmentally friendly vessels, which will create new ⁵ jobs.

It is therefore important to get started quickly with the transition of Stockholm's archipelago traffic and not get stuck with investments in yesterday's technology. In the following, some suggestions are given on how and where to start the transition.



7.1 Electric drive plus HVO (Biodiesel)

The Archipelago fleet currently uses HVO to 20%. The disadvantages of this is continued environmental impact, high cost and the risk of shortages. Today, Sweden uses 35% of the world's supply of HVO but accounts for only 3% of Europe's operating volume and in case of shortage, it has to return to fossil diesel. HVO should therefore only be used where it is most needed, and this applies to the historic vessels and peak-shaving vessels. The transition to electric and hydrogen operations should get started as quickly as possible.

7.2 Electrification of the ferries in Hammarby Sjöstad

Hammarby Sjöstad has attracted a lot of international attention and many visitors come from other countries to study the energy-efficient buildings. In the middle of Sjöstaden on Hammarby Sjö, two old diesel-powered ferries operate with harmful emissions. Retrofitting these into electric power can be made at a marginal additional cost for the City of Stockholm, which in this special case is responsible for ferry traffic.

⁵ Ursula von der Leyens speech https://ec.europa.eu/commission/presscorner/detail/en/ip_20_940



7.3 Ropsten - Storholmen

The route is an extension of SL's line 80 and is served by two vessels that are 47 and 118 years old respectively and which burn about 500 000 liters of diesel every year. A battery-powered high-speed vessel could replace these two with essentially the same timetable at a lower cost than today. In addition, travel time would be shortened. Charging station would be located at Ropsten.

This can be done within the framework of the existing agreement with the shipping company that operates the traffic.

Exchange 2 vessels for 1	Option 1		Option 2
Ropsten - Storholmen	Kung Ring	Ballerina	BB Green 24
Capex Vessels (20 years)	1 Mkr	1 Mkr	4 Mkr
Capex Charging station + batteries (10 years)	0 Mkr	0 Mkr	1,6 Mkr
Energy (20% HVO)	2,8 Mkr	2,1 Mkr	1,1 Mkr
Crew (2 persons)	1 Mkr	1 Mkr	1 Mkr
Maintenance	0,3 Mkr	0,3 Mkr	0,1 Mkr
Other	0,5 Mkr	0,5 Mkr	0,5 Mkr
Total per ferry	5,6 Mkr	4,9 Mkr	8,3 Mkr
Total per option	10,5 Mkr		8,3 Mkr

7.4 Ålstäket - Stockholm

The Transport Committee (politicians) in Region Stockholm has decided to start a commuter boat line from Ålstäket on Värmdö to Strömkajen on a trial basis for two years with new vessels. Electric power would be appropriate, but it requires charging infrastructure. Procurement process has started.

Region Stockholm has here to decide whether the new traffic will be carried out with yesterday's technology or whether this route will mark the start of the Region's transition to an emission free Archipelago fleet.

7.5 Ljusterö - Husarö

Hydrogen as a fuel is becoming commercially viable for vessels. In Norway, hydrogen vessels are being built and new public tenders require either battery or hydrogen operation. In Stockholm, there is now an initiative to build a wind and solar power-driven hydrogen production facility in the Archipelago and hydrogen is already available to refuel vessels.

Region Stockholm has here to decide whether the new traffic will be carried out with yesterday's technology or whether this route will mark the start of the Region's transition to an emission-free Archipelago fleet.