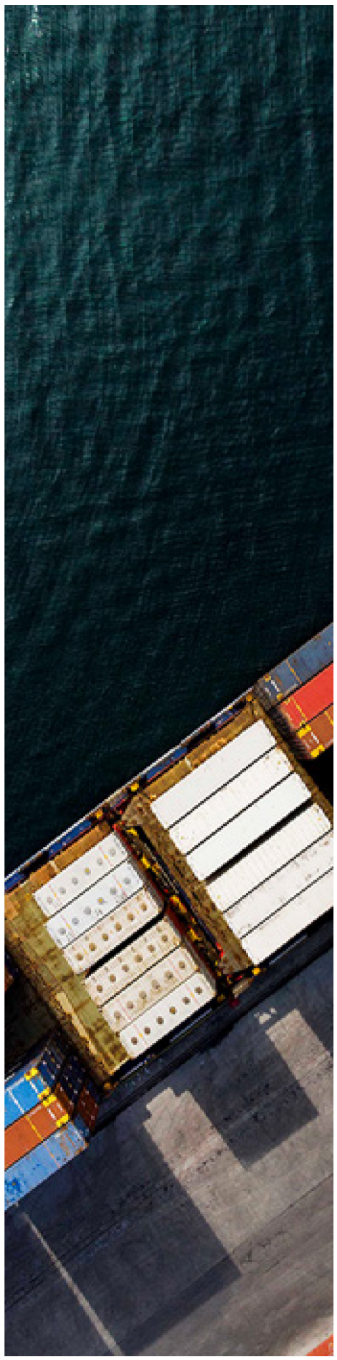
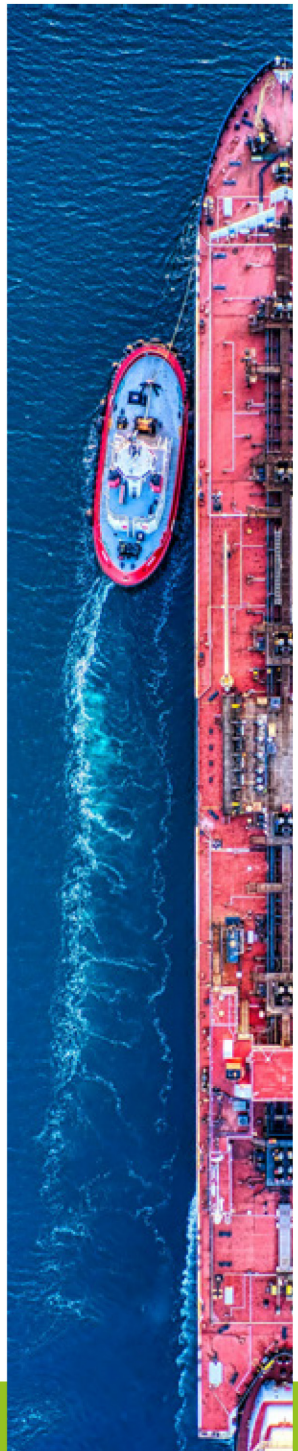
SETS II



Electrification of
Scandinavian ports
- an Interreg project



Final report

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund

EUROPEAN UNION

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We would like to express our deepest gratitude to all interviewees and partners who participated in the project.

About this report:
This report is the final conclusion on the Interreg Project SETSII – Skandinavisk Elektrisk Transport System. Despite the partners and Interreg have been very consistent on utilizing our native languages (Danish, Swedish, and Norwegian), we have chosen English as the language of dissemination, as we consider some of the findings relevant outside the Scandinavian Kattegat and Skagerrak (KASK) region. Further it can be used as inspiration for other ports within the European region, as shore power has shown to improve the environmental footprint from the vessels staying in the ports. The findings will serve as inputs for the partnering ports and as a documentation of the project outcomes for others. The statements herein do not directly represent the direct or affiliated partners views.
For more information visit: https://interreg-oks.eu/larkannaoss.656.html or https://www.sets-kask.eu/

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Contents

EXECUTIVE SUMMARY

Scandinavian Electric Transport System II

The SETS II project facilitates a faster conversion to sustainable electrical operations in the ports of the Kattegat-Skagerrak Region.

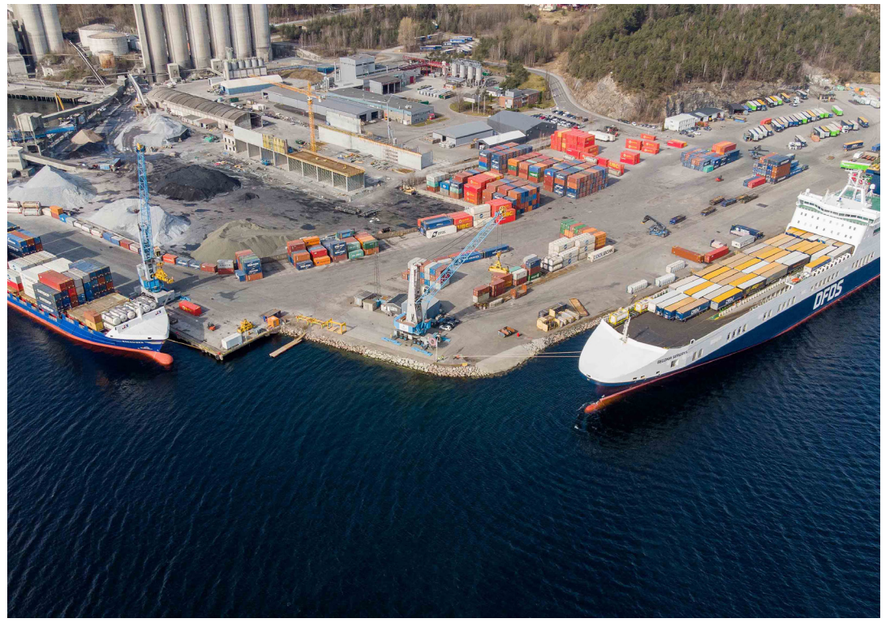
It aims at ensuring a green and flexible energy supply in port areas and a reduction in CO2 and particle emissions. The regional ports will be models, which can further contribute to the promotion of a full-scale sustainable transport system in the cross-border region.

SETS II promotes cross-border and cross-sector cooperation in the region regarding new methods, approaches, and solutions related to port electrification. Cooperation has been conducted across university environments, public actors, business promotion organizations, local authorities, utilities, advisors, and private companies.

The project supports ports in preparing electrification plans with an accompanying strategy for implementation. It focuses on electrification and potential battery operation in maritime areas as well as technical service, business models, and financing models.

Main results and learnings form the project:

- Shore pilot power installations leading to a reduction of CO2, reduction in particle emissions, noise reduction, final gain for ship owners, and a better environment for local citizens
- Mapping energy flows leads to a better understanding of the need for Energy Management Systems and electrification action plans supporting the ports' green transition
- A plan for dissemination of knowledge and information and further development of the accumulated experience with green transition at the local ports, including focusing on ensuring continued sparring and development between local communities, regional and international development environments
- Higher level of stakeholder awareness about the ports' roles as multimodal transport hubs



The Interreg ÖKS Programme

The SETSII project has been co-funded by the Interreg V-A ôresund – Kattegat – Skagerrak Programme (2014-2020).

The cooperation programme set off to addresses the most important cross-border challenges linked to the implementation of the European development strategies in the dynamic cross-border region between Norway, Sweden and Denmark.

Some of the priorities of the programme has been aiming at contributing to green growth by increased production and use of renewable energy, by improving and extending distribution networks, by promoting innovation in renewable energy, and by decreasing energy consumption in the public sector. In the area of connectivity, the programme has been focusing on improving the connection of the regional transport corridors with the TEN-T network and supporting the TEN-T network with sustainable solutions.

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PARTNER PORTS

Scandinavian partner ports in Denmark, Norway, and Sweden

This chapter presents all the partnering ports in the SETSII project [1] within the Interreg öks portfolio [2]

As illustrated, the ports are positioned around the Kattegat-Skagerrak (KASK) region in Scandinavia. The ports have been engaged with in the time period between 2019-2022. This will be reflected in presentations of each port. The chapter presents the ports alphabetically according to the countries where they are location, Denmark, Norway and Sweden. The Danish and Norwegian ports are part of the Jyllands corridor, enabling the transportation of goods and passengers in the region.

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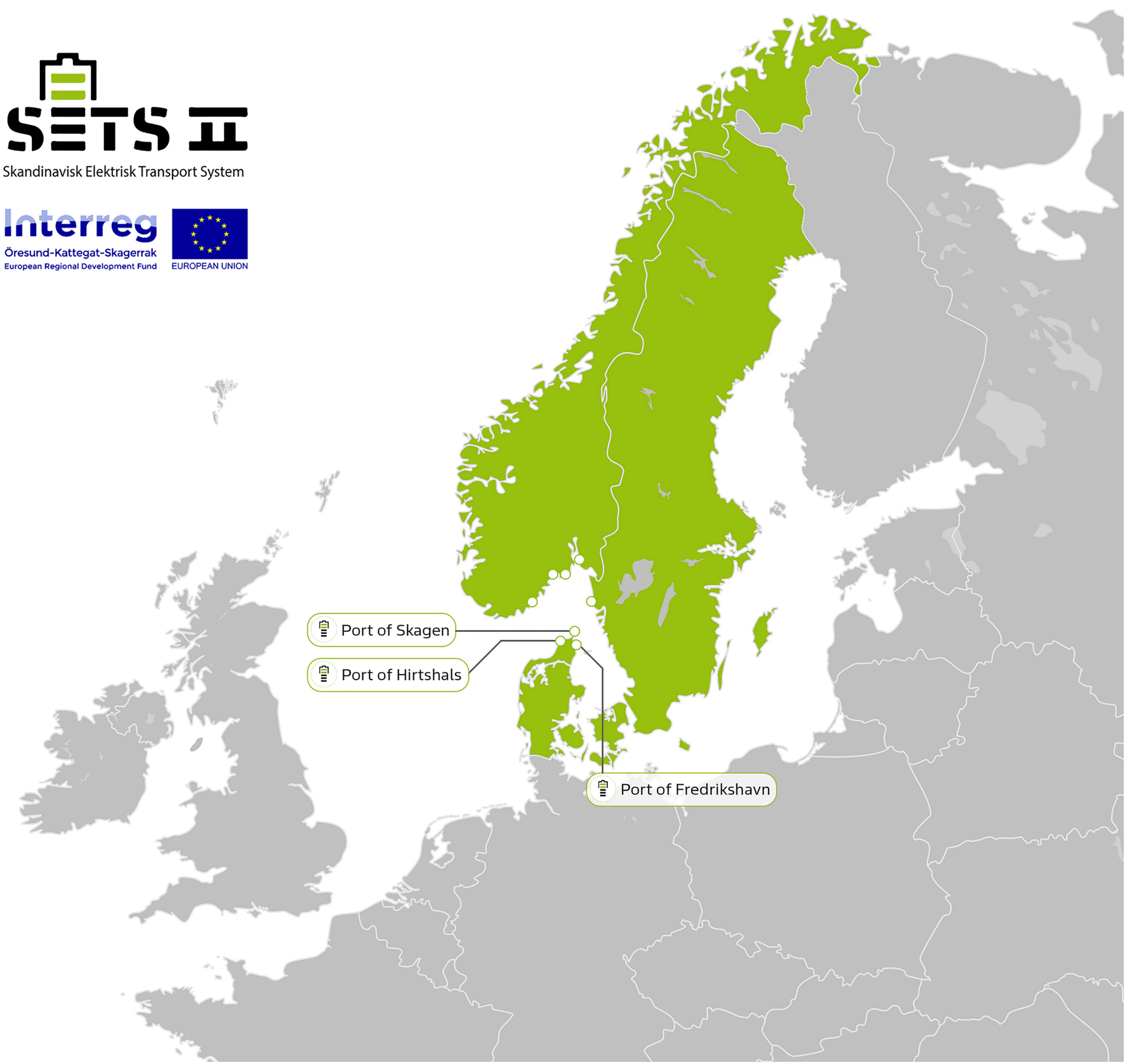

PARTNER PORTS

Partner ports of Denmark

The Danish partnering ports are Frederikshavn, Hirtshals, and Skagen, as illustrated they are all positioned in the of north Jutland, with ferry routes connecting them to both Norway and Sweden. The Danish ports are regulated by Havneloven [3] defining the organizational ownership and responsibilities with intention of following local and EU-regulations.

PORT OF FREDERIKSHAVN

Port of Frederikshavn is located in northern Denmark and serves as one of Denmark's most important commercial ports.

Located between the North Sea and the Baltics, Port of Frederikshavn is next to the T-route, the world's third busiest passageway.

Currently, the port's size is 2,419,063 m 2, of which the water area is 975,500 m2. The port is currently undergoing a major expansion project, with Stage 1 estimated to add 390,600 m 2 to the port and Stage 2 is estimated to add 17,400 m 2 to the port area.

The Port of Frederikshavn has a strategic focus on tourism and ferry traffic, as well as conventional port activities. In addition to this, the port also focuses on the environment and recycling in addition to the general maritime service industry. The harbor hosts five ferry berths and three ro-ro berths.

On 1 January 2014, the port changed from a public limited company to a municipal self-governing organization. The board consists of seven members. The port is 100% shareholder of FH Ejendom A/S.

The Port of Frederikshavn has experienced great progress and success and hosts approximately 100 companies. Due to this growth, an increase of capacity is needed. This increase will allow larger ships to use the harbour, thus the need for larger quays and water depth.

PORT OF HIRTSHALS

The Port of Hirtshals was initially proposed in 1804 as a way to bring a new transport route between Norway and Denmark, and the location was chosen due to the need to bring economic relief to the area. However, the port was not realized at that time due to the technical needs of the construction project. In 1917, The Ministry of Public Work began construction on the port. Since then, the port has grown over the years while experiencing economic and political growth and setbacks.

Port of Hirtshals has an area of 1,100,000 m^2 with a water area of 465,000 m^2. The road and quay is 330,000 m^2. The port has two ice factories, four ferry berths, two ro/ro ramps, one slip ways, and one floating dock. The port sits on the motorway and has train access at the port. The water depth is up to 10.5 meters deep in the port basins, and the quay length is 4.7km.

The Port of Hirtshals is a commercial port that focuses on transport, fishing, and maritime service. The port sees approximately 2.02 million tonnes of cargo volume annually. In an average year addition to this, the port hosts 760.000 cars, 2.200.000 travelers, 150.000 lorries 768,000 travelers, 152,000 lorries, 307,000 cars, and has a turnover of approximately 76 million dkk annually. Since 2021, the Port of Hirtshals has been a part of TEN-T ScanMed Corridor as Comprenhensive Network Port

Port of Hirtshals is located in northern Denmark and only about 20 minutes from shipping lanes between the UK, Scandinavia, and the Baltics.

In 2001, the Port of Hirtshals underwent one of its largest transformations. On January 1, 2021, Hirtshals municipality became the owner of the port, buying the port from the Danish state for approximately 115 million dkk. The port has its own board of directors, which consist of both political and business members. The port is managed by its own organization and employees, who manage the day-to-day activities of the port. Furthermore, there is a User Council that works in close dialog with the port organization.

The port sees itself as responsible for economic development for northern Jutland, and in order to do so, the port has set several goals it sees as milestones for successful economic development. This includes expanding ro/ro traffic, expanding general cargo transport, and increasing the amount of dry and liquid bulk transported through the port.

The port is also a participant in the UN's 17 Sustainable Development Goals initiative, including converting energy use to affordable and clean energy, ensuring responsible consumption and production, and developing industry, innovation, and infrastructure.

PORT OF SKAGEN

Port of Skagen is Denmark's northernmost port. The history of the harbor dates back to 1907 when King Frederik VIII inaugurated the harbor.

Skagen harbor has been expanded several times. Especially in recent times, the port has undergone significant expansions through three stages. First stage was carried out during 2006 - 2007, which led to a land expansion of 110,000-m2 port area. Second stage was executed in the period of August 2013 - early summer 2015, whereby the port expansion resulted in a wider entrance of over 250 meters, increasing the water depth to a minimum of 11 meters at the quay, 600 meters new quay and the creation of a new quay pool. The third stage was accomplished during 2020-2021, whereby 190,000-m2 expansion of new land was added to the port area, including 155,000-m2 land for renting to Business enterprises and 1,050-m quay.

The Port of Skagen is a commercial port with a strong platform of business areas such as cruise, freight, goods, and bunkering, maritime service, rental of commercial space, and fishing. Fishing is the core area of the port.

The Port of Skagen is organized as a municipal self-governing port and is owned by Frederikshavn Municipality. A port board of seven members handles the port's overall management. The port director handles the day-to-day management.
The port operates as an independent company and is separated administratively and financially from the municipality, in accordance with the legislation in the Port Act. The port invests continuously in the development of the port, including projects to improve the infrastructure and superstructure.

In 2021, the Port of Skagen prepared a strategy for sustainability, in which the port emphasized that Sustainability for the port means finding the right balance between economic, environmental, and social sustainability.

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Partner ports of Norway

The Norwegian partnering ports are Arendal, Grenland, Larvik, and Moss, except Arendal these ports are all part of the Oslo fjord climate network collaboration. The Norwegian ministry for nutrition and fishery (Nærings- og fiskeridepartementet) [4] governs the ports of Norway, with intention of efficient and sustainable port operations. Norway is not an EU member state such as Denmark and Sweden, but is part of the European free trade association (EFTA) [5] taking part in the European economic area (EEA) [6].

PORT OF ARENDAL

The Port of Arendal is a medium-sized Norwegian port, and in recent years has moved out of the city center and towards Eydehavn.

The port operations are now established in a suitable location, rigged for growth and future port solutions. Eydehavn has several comparative advantages and has strong freight growth. This will be reinforced in the coming years with the establishment of the Morrow battery factory close to the port. The freight growth through Eydehavn must be cost-effective and with sustainable solutions. The port achieves this in collaboration with others, where the solutions are universal and standardized across national borders.

If the port is to succeed with the green value creation of the future, then the logistics must be blue and the solutions standardized, both in the ØKS area and the rest of the world.

Maritime transport and ports are facing major changes, but no region, port, or shipowner can save the world alone. Community solutions and a willingness to share are the way to achieve the best solutions, lower emissions, and lasting changes.

The shared arenas (in which SETS II is included) are important and will continue to be so in the future.

The ports' traditional role as only a place for transshipment between sea and land is changing. New tasks are added without the current tasks disappearing. The ports have become both freight and energy hubs - supplying transport with clean fuel and energy solutions. Land power is important, but the production and supply of alternative zero-emission fuels is also crucial. Maritime transport and ports will play a decisive role in achieving international ambitions and national obligations relating to future sustainable transport.

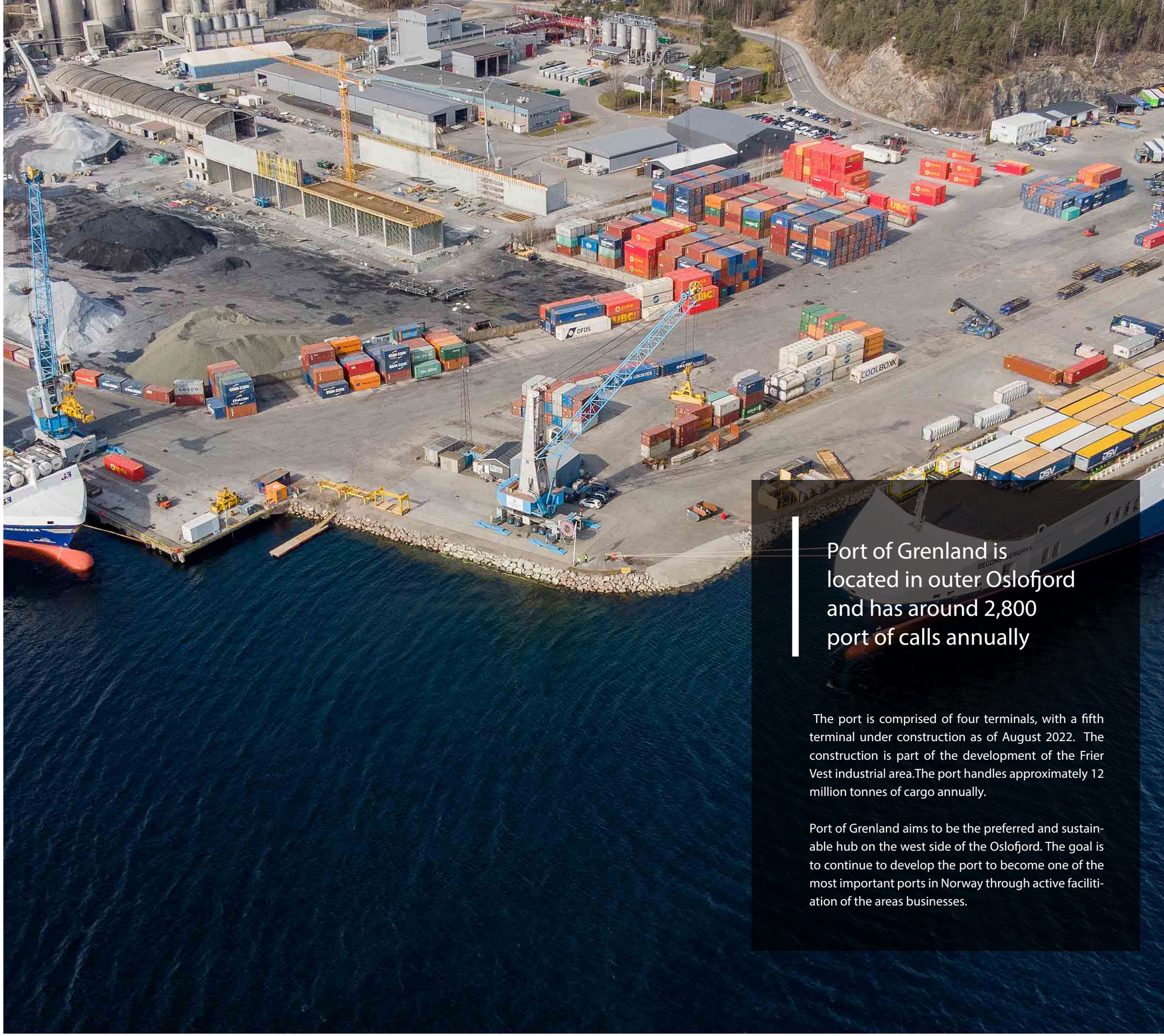
The ports' role as an important tool for new industrial establishment and value creation will be further strengthened. The regions that have efficient and sustainable ports will be the most attractive for new businesses.

PORT OF GRENLAND

Port of Grenland aims to contribute and transform the transport sector by emphasizing sustainable development within everday operations.

Port of Grenland is situated in a location that provides access to busy shipping routes to Denmark, Sweden, the Netherlands, Great Britain, and Belgium. In addition to cargo shipping, Port of Grenland also hosts ferry routes between Langesund Ferry Terminal and Hirtshals.

The port is owned by Bamble, Porsgrunn, and Skien municipalities and has 19 employees maintaining daily activities. The port was established as an inter-municial company in 2004, and is managed by the Committee of Representatives. This committee consists of four politically elected members from each municipality, bringing the total leadership team to 12 individuals. Leading the committe is Board of Directors. This board consists of seven local business leaders and they are responsible for the overall management of the port.
Leading the daily management of the port is the Port Director. The Port Director is responsible for 19 employees and serves as the liason between the port and the board.



Port of Grenland is located in outer Oslofjord and has around 2,800 port of calls annually

The port is comprised of four terminals, with a fifth terminal under construction as of August 2022. The construction is part of the development of the Frier Vest industrial area.The port handles approximately 12 million tonnes of cargo annually.

Port of Grenland aims to be the preferred and sustainable hub on the west side of the Oslofjord. The goal is to continue to develop the port to become one of the most important ports in Norway through active facilitiation of the areas businesses.

PORT OF LARVIK

The Port of Larvik is located on the west side of the Oslo Fjord in Norway at Kanalkaia and Revet.

The port has cranes with a capacity up to 100 tonnes of lifting capacity and up to 300 meters of quays. For convivence, the port has terminal and storage facilities within the immediate area.

The Port of Larvik is a commercial port with business areas of water management, execution of service assignment of ships in Larvik harbor, operations of marinas, and renting plots, land, warehouses, and terminals to various businesses.

Port of Larvik is a municipal enterprise and employees 14 people. It is a self-financed company and operates without public contributions. The Larvik Municipal Council is the governing body and consists of nine members. The cranes in the port are owned by the port while other terminal activities are primarily completed by private companies.

Port of Larvik has a vision to be developed into an environmentally and commercially sustainable port.

PORT OF MOSS

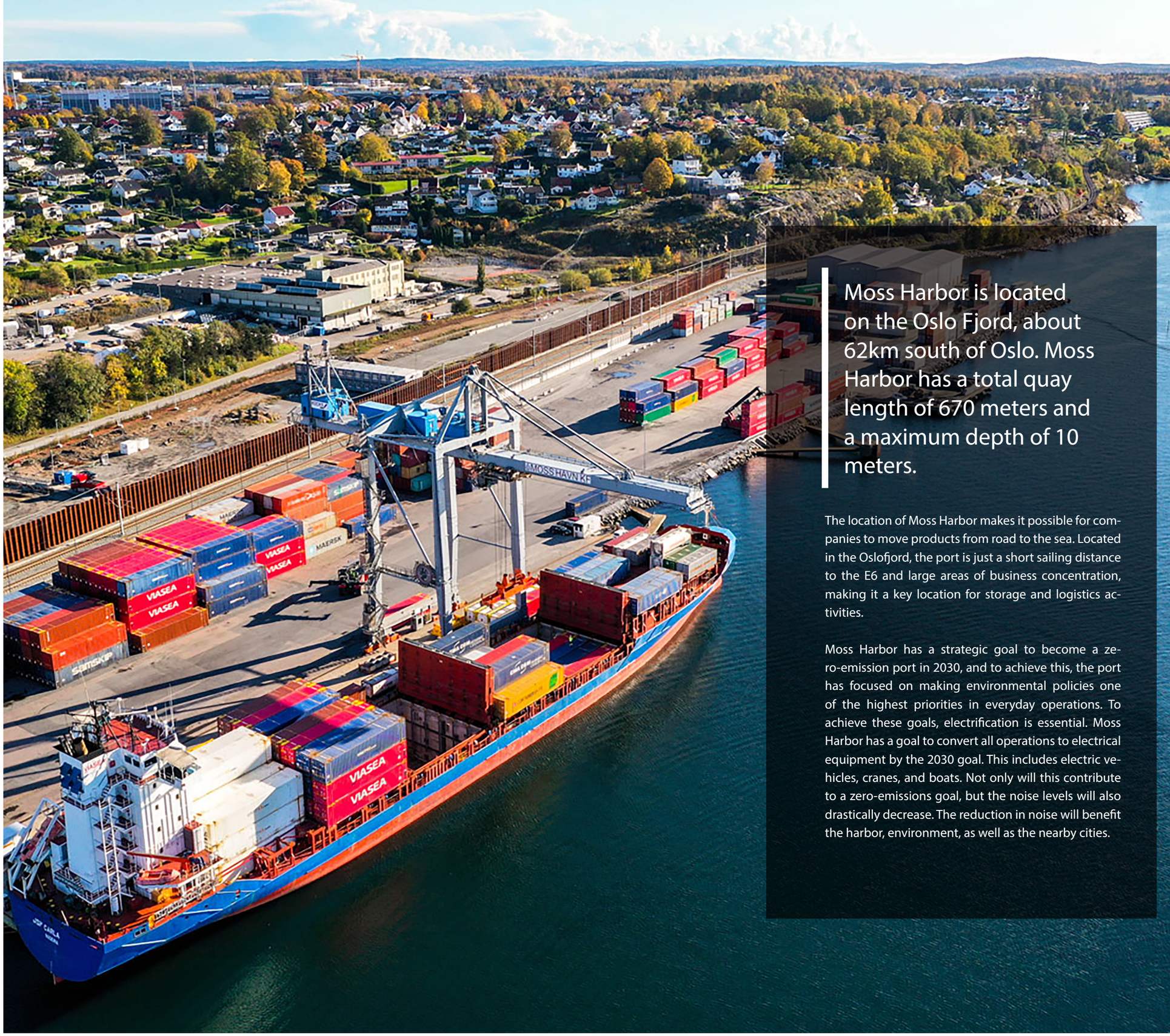
Moss Harbor is a commercial port with a focus on bringing goods from the sea to businesses on the land.

In September of 2022, Moss Harbor, along with ASKO, has become home to a new sea drone port. The drones will sail between Moss and Horten, and the drones are 100% electric. This will provide zero-emission transport from door to door, as well as sea transport around the Oslofjord area.

Moss harbour is a municipal enterprise and is owned by Moss Municipality. The port is regulated through the Ports and Waterways Act and the Planning and Building Act. The goal of the acts is to establish the best possible conditions for planning, development, and operation.

The Port of Moss has been a certified Environmental Lighthouse since 2008. Since then, the CO2 environmental footprint has been reduced every year as the share in electricity energy consumption has increased.

The port was rewarded the 2021 Climate Østfold prize due to the port's achievement in sustainable transit solutions.



Moss Harbor is located on the Oslo Fjord, about 62km south of Oslo. Moss Harbor has a total quay length of 670 meters and a maximum depth of 10 meters.

The location of Moss Harbor makes it possible for companies to move products from road to the sea. Located in the Oslofjord, the port is just a short sailing distance to the E6 and large areas of business concentration, making it a key location for storage and logistics activities.

Moss Harbor has a strategic goal to become a zero-emission port in 2030, and to achieve this, the port has focused on making environmental policies one of the highest priorities in everyday operations. To achieve these goals, electrification is essential. Moss Harbor has a goal to convert all operations to electrical equipment by the 2030 goal. This includes electric vehicles, cranes, and boats. Not only will this contribute to a zero-emissions goal, but the noise levels will also drastically decrease. The reduction in noise will benefit the harbor, environment, as well as the nearby cities.

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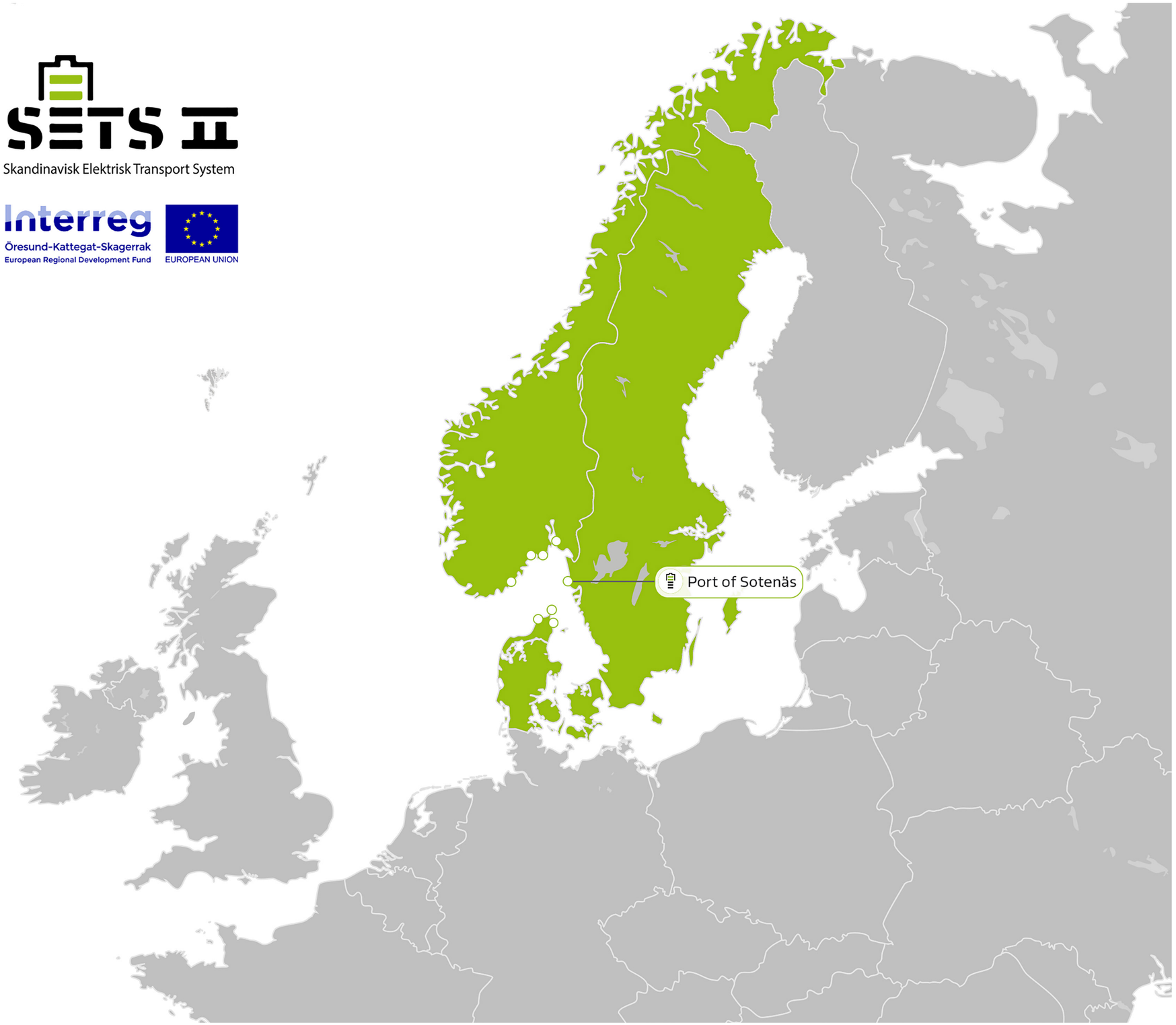

PARTNER PORTS

Partner ports of Sweden

The port is located north of Gothenburg one of Swedens largest ports. Like other ports, the Swedish partnering port Kungshamn in Sotenäs municipality is considered a small port without large commercial assets. Swedish ports it falls under the regulation of havs- och vattenmyndigheten [7] which have a strong intention of meeting the UN sustainability goals and lowering the emissions in general.

PORT OF KUNGSHAMN

Kungshamn Harbour is located in Sotenäs municipality, which is about 130km north of Gothenburg.

Kungshamn Harbour is located in Sotenäs municipality, which is about 130km north of Gothenburg. The harbour is located on the west side of Sweden in the North Sea and has a long history of commercial fishing and the fishing industry. The Swedish fishing industry is highly concentrated on the Bohuslän coast and over half of all fishermen in Sweden are active in Västra Götaland. Since a large part of the business community in Sotenäs is based on sea transport and fishing, ensuring that the ports are sustainable is seen as a significant goal for the future of the harbour.

One of the main activities at Kungshamn Harbour is tourism. However, tourism carries a large threat to the sea and costal environments. Therefore, the harbour wants to work together with the municipality, businesses, and other stakeholders within the harbour to increase sustainable tourism while creating a sustainable environment for the marine life and surrounding environment. This could include the development of sustainable boating, marinas, and the electrification of the ports.

In order to achieve the harbour's goals, Sotenäs municipality is a participant in the UN's Global Goal 14- Life Below Water, which aims to conserve oceans and seas, and only apply sustainable practices for marine sources and development. The harbour aims to be a leading player in maritime development in the use sustainable sea and maritime resources.

The municipality is also a member of KIMO, Kommunes Internasjonale Miljøorganisasjon. KIMO, which works to protect, preserve, and enhance the marine environment.

For several years, the political leadership in Sotenäs municipality has clearly indicated that they intend to work for a green sustainable transition. Sotenäs municipality has adopted goals and visions saying that Sotenäs municipality should be a leading player in maritime development, where the ports are an important part of this goal.

The harbours in Sotenäs are owned, regulated, and maintained by Sotenäs Municipality. The foundation of Sotenäs municipality's goal structure was established by the city council's vision of "The good coastal life that unites tradition, renewal, sustainable development, and faith in the future". With this vision in mind, the city council has adopted a goal to promote sustainable development from a social, economic, and environmental perspective.

The SETS project partnership provides important support in the work of the municipality.

Skandinavisk Elektrisk Transport System

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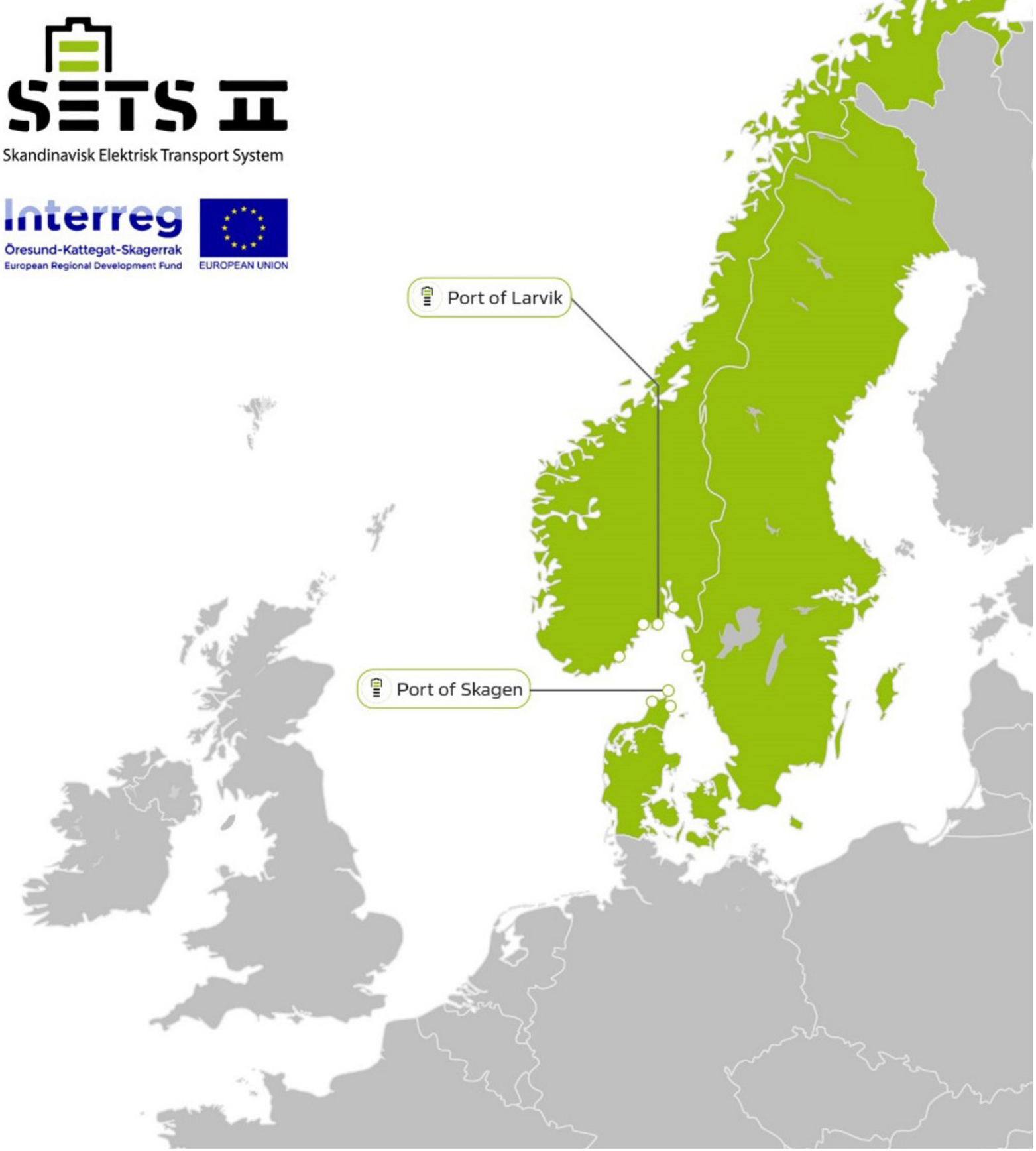


SHOW CASES

Introduction to the show cases

This chapter will provide more information around two of the partner ports, respectively Larvik (NO) and Skagen (DK), providing understanding of current status of the selected ports from an environmental and electrification perspective.

The case presentations will first expand on their conditions in following order; political, economic, social, environmental, and technological. Afterwards, a section will introduce the undergoing initiatives which the port has identified, and potentials identified in affiliation with the SETSII project. The findings are the outcome of an assessment conducted with each port. The assessment is consisting of interviews with key port stakeholders, a desk study of data (economic, technical, financial, and port related information), a walkthrough of the port facilities, and a workshop between the lead partners and the port stakeholders. The findings are verified with the workgroup and approved for publication by the port.

SHOW CASES

Port of Skagen

Port of Skagen is Denmark's northernmost port. The history of the harbor dates back to 1907 when King Frederik VIII inaugurated the harbor.

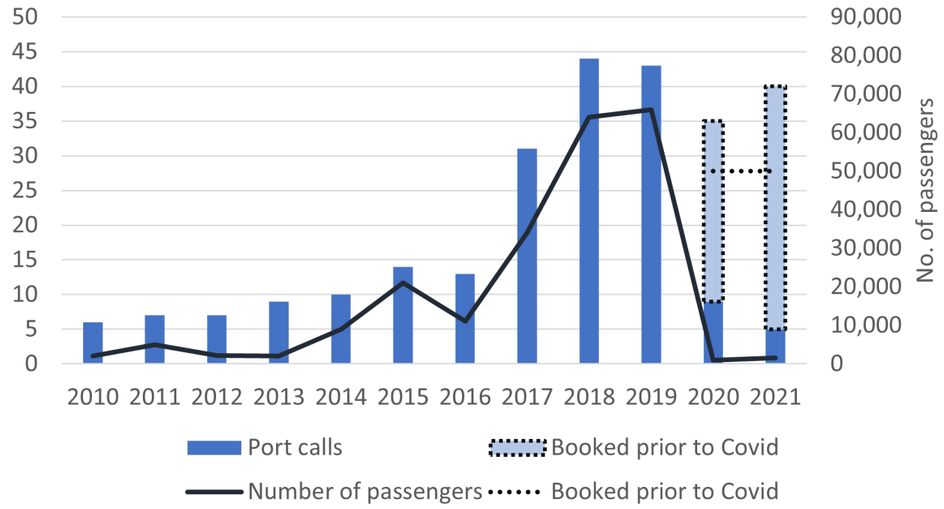
Introduction

Skagen harbor has been expanded several times. Especially in recent times, the port has undergone significant expansions through three stages. The first stage was carried out during 2006 - 2007, which led to a land expansion of 110,000-m2 port area. The second stage was executed in the period of August 2013 - early summer 2015, where the port expansion resulted in a wider entrance of over 250 meters, increasing the water depth to a minimum of 11 meters at the quay, 600 meters new quay and the creation of a new quay pool. The third stage was accomplished during 2020-2021, whereby 190,000-m2 expansion of new land was added to the port area, including 155,000-m2 land for renting to Business enterprises and 1,050-m quay.

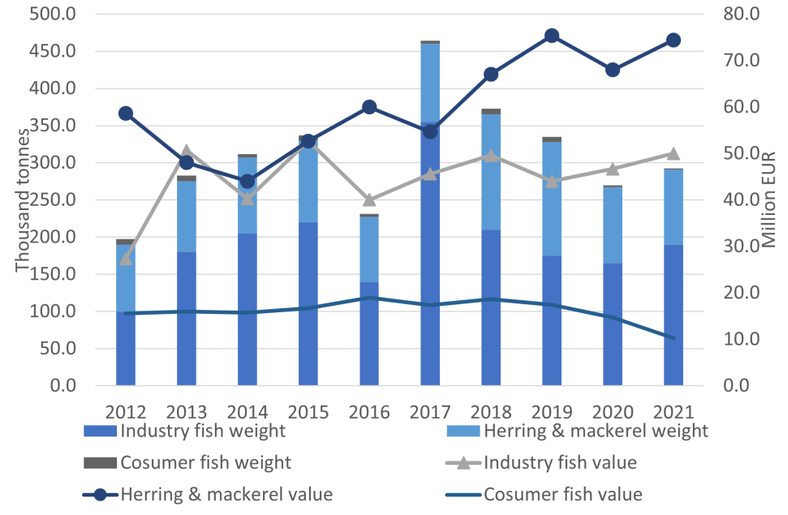
Main activities

The Port of Skagen is a commercial port with a strong platform of business areas such as cruise, freight, gods og bunkering, maritime service, rental of commercial space and fishing. Fishing is the core area of the port.

The cruise ships landing at port of Skagen was a developing industry, not only for the port but also for the city and community in terms of tourists arriving yearly on these vessels. To accommodate these large vessels, the shore power has been dimensioned to accommodate these vessels. The trendline in the figure below shows how the impact of the pandemic through the dotted lines and bars, revealing above 80 % points drop among cruise activities.



The cruise port calls and passengers from 2010-2021

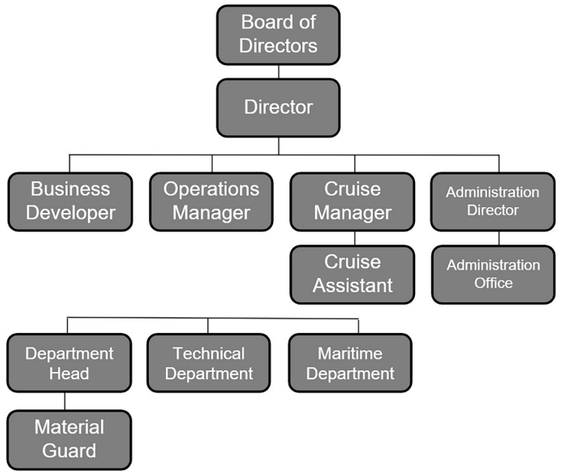


The fishing industry in weight and value from 2012-2021

The figure above shows the development of the amount of fish being landed at the port of Skagen. The fishing industry has by quantity been the largest fishing commodity since 2012 for the port of Skagen, where as herring and mackerel until 2017 was less than half in quantity but almost double in value. In 2017 the total Danish fishing export market dropped by 7% points, which is also seen reflected in the quantities of fish being pulled out of the sea. The quantities of consumer fish has had small changes in weight since 2012, despite the value has doubled since 2019, the weight has continuously declined from 7,000 ton in 2019, 2,800 ton in 2020, and 1,100 ton in 2021. Port of Skagen has for several years been landing the highest quantities and values of fish in Denmark.

Organization

The Port of Skagen is organized as a municipal self-governing port, and is owned by Frederikshavn Municipality. A port board of eight members handles the port's overall management. The port director handles the day-to-day management.



Organisational chart for Port of Skagen

SHOW CASES

Port of Skagen

The port operates as an independent company and is separated administratively and financially from the municipality, in accordance with the legislations in Port Act.

Political

Skagen port has an independent board of directors of its own. The board consists of seven members, of which two city council members are appointed by Frederikshavn Municipality and represent the municipality as the legal owner of the port.

Frederikshavn City Council approved a holistic climate plan, which meets the UN's Paris Agreement of emission neutrality and climate resilience in 2050. The climate plan applies to the entire Frederikshavn municipality in terms of geographical area. The prerequisite for meeting municipality's climate goal in 2050 is cross-sectoral cooperation, where all sectors make their contribution to reducing the municipality's total CO2 emissions. That includes especially contribution from energy-intensive industries, including commercial ports. In 2021, the Port of Skagen signed a climate partnership agreement with Frederikshavn Municipality to contribute to the municipality's climate goals, including the execution of the port's own sustainability strategy, increased electrification of the port's operations, phasing out fossil fuels and green transition.

> "Port of Skagen has a strong focus on the UN's 17 global goals for sustainable development."

Port of Skagen has a global outlook and see itself as a part of the world outside the port area. The port collaborates with international companies worldwide. The port has projects aiming to meet all the UN's Sustainable Development Goals, SDG. SDG are integrated in the daily operations of the port through interaction with many collaborative companies. For example, exports from Skagen Harbor include over 125,000 tonnes of fishmeal annually as well as oil to more than 60 countries, where the port indirectly affects the global goal of stopping hunger.

Port of Skagen has a strong focus on the UN's 17 global goals for sustainable development. Even though Port of Skagen's daily operation accommodates almost all the SDGs, the port has prepared its own strategy for sustainability related to the certain SDGs, where the port possess special experience to make a difference in order to promote sustainability. Port of Skagen emphasizes that by having particular focus on a few of the SDGs, the port has not opted out any of the other SDGs

For the Port of Skagen, sustainability means the economic, the environmental, and the social sustainability combined with the right balance between these three elements. Based on this understanding, the port has worked thematically with the world goals and established benchmarks and ambitions that will shape the projects that the port wants to work on in the future.

Some of Port of Skagens past SDG achievements

In order to manage consumption of water and energy, a large mapping was conducted, enabling an understanding of the different potentials on the port site, e.g., exchanging light bulbs on site into LED lighting instead, reducing the energy consumption. The detailed water consumption mapping further allowed lowering of the consumption. While achievements benefitting the surrounding community and society was found through waste management initiatives, establishing weekly waste container routes and taking in fishing trawler waste, further strengthening the waste stream segregation and allowing it to be reused or recycled in increasing degrees.

The port of Skagens future perspectives on SDG

The port has further expanded their energy mapping and through this analysis, they wish to lower the energy consumption at the fishing terminal while also establishing piping solutions, allowing the transport of wastewater from the fishing terminal and factories. Again, with the intention of segregating the wastewater according to the content or process steps, it transforms these waste streams into potential resources as for instance biogas material. As part of the port expansion, they are constructing a new office building to support their expansion of operations, and to cater for the infrastructure and community, this building will be constructed as a sustainable building that is DGNB certified [8]. The decision of certifying the building under DGNB requires not only the materials to be of sustainable character, but it ensures that emissions and waste is taken in with an end-to-end perspective. These developments have been further strengthened by the port decision of hiring an individual who is responsible for the sustainability initiatives on the port.

Environmental

Port of Skagen has a very ambitious goal of being climate neutral by 2030. The Port has therefore initiated a detailed mapping of the Port of Skagen's CO2-emissions in the period from 2015-2020. The aim of this survey is to observe, whether the CO2 reduction Initiatives efforts the port initiate have reel impact on port's climate footprint continuously.

Port of Skagen

SHOW CASES

Port of Skagen

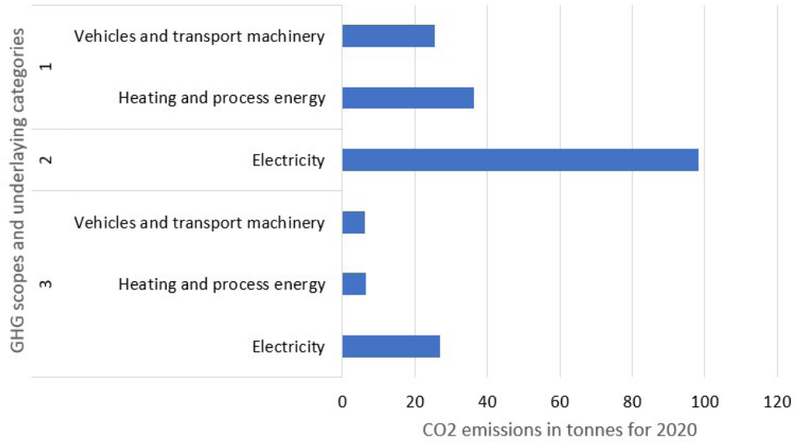
In 2020, the Port of Skagen launched a study of the possibilities for electrification of the port's eastern basins. The study was based on an analysis of the ship segments that make up the traffic in Skagen Harbor's east basins. The analysis also included assessments of the potential for the use of shore-side electricity and the visibility of the positive consequences that shore-side electricity can have for local CO2 emissions and particulate pollution, which are emitted by the ships that take up residence in Skagen Port's eastern basins. The survey provides recommendations for setting up shore power systems for the supply of various vessels.

Port of Skagen has a long history of wanting to appear as a climate-friendly and sustainable port. In 2021, the Port of Skagen prepared a strategy for sustainability, in which the port emphasized that sustainability for the port means finding the right balance between economic, environmental, and social sustainability.

Greenhouse Gas protocol

Port of Skagen applies a management tool called Climate Compass for managing its energy consumption and emissions in order to calculate its carbon footprint. The climate compass is based on the internationally recognized system "Green House Gas protocol, GHGP". The Carbon footprint is a metaphor for the total impact that Port of Skagen has on environment and the Carbon is a shorthand for all the different greenhouse gases that contribute to global warming.

A carbon footprint is thus a simple way of expressing that impact on global warming. The "size" of the carbon footprint depends on several factors.



Port of Skagen GHG measures for 2020.

The primary one is the amount of greenhouse gas emissions released into the atmosphere by a given activity.

Greenhouse Gas Protocol provides standards and tools that help countries, cities, and companies track progress toward climate goals. More than 9 out of 10 Fortune 500 companies reporting to CDP use GHG Protocol. Launched in 1998, the Initiative's mission is to develop internationally accepted greenhouse gas (GHG) accounting and reporting standards for business. The aim of the scheme is also to promote their broad adoption WRI (World Resources Institute 1) and WBCSD (World Business Council for Sustainable Development 2) to create the GHGP3 (Green House Gas Protocol) as an international standard for corporate accounting and reporting emissions, categorizing GHGs into Scope 1, 2 and 3 based on the source[9].

While the measurement actually accounts for the release of a number of different world-warming gases — like methane, nitrous oxide and fluorinated gases — results are typically expressed in terms of carbon dioxide equivalency (for example: 5 tons of CO2-equivalent). The CO2-equivalency measurement enables straightforward, apples-to-apples comparisons of activities, events, or industries that might otherwise be difficult to compare directly.

To halt climate breakdown and avoid its worst impacts, we need to shift to a low-carbon economy and protect our best natural allies in the fight against climate change. Drastically cutting greenhouse gas emissions will require, everyone — from individuals to industries to countries — to vastly reduce their carbon footprint.

Port of Skagen measures its Carbon footprint in all sources and therefore registers its carbon footprint in all three scopes under the categories shown in the figure to the left. Scope 1 heating and process energy is generated from natural gas, and the vehicles and machinery being combustion engines provides an opportunity for improving from an CO2 perspective. It is also why the port has by end of life for a truck, deciding to change it from gas to electricity. Scope 2 electricity emissions are generated from the energy distribution net, these figures are based on average emission per kWh in the Danish power generating mixture of energy sources. As electricity sales have gone up significantly since the shore power plant was installed, this is anticipated to grow. Scope 3, here again the electricity generates the larger percentage of the total emissions. 63 % of the total emissions are generated from the electricity received from the national grid, with an expectation of it to grow in the same rate as the popularity of the shore power.

F/N Voyager in the Port of Skagen

The shore power installation at Port of Skagen

Social

Port of Skagen attaches great importance to social interaction with the local community. For example, the port is exploring the potential for value creation for the local community through its new investments, e.g., in addition to the port extensions, the port has established a new beach promenade and fishing platforms that will be to the delight and benefit of the city's citizens. The port strives continuously to ensure public access for the citizens in the port area, as the Port of Skagen and the city of Skagen are very closely connected, which is clearly reflected in the port's location in the center of the city.

Port of Skagen has the will to be accessible to the city's citizens as much as possible. In addition to the relative free public movement of the port area, the port makes its areas available for a wide range of cultural events, such as the Skagen Festival and the Skagen Marathon. The port has taken these actions in order to give citizens and visitors a positive experience at Port of Skagen.

In the same way that the close connection between the city of Skagen and the Port of Skagen gives rise to a large number of synergies, the Port of Skagen is also aware of the environmental impacts that may be associated with the port's operations. Such interdisciplinary considerations have been found vital for the transition and deployment of green technologies [10]. which is reflected in the analyses of all the case locations, respectively. The port wants to work with the local community to find solutions that can reduce potential impacts.

Technological

The port continuously invests in the development of the port, including projects to improve the infrastructure and superstructure.

The Port of Skagen operates with an energy registration / management system, in which all types of energy consumption are registered on a monthly basis. The total energy consumption is divided into areas of application. The port also has a waste management system in which different segments of waste are sorted and treated, in accordance with current laws on the ports' waste management. The Port of Skagen reports its waste management to the Danish Environmental Protection Agency once a year.

Initiatives

During SETS II project collaboration, Skagen expressed a desire to establish a standardized environmental management system in the near future. Based on this, the WP-responsible prepared introductory material for the Environment Management system according to ISO-14001. The introductory material contains a presentation of the individual components of the ISO system, including guidance, requirements specifications, maintenance and development of a tailor-made standardized management system.

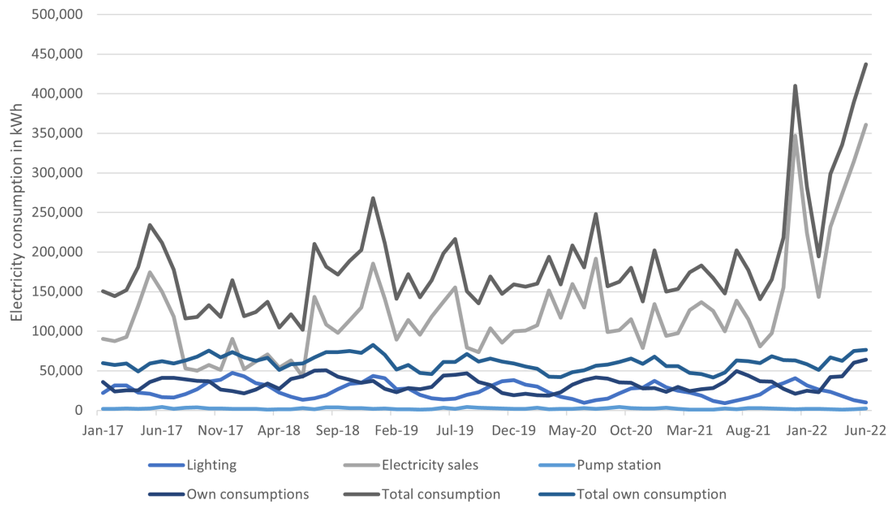
Port of Skagen is aware of its impact on the environment during the port's daily operation. The port also attaches great importance to environmental considerations, when investing in new facilities, or in connection with port's various expansion planning. Port of Skagen has taken several initiatives for energy savings, rational energy consumption and noise reduction in the port area.

Shore power initiative

During the project period, the Port of Skagen has succeeded in establishing land connection facilities so that fishing vessels are offered power shore electricity supply when staying at the quays. Meaning that in 2021, a brand-new shore power facility was established in port of Skagen. It is the most flexible shore power facility around the North Sea, being able to supply up to 10 vessels simultaneously with individual set voltage and frequency. This means that the vessels can switch off their diesel-powered engines, or auxiliary engines, while it is at berth. It saves the environment from CO2 emissions, harmful particles and noise from vessel engines. Furthermore, it allows for strategies following the design principles of utilizing the clear relationship between electricity prices and green electricity in DK1, as expressed in Roungkvist and Enevoldsen [11] and Schütz Roungkvist, Enevoldsen [12].

One of the users, the fisher vessel Voyager states the following around why they have switched to shore power "*Our main reason for using the shore connection was the reduced cost of keeping the vessel while it was not being used.*" He continues; "*And there is also the benefit of decreased maintenance costs on our auxiliary engines onboard due to decreased running hours.*" According to the port of Skagen, F/V Voyager stayed at their port for 51 days, when calculating the environmental impact, moving from utilizing auxiliary diesel engines to shore power instead, Voyager has saved 8.750 kgs of CO2 and 1.120 kgs nitrogen oxides (NOx). The total reduction of CO2 and NOx corresponds to a car engine on gasoline running 67.830 kilometres equal to 1,5 times round the planet.

The availability of shore power has also proven to be of interest among other vessels using the port, which the figure below shows, as the peak in electricity sales for 2022 in June has already reached above the total electricity sales for 2021. Interestingly enough it is also possible to see that the consumption estimates used for dimensioning the electrical system were overestimates, as they accounted for the vessels to have every electrical system running constantly. Which would be the case for a vessel running on auxiliary gensets, as this guarantees a good fuel efficiency on the gensets compared to if you lowered the vessel electrical load. But with shore power, it has proven to be the opposite, because the vessels are seemingly more aware of what they use electricity for.



Port of Skagen electrical consumption (January2017- June 2020)

Port of Skagen

SHOW CASES

Port of Larvik

The Port of Larvik is located on the west side of the Oslo Fjord in Norway at Kanalkaia and Revet. The port has cranes with a capacity up to 100 tonnes of lifting capacity and up to 300 meters of quays. For convivence, the port has terminal and storage facilities within the immediate area.

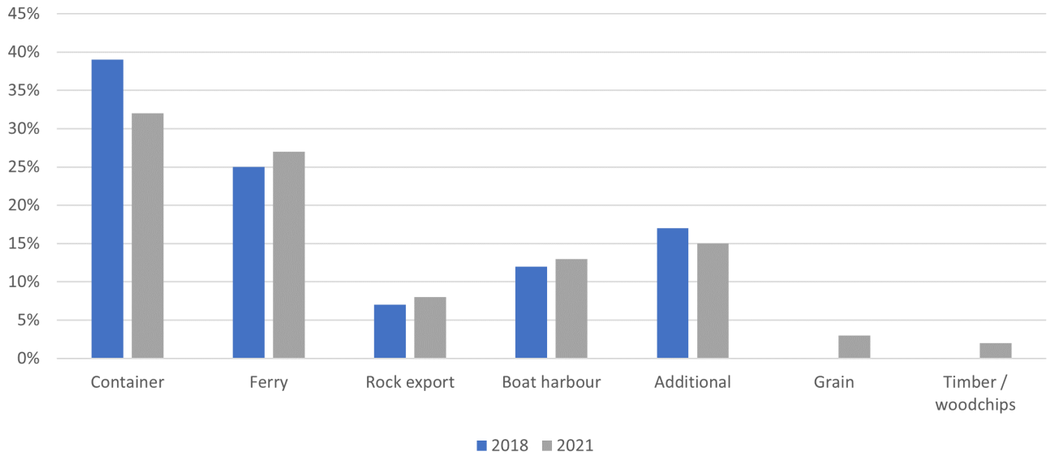
Political

The port of Larvik is a public company without subsidies, owned by the municipality, operating under the national law for harbours and waters (lov om havne og farvann) stated by the Norwegian ministry for nutrition and fishery (Nærings- og fiskeridepartementet) [4]. The law encourages an efficient operation of the port infrastructure with considerations of safety and environmental protection, further stating that all ports have a duty to receive vessels unless these are deemed a potential security or environmental risk.

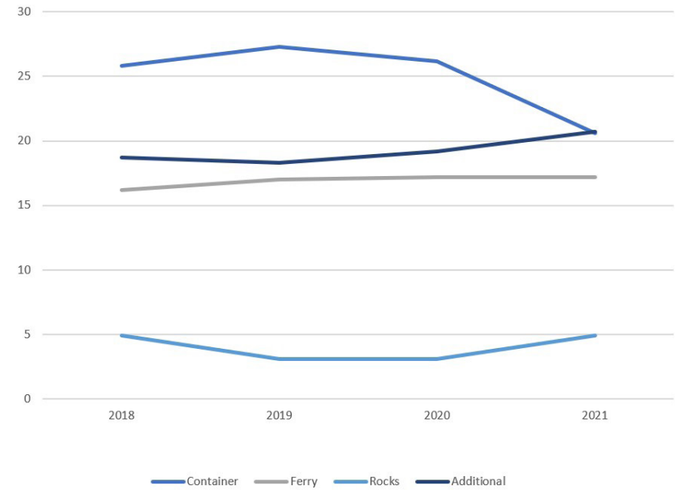
Economic situation

The port of Larvik has an average yearly income of 60 million NOK, arriving from four main revenue streams; Container terminal, Ferry operations, Rock export, and additional, which covers the port tenants e.g., the expanding timber export which also the trend lines in the figure reflects. The container operations were changed during 2020 going from approximately 80,000 TEU to 50,000 TEU. This yearly reduction of 30,000 TEU was the result of a political decision for the area, as the commodity was being transported by road to Larvik from the Grenland area and now instead will be loaded and shipped from Grenland, saving the 30 km road transportation. The ferry operations remained constant, despite of the pandemic in 2020.

The graph reveals the development of port revenue categories between 2018 and 2021. The



Revenue distributed according to categories in 2018 and 2021

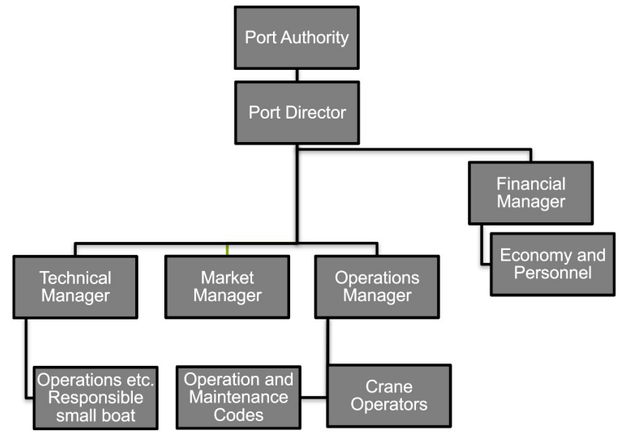


Revenue according to areas in million NOK

container terminal represents around a third of the total income, ferry operations marking a quarter of the total income, while boat harbouring accounts for the rest. The additional category shows a slight decrease, this could be part of the increased tracking and will help the future understanding of how the income categories have developed. The timber export of 2 %, and another 3 % related to grain witnesses to this development. The rock export is seemingly consistently contributing with 7-8 % of the total income.

Organization

The port employs 14, four of these being the management team. The operation organization for port of Larvik is illustrated in the figure, with a board of directors including the municipality (havnestyret), a port director (havnedirektør), a technical manager (teknisk sjef), a marketing manager (markedssjef), and financial manager (økonomisjef). The technical manager also holds the position of operational manager (driftssjef) organizing all operational and maintenance tasks such as craning.



Organisational chart for Port of Skagen

"The municipality and port of Larvik has a strong focus on the UN's 17 world goals for sustainable development and supports all the world goals."

Social Sustainability goals

The Port of Larvik has ensured that their strategy plan focus on following sustainability goals, the port identifies it can impact before 2030. These goals are:

SDG 7: Sustainable energy
In agreement and collaboration with other ports around the Oslo fjord, Larvik port will focus on the environment through shore power for the vessel fleets.

SDG 9: Industry, innovation and infrastructure
The port wants to be a regional spear in intermodal transportation, in order to achieve this, they will focus on expanding their container and sea freight business. Thereby contributing to the reduction of road transportation and emissions.

SDG 11: Sustainable cities and communities
As the port is centrally positioned in the city centre, they need to collaborate to find solutions that not only ensures that the port of Larvik will become more sustainable, but also contribute to the city as a good place to live. The increasing electrification of the terminal operations at the port of Larvik and smaller freight operations are seen as an important part of the environmental protection in the city and area surrounding the port. Electrical autonomies vessels as part of shorter feeder routes will further support reducing the road transportation. Another action identified is digitalization of surveillance of port assets and activities, enabling further focus on sustainable operations.

SDG 12: Responsible consumption
The port of Larvik intends to reduce its generation of waste, both material and immaterial, through a change a of attitude, control, and active choices as part of their ISO 14001 certification process and maintenance. Seeking to use fossil free vehicles and environmentally friendly materials for boats, recycling of these generated waste streams. It intends to work with their administration of chemicals, materials, and other substances, which become actual waste following regulations and frame agreements, further expecting the digital surveillance to be part of their energy consumption in and around their assets.

SDG 13: Climate action
As part of the Paris agreement, Norway has confirmed to reduce emissions with 55 %, formerly 40 % from the climate negotiations 2019 in Madrid before 2030. The maritime industry is part of the pollutions and emissions, the ports of Norway unitedly and independently have to continuously work for green transport solutions. Port of Larvik wishes to participate in the work of developing climate sustainable solutions by actively reducing emissions. One of their actions is to ask construction or facility management to transition towards emission free machinery.

SDG 14: Life in the sea
As the life in the ocean is important for Norway and Larvik, the Yrke fishermen provide food, joy and usefulness for the citizens and visitors of the city. Larvik port will be arranged to accommodate the Yrke fishermen, ensuring that the fishing is available for the people of Larvik for generations to come with a focus on avoiding pollution or contamination of the water and sea life.

SDG 17: Partnerships for Action
The port collaborates actively with other ports, municipalities, authorities, unions, academia, and organizations. Involving itself in research and innovation, like for instance the SETSII project in order to reach the sustainability goals.

Environmental

A big part of the environmental assessment of port of Larvik relates to how they see themselves managing the sustainability goals and how they action their improvements. But also shows actions made by the port to fulfil their commitment to the sustainability goals. A part of this commitment is how the noise pollution from the port affects the surrounding city and initiatives taken to reduce this.

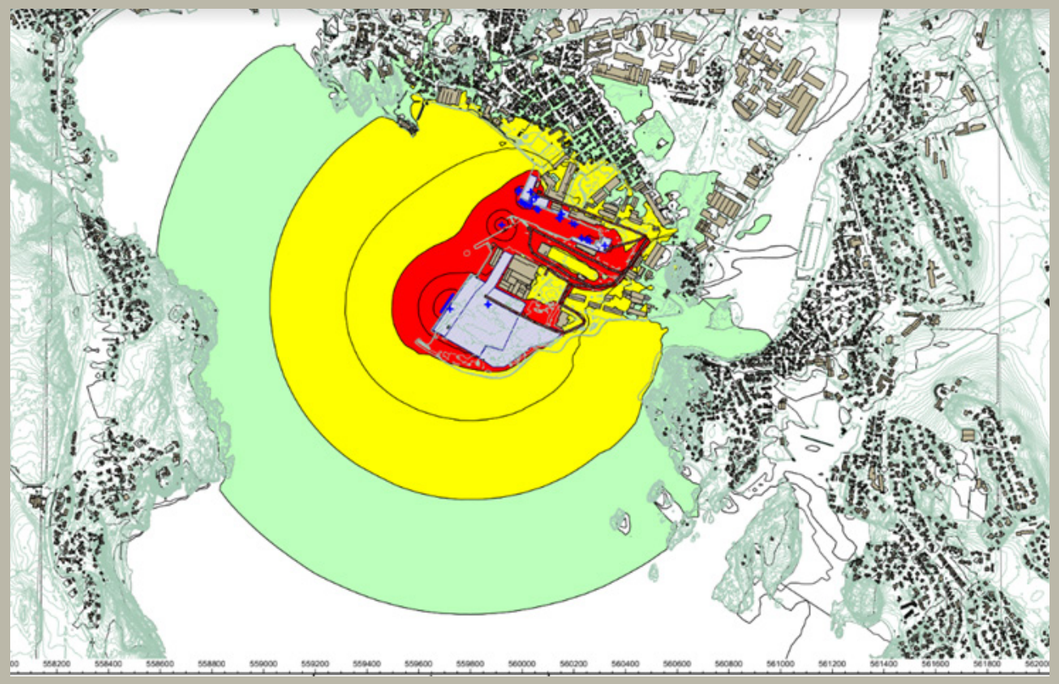
Port of Larvik

SHOW CASES

Port of Larvik

Noise measurements

The port of Larvik has experienced concerns from the surrounding society concerning their noise levels, which have encouraged the port to install multiple sound meters, providing understanding of their sound levels and how it impacts the surroundings. This could be part of why the port of Larvik has made it one of its environmental goals to reduce the air and noise pollution. The map below shows how there is a focus on measuring the noise levels throughout the year and identifying focus areas. The dB measurements furthermore can generate the following noise overview of the port and visualize the level of noise impact to the surroundings. Noise measurements similar to these contributed to the understanding of how vessels mooring in port affect surrounding environment [13], the marine mammals [14], but also provides knowledge of how mooring vessels generate noise with shore power [13], but also for when not attached to shore power [15], this also adds port of Larvik's future initiatives with introducing shore power as a mean to reduce noise emissions even further.



Overview of the port of Larvik, with their noise level quartiles, red being area of occurrence and

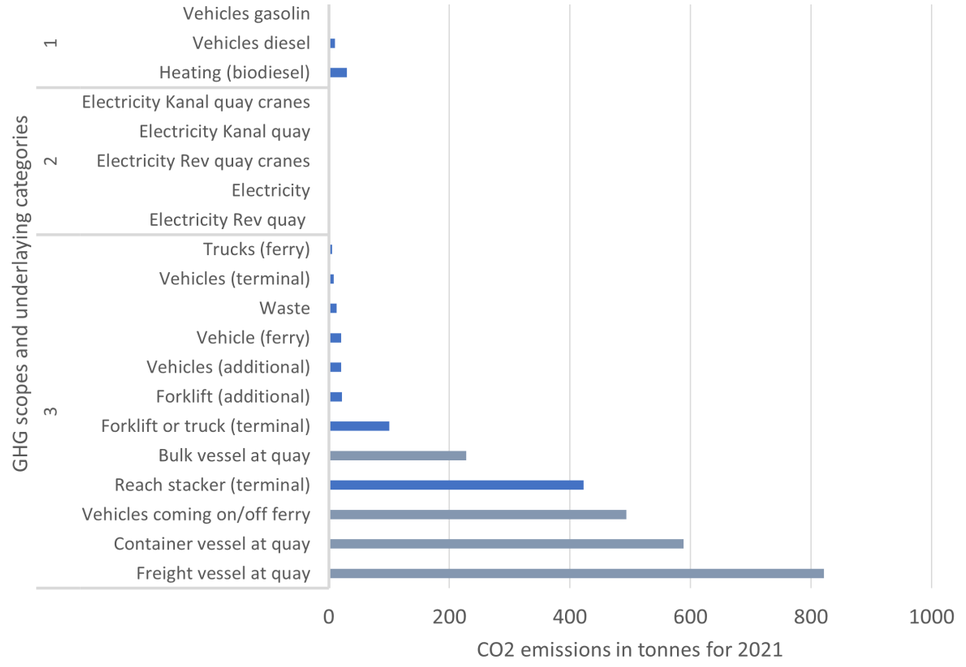
Changing the container spreader as a noise reducing initiatives

This initiative to reduce the noise from port operations and container movement required the purchasing of a Stinis Spreader, with the Shock absorbing system (SAS) included, reduces the noise from connecting with containers. This prohibits the loud noise from impact and release of the container hooks, but also prevents the beam from bouncing, allowing up to 50m/min in landing speed. This system was in place before the db measuring campaign begun, meaning a before and after does not exist.

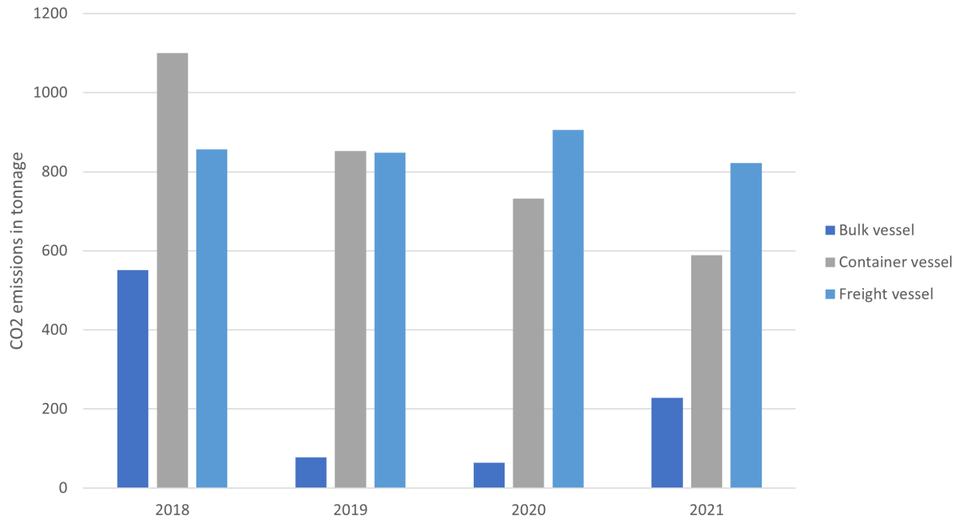
Stinis shock absorbing system
(https://www.stinis.com/unique-features/)

Greenhouse Gas (GHG) protocol

This section will show how the emissions from the various sources related to the port of Larvik divided according to the Green House Gas (GHG) protocol. The bars with blue color shows those emissions sources which the port either control or can influence, while the grey tone bars represent those emission sources that are owned by others. Scope 1 contains the ports own sources of emissions, like the vehicles used on site and the heater. Scope 2 emissions also reveal how the electricity in this particular area is estimated to generate 0 g CO2/kWh, as the distribution network is supplied with hydro power. The 0 g CO2/kWh supports the ports focus on future shore power with a direct impact to the emissions. Scope 3 includes the vehicles coming on and off the ferry which generates an average of 494 tons CO2 on a yearly basis, which with 836 thou-



The GHG emission categories



The estimated yearly CO2 emissions related to vessel type at the available quays

sand passengers in the same period is 0.59 kg CO2 / passenger. This is roughly equivalent to a driven kilometre in a city bus. On the influential side, the reach stacker emissions are a potential focus area as it is top 5 of the emissions. The largest emissions within scope 3 are the vessels when they stay anchored at the quay sides.

Scope 3: expanding on the emissions related to vessels

Further expanding on the external generated emissions, here the port of Larvik has kept a registry over the last 4 years, allowing them to understand how this has developed in this period, which is reasonable considering that these are the main emissions for the port area. Each of the vessel types are assigned to a given geographical area of the port of Larvik, meaning Rev quay handles the container vessels, Kanal Quay the freight vessels, and Svarte bay the bulk vessels. Interestingly, the average MegaWatt hour (MWh) consumption for the three types of vessels remain 1862 annually, almost with a ratio of 1:1, with the individual emissions bars shown in the figure The average annually consumptions are for:

- Rev quay (Revkaien) ~770 MWh
- Kanal Quay (Kanalkaien) ~806 MWh
- Svarte bay (Svartebukt) ~130 MWh (result from 2018 is considered an outlier and therefore removed).

This also indicates that shore power be beneficial and applicable at each port area receiving the three different types of vessels (bulk, container, freight).

ISO 14001 certification

One of the initiatives that port of Larvik has undertaken the last year, culminating with a certification in the summer of 2022, has been the establishment of the environmental management system ISO 14001[16], allowing them to further strengthen their focus and engagement around the environmental aspects of the port. Environmental management system is utilized broadly in other industries but is less used among the partnering ports in the SETS project. One of the main motivations from the port of Larvik is the expectancy of further business development and increase, making it a potential pathway for further growth. The technical manager has led the development of the management system, adapting processes and along with stakeholders generated the future action plans.

SHOW CASES

Port of Larvik

Technological

The city area develops around the port, which also means that the community comes closer. Part of the development has also led to the port relocating its office into a building positioned more central to its activities. Here will be a potential to investigate the buildings consumptions of energy (heating, electricity), water, and waste generation. Other technological installations undergoing development include the railway extension and there is further a potential for the port lighting.

Railroad extension initiative

Extending the railway is estimated to remove 800-900 trucks from the road around the port facilities yearly, not only positively impacting the environment by reducing emissions, but also opening up for new potential logistical solutions in the area and strengthening the ports connection to the inland logistical hubs. This initiative is also active steps towards achieving the SDG 9 and 13, reducing emissions and improving the infrastructure for the community. The railway operations and loading schedules have been arranged at certain times of the day to limit the noise and other effects on the surrounding community. It is also seen by the port as a part of the coming expansion with movement of office and see this initiative as a mean for generating new revenues within the coming 10 years.

Picture of the port and current railroad (provided by port of Larvik)

SHOW CASE OF SYMIOSE PROJECT

Port of Kungshamn

This show case will contain examples from the symbiose project at the Sotenäs municipality [17], focusing on changing the mindset around how waste is perceived – seeing it as potential resources, which can generate revenue not only for you but also for your neighbouring industry partners

Overview

The industrial and social symbiosis network in Sotenäs involves exchange of materials, energy and knowledge among diverse actors. The network is mainly connected to fish processing companies, biogas and wastewater treatment plant, agriculture, land-based fish and algae farms, fishing gear production and a marine recycling centre. One important part of the symbiosis development is to secure the right competence for each actor and function. The jobs created is for different grades of education and skills, so every person can become a part of the development, from beach cleaning, factory and restaurant workers, to engineers, artists, and researchers. The Centre of Symbiosis is working close with the municipal adult education and the work training unit.

Operational Highlights

As the core of the symbiosis network is working with the sea in one way or another, environmental benefits are reached on both local and international level. Research reports have shown that we reduce both eutrophication to the sea and reduce the problem with plastics in the oceans. Relationships between the actors also enable productive utilisation of various organic residue streams.

Development dynamics and enablers

The symbiosis network in Sotenäs has evolved in a facilitated fashion. Sotenäs municipality has together with local companies, academia, and other entities developed a symbiosis network with the ambition to create innovative and sustainable business environment with industrial and social symbiosis as main methodology. In order to support further development of symbiosis between actors Sotenäs Centre of Symbiosis facilitate and coordinate the development, as well as contribute with know-how, Sotenäs has established a network in the municipality which is continuously growing. It is an on-going process with lots of opportunities for further developing movements and projects. The symbiosis network and the municipality's ambitions to promote sustainability motions, also came to be main reasons for several additional companies to operate in the municipality of Sotenäs and take part in the network.

Description and ambition

Sotenäs Centre of Symbiosis shall be a leading actor in maritime development. We are an innovative hub in an environment where the human meeting is the basis for the transition to a circular economy. With the sea as the basis, we strengthen the existing business and create opportunities for new green business.

Sotenäs municipality has together with local companies, academia and other entities developed a symbiosis network with the ambition to create innovative and sustainable business environment with industrial and social symbiosis as main methodology. Industrial symbiosis is based on a model of corporativism that seeks to optimize resource flows to obtain a collective benefit greater than the sum of benefits that could be achieved individually. Waste or by-products of one is used as a resource for someone else.

SHOW CASES

Port of Kungshamn

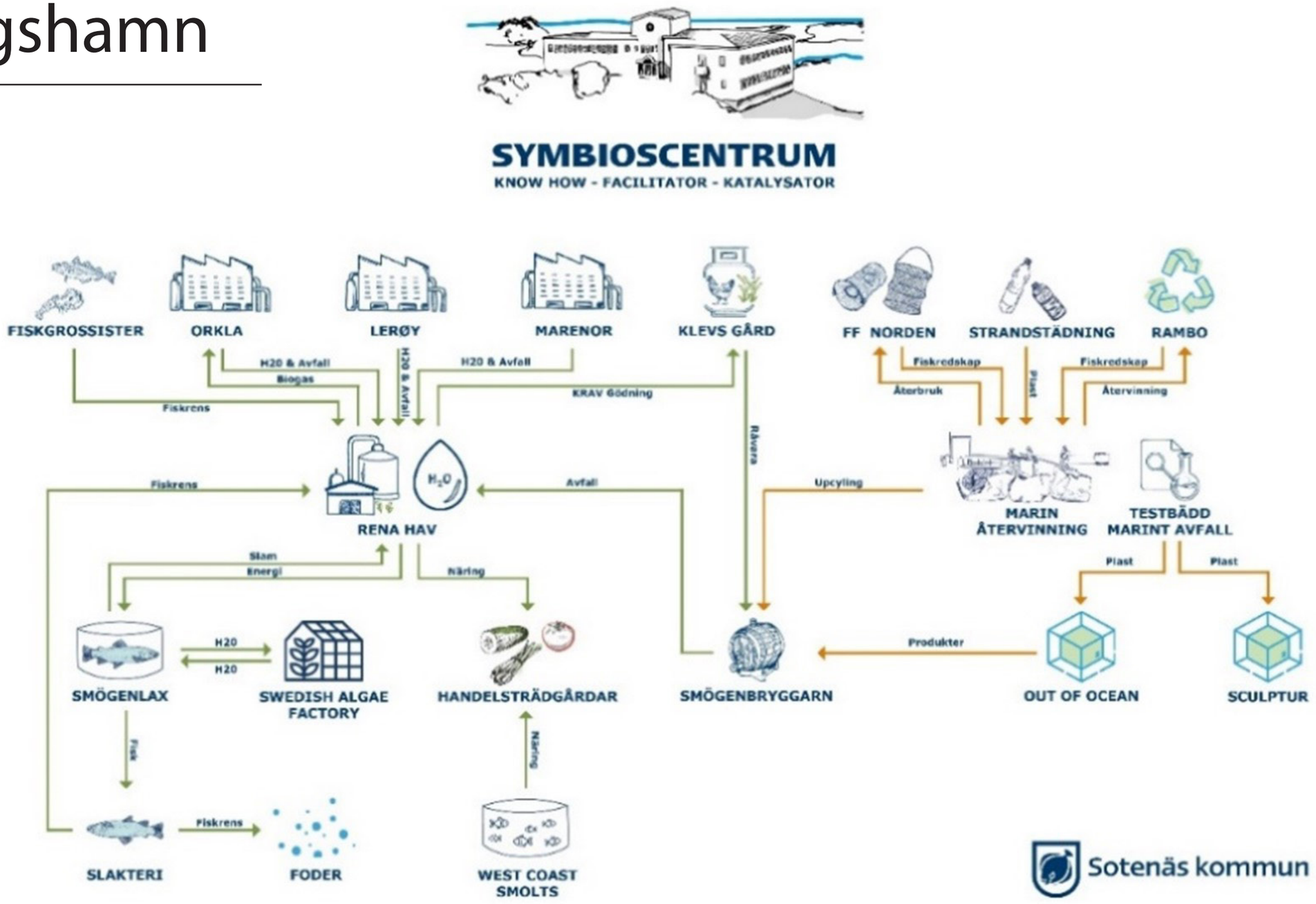
In social symbiosis, human resources are being used more efficient in collaboration, than if everyone operate for themselves.

In order to support industrial and social symbiosis between actors, Sotenäs Centre of Symbiosis facilitate and coordinate the symbiosis development. In a symbiosis network, the companies or other entities exchange competence, products, energy, services and other benefits in order to create added value and improve industrial productivity. Benefits created in the symbiosis network retained jobs and companies, reduced eutrophication and CO2-emissions as well as increased revenue and lower costs for transportation and waste handling.

The benefits in the case of Sotenäs are mainly connected to fish processing companies, land-based fish and algae farms, fishing gear production and the marine recycling center. One important part of the symbiosis development is to secure the right competence for each actor and function. The jobs created are for different grades of education and skills, so every person can become a part of the development, from beach cleaning, factory and restaurant workers to engineers, artists and researchers. The Centre of Symbiosis is working close to the municipal adult education and the work training unit.

Resources mobilized

Sotenäs Centre of Symbiosis is funded by the municipality. We work with development through several externally funded innovation- and development projects together with companies and experts in many different areas, from circular economy, plastic, business development, aquaculture etc.



The networks created as part of the symbiosis in Sotenäs

Expected impact

These symbiosis collaborations contribute to meeting societal and industrial needs more sustainably, often by creating improved value from otherwise wasted or underutilized resources. They also have significant potential to contribute to business competitiveness, reduced resource demand and environmental impact and to sustainable societal developments. These partnerships can contribute to increased business value, improved environmental performance, regional development, and stimulate innovation. It's a way to circular economy and sustainable lifecycles. In addition to more efficient resource management, symbiosis activities contribute to a better relationship and collaboration between different companies and other entities in the municipality. It has made it possible to exchange knowledge, reach a stronger economy in the municipality and region, promote sustainable behavior, create employment and contribute to innovation and research.

For the companies within the network, this means reducing the cost of resources and waste management, increased revenues when value is created from by-products and waste, and reducing the burden on one's own system. It also opens new innovative products and services and enables development work that some companies themselves have not been able to carry out. Symbiosis networks create social values between companies and open for new business opportunities.

As the core of the symbiosis network is working with the sea in one way or another, we reach environmental benefits on both local and international level. Research reports has shown that we reduce both eutrophication to the sea and reduce the problem with plastics in the oceans.

Related SDGs and targets

Mainly 9, 12, 14

Results

Sotenäs has established a symbiosis network in the municipality which is continuously growing. It is an on-going process with lots of opportunities for further developing movements and projects. The symbiosis network and the municipality's ambitions to promote sustainability motions, also came to be main reasons for several additional companies to operate in the municipality of Sotenäs and take part in the symbiosis network.

In 2017, the Swedish Environmental Institute - IVL [18] conducted an environmental and socio-economy analysis of the ongoing development. The result was that in 2022 we can achieve:

- A reduction of nearly 60.000 ton CO2-eq emissions per year
- Eutrophication impact reductions of 388 tons PO4-eq per year
- Reduction of over 19 million tonnes-km per year in transportation of wastes and other products
- Economic contribution of the network would be about 10% of the Sotenäs GDP
- 20 new companies
- 100 new or retained jobs
- Double the number of visitors to the symbiosis network
- 164 MSEK in savings on waste disposal transport compared to reference model levels

As the development is progressing, we see that these numbers are too low and a new industrial park is now under development which will be much bigger, on at least a factor 10-level.

The key factors of success in Sotenäs:

- Anchoring with local politicians and companies
- That the municipality together with local key actors visited the Kalundborg industrial symbiosis network
- Local entrepreneurship and culture of collaboration
- The skills of applying for external funding, to create projects and the network of relevant actors
- That the municipality has had the courage to speak about the symbiosis development in an early stage of the development which has attracted new actors to the network
- The skills of connecting "the right" actors to each other
- Collaboration with academia and consultants
- The local companies agreed on a common challenge regarding water treatment limitations

Port of Kungshamn

SHOW CASES

Port of Kungshamn

Why industrial symbiosis and the importance of facilitation and communication

Most of the environmental challenges the communities have faced depend on the increasing population and human activity, especially of the industrial development and the growth of industrial parks. There is a need to develop industrial parks in a way that contributes to minimal environmental impact, economic prosperity as well as local and regional sustainability. One challenge is to use their large amounts of underutilized resources. This can be achieved by creating circular models and coordinating resource exchanges in an industrial and social symbiosis. Industrial symbiosis means that actors collaborate through sharing of resources for collective benefits. Industrial symbiosis involves cross-sectoral, multi-actor collaborations enabling increased value creation from secondary resources. It is an effective enabler of more circular and bio-based economies. In a social symbiosis the human resources and competences are strengthened, in parallel as the industrial symbiosis is assured. Previous studies highlight that there is a need for a better understanding of how symbiosis networks can develop and what role different actors should take. An interesting case to study in this context is the municipality of Sotenäs, where symbiosis development started 2011 and a Centre of Symbiosis under municipal management was established in 2015. In Sweden, where the lower-hanging-fruits are mostly collected, scaling up industrial symbiosis practice, and associated benefits, requires systemic facilitation, as have been taken in to place in Sotenäs. Here, the municipality have a particularly important role in coordinating and conducting symbiosis development activities. They are an actor that remains in the long term, possesses many different functions and invests in the social benefits. Approaches aiming to increase the actor's internal capacity and engagement in collective actions are needed to develop symbiosis networks. Here, communication has proven to be most crucial. Having that said, all actors should communicate the benefits that symbiotic collaborations both internally and externally to contribute to the anchoring process as well as understanding and increasing knowledge of the subject.

Other Initiatives during SETSII Project

This section contains a combination of the projects conducted in association with the SETS project, relevant literature around the ports as part of the future green supply chain and interviews with the partnering ports around sustainability and what the future looks like.

ASKO Sea Drones

SETS II

Facts: ASKO sea drones
Length: 67 m
Width: 15 m
Loading capacity: 16 semi-trailers
Operation: Electric
Battery capacity: 1846 kWh
Operating speed: 8 knots
Saves: Two million kilometers driven annually

Port of Moss - Drone Port will open in 2022

Together with ASKO, a drone port is being built in Moss. The ASKO sea drones will be christened in Moss in September 2022 and will then be put into operation, sailing between Moss and Horten. It is ASKO Maritime that owns and have developed the sea drone concept. The entire chain of truck transport, terminal handling, and the sea drone itself are 100% electrified. This will be zero-emission transport from door to door - including sea transport across the Oslofjord.

All-electric and autonomous maritime drones can replace truck transport

ASKO is Norway's largest grocery wholesaler and part of the Norgesgruppen. With its 700 trucks on Norwegian roads, ASKO is also one of the country's largest transport companies. ASKO is now using new and innovative technology, which will contribute to developing green, efficient and sustainable goods logistics. They have established a new shipping company that will transport goods with their electric and autonomous ships across the Oslofjord.

Autonomous vessels will cross the Oslofjord between the cities of Horten and Moss

By using electric sea drones to transport goods, ASKO wants to make the entire supply chain emission-free. The sea drones will replace as many as 150 daily trailer trips between Østfold and Vestfold. The drones are 67 meters long, 15 meters wide and have battery packs of 1,846 kWh. That's enough for five hours of sailing at 8 knots. The drones will spend an hour crossing the fjord and charge for 1 hour while the vessel is loading and unloading in Horten and Moss.

A quay and terminal have been built in the Port of Moss and Horten to host the sea drones and their solutions. The port of Moss and Horten have good opportunities for development, suited for efficient and green logistics and there is good cooperation between the two ports.

Green, efficient and sustainable logistics

For ASKO, the goal is that all transport under ASKO's umbrella should take place without emissions, preferably with electricity or hydrogen, produced with renewable energy sources.

Each of the sea drones will have space for 16 standard euro trailers that are backed on board by electric terminal tractors. On the other side of the fjord, terminal tractors are ready to pull the trailers ashore. Electric trucks will transport the goods between the port, warehouses and customers. In this way, the entire transport chain will be fully electric and sustainable with 0 emission.

Port Environmental Performance Index (PEPI)

As part of the SETS project Ravn [19] in collaboration with University of South-Eastern Norway, developed an understanding of how a port environmental performance index (PEPI) could be categorized, allowing ports to see the environmental aspects from multiple perspectives and layers.

"People can't respond to information they don't have. They can't react effectively to information that is inadequate. They can't achieve goals or targets of which they are not aware. They cannot work towards sustainable development if they have no clear, timely, accurate, visible indicators of sustainable development" (Meadows [20]).

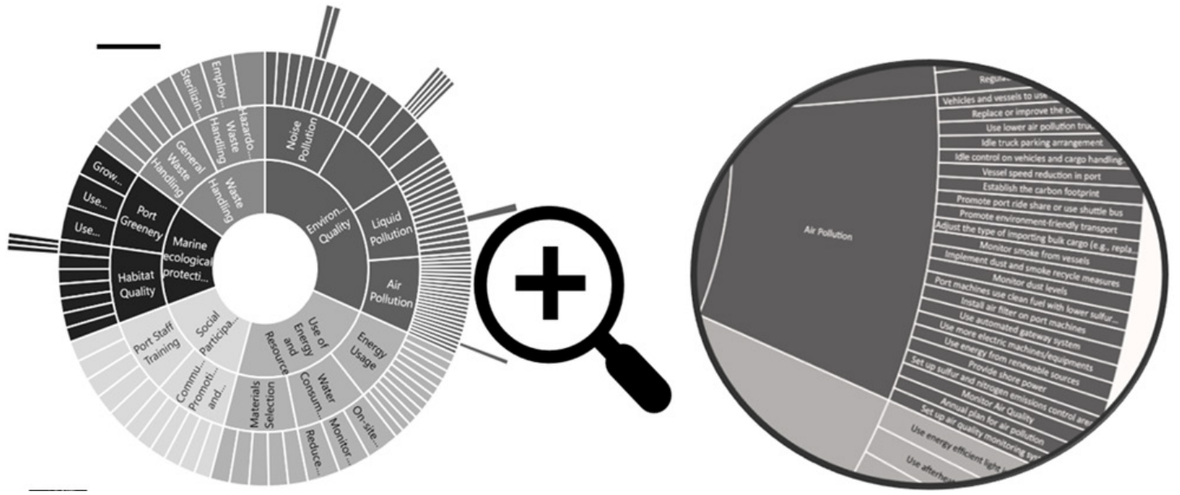
Port environmental issues are usually multidimensional and lead to difficulties for port decision makers to act based on port environmental data coming from large, heterogeneous, multi-numbered data sources. Performance measurement is critical if any organization wants to thrive, and when it comes to ports and environmental performance there is great challenges in the increasing availability of data sets with a large quantity of information, unstructured, or coded in many different features. The challenge for port management in this context is the translation of raw data into useful information that can be used to improve port environmental strategic decision-making processes, detect relevant profiles, understand relationships among operational features and detect environmental measures.

As such, integration of the heterogeneous and uncertain information demands a systematic and understandable framework to organize the environmental information and processes to interpret and use in actual port advising or decision-making context.

The PEPI model functions as an integrated port environmental indicator which can serve as a strategic tool for port environmental performance management and as a multidimensional framework for port environmental management. The PEPI model makes it easier to control and monitor the port environmental process thereby achieving the overall environmental goals of the port. The model can also be used as a specified strategic approach to guide implementation of port environmental performance measurement.

The model can be used to strengthen the ports multidimensional framework, integrated model, and the related specified strategic approach for implementing port environmental performance. The results of this model [19] can be used as an inspiration or guide for ports with similar conditions. The PEPI model is not a final development, implementation, and assessment tool, but it is a proposed framework and indicators for port environmental performance allowing for continuous improvement within the field.

The Port Environmental Performance Index is an impact assessment tool that is strategic in nature and has the objective of facilitating environmental integration and the assessment of the opportunities and risks of strategic actions in a port environmental development

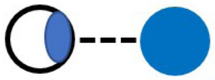


The conceptual PEPI model with the detailed actions of the element of Air Pollu-

Port-City Symbiotic Collaboration in Norway

Another master thesis conducted in collaboration with the Norwegian partner ports [21], built on the existing knowledge of how the port-city relationship has deteriorated over time since the early 20th century. The study analyzes the relationship between municipalities and small and medium landlord ports in Norway located inside or near the city center and the community. Investigating how the relationships are see how the land, pollution, social welfare, and fast-paced globalization contribute to the evolution of the port-city relationship.

The study has identified the challenges of achieving port-city symbiosis and the drivers for a symbiotic collaboration in business development and project implementation. It is crucial to have a consistent and honest dialogue, commitment to cooperation, and competent trust to create a symbiotic collaboration. Thus, exerting focus on sustainability as a starting point allows synergy. Furthermore, it builds trust among city/state politicians and the community to cooperate, openly communicate, collaborate, and be innovative in achieving port-city sustainability goals. The result of the study underline two relevant themes, i.e., areas of conflict/challenges and drivers in working symbiotically. As stated by Verhoeven [22], it requires government-owned ports' input to establish trust in sharing data or information. Thus, trust competency is vital in building the relationship between the port authorities and municipalities. The port-city relationship in Norway is unstable due to unclear communication, imprecise role awareness, failure to cooperate, political influence, land use, and environmental issues such as noise/traffic. On the other hand, it also shows that symbiotic collaboration is achievable through consistent dialogue and cooperation, a clear role, and acknowledging competence, shared vision, and sustainability as a starting point. It is relevant to emphasize that symbiotic collaboration is achievable in large ports and small-medium landlord ports regardless of whether it is commercialized or corporatized.

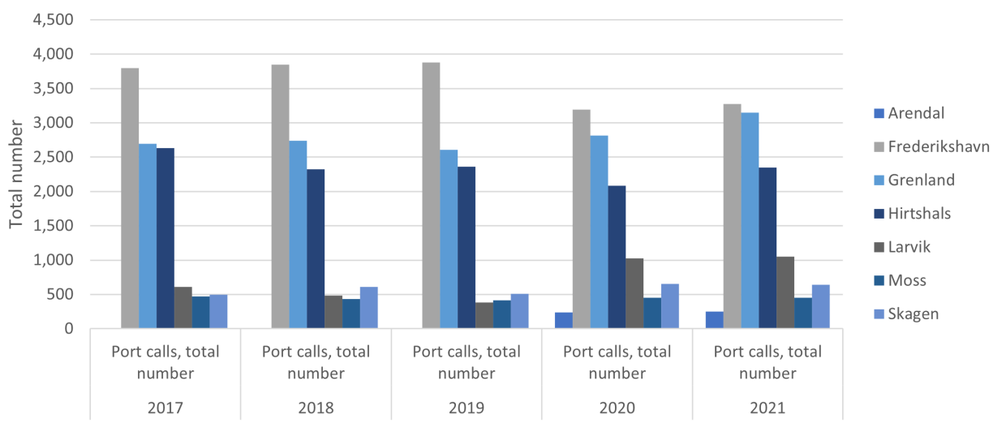
Stage	Period	Symbol (City / Port)	Characteristics
1. Primitive port/city	Ancient/medieval to 19th century		Close spatial and functional association between city and port.
2. Expanding port/city	19th - early 20th century		Rapid commercial/industrial growth forces port to develop beyond city confines, with linear quays and break-bulk industries.
3. Modern industrial port/city	Mid-20th century		Industrial growth (especially oil refining) and introduction of containers/ro-ro (roll-on, roll-off) requires separation/space.
4. Retreat from waterfront	1960s – 1980s		Changes in maritime technology induce growth of separate maritime industrial development areas.
5. Redevelopment of waterfront	1970s – 1990s		Large-scale modern port consumes large areas of land/water; urban renewal of original core.
6. Renewal of port/city links	1980s – 2000 +		Globalization and intermodalism transform port roles; port-city associations renewed; urban redevelopment enhances port-city integration.

Evolution of the port city interface adapted from Hoyle [23], [24].

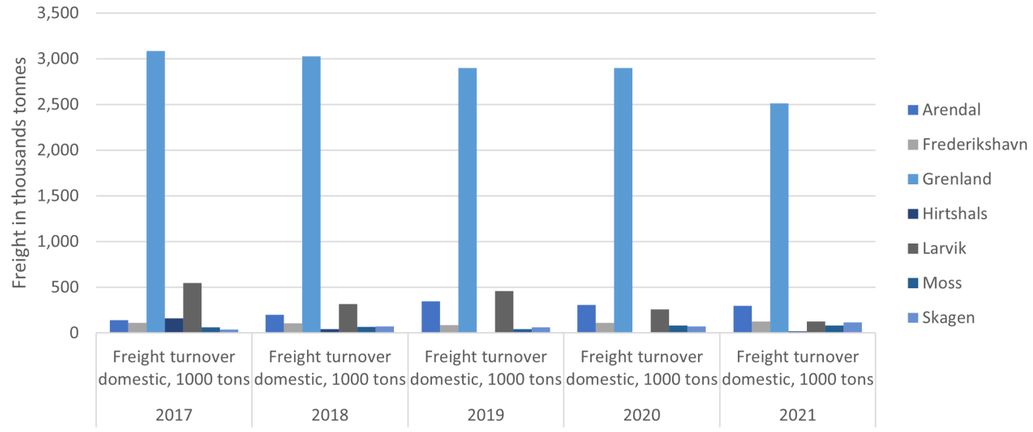
Comparison between the partnering ports

This section provides insights to the port calls, freight in tonnage, passengers, and energy consumption of the partner ports in the period from 2017-2022. For freight and passenger statistics, these are divided between domestic and foreign. The data collection was conducted through national statistical databases DST [25] for Denmark and SSB [26] for Norway, Sweden statistics SCB [27] did not contain useful data for Sotenäs, hence they are not represented in the analysis below.

The total number of port calls for each port are visible in the figure below showing the historical trends during the SETS project. Grenland and Larvik are the only ports which increased their number of port calls during the pandemic (end 2019 - 2020). Frederikshavn had the biggest drop in number of port calls during the registered period, while the national statistics only started registering port calls for Arendal in 2020 providing a limit knowledge of their development.

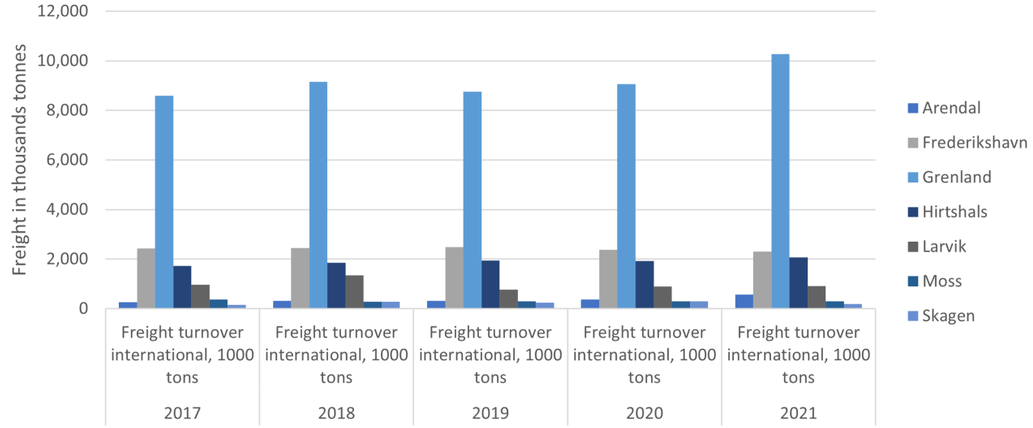


Comparing total number of port calls



Comparing the turnover for domestic freight logistic (1000 tons).

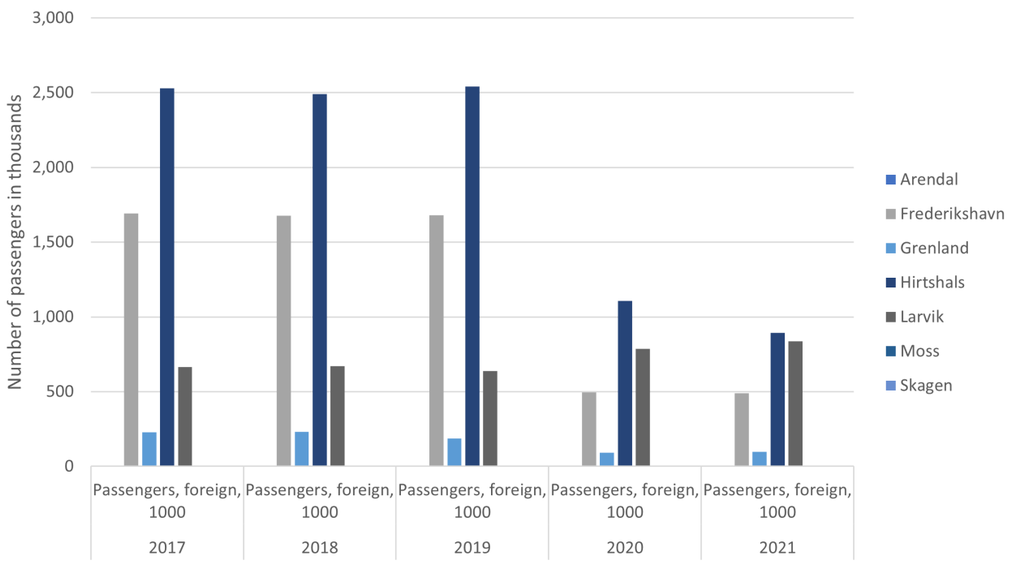
The freight turnover both domestic and international include everything not passengers, indifferent to whether it is liquid, gas or solid materials. Grenland is in terms of tonnage, the far largest domestic freight port of the participating ports, more than 6-fold larger than Larvik which is ranking second from 2017 to 2019. Then replaced by Frederikshavn from 2019-2021.



Comparing the turnover for international freight logistic (1000 tons).

The international freight shows a similar pattern as the domestic freight, Grenland has again the largest tonnage per year, Frederikshavn rank second an average of 2.1 million tons a year, and Hirtshals rank third. Larvik taking the fourth ranking position. The yearly trends are with little difference for most of the ports, while Grenland and Hirthals both have seen slight increases.

The number of passengers shown here are only related to the international or foreign passengers, as Frederikshavn is the only port with registered domestic passengers, yearly average of domestic passengers being 285 thousand. It is also apparent that the statistics for port of Moss does not account for their local ferry cross the bay area. In the figure it is also apparent that Larvik is the only port which had an increase in foreign passengers during the period of the 2020 pandemic. Identical for all of the ports is that a recovery in number passengers is still not seen. Hirtshals saw the biggest drop of 1.4 million foreign passengers in total between 2019 and 2020, followed by Frederikshavn with a 1.1 million foreign drop in foreign passengers, while actually seeing a small domestic passenger increase from 279 to 287 thousand domestic passengers. Other industries, such as the offshore wind industry highly relying on the ports were also impacted by the pandemic with shortage in deliveries [28] and limitations on their resource movements in the same period [29]. For the ports involved in this study the freight movements internationally and domestically are less impacted by the pandemic, while the lack of passengers shows similar tendencies as the labour movements.

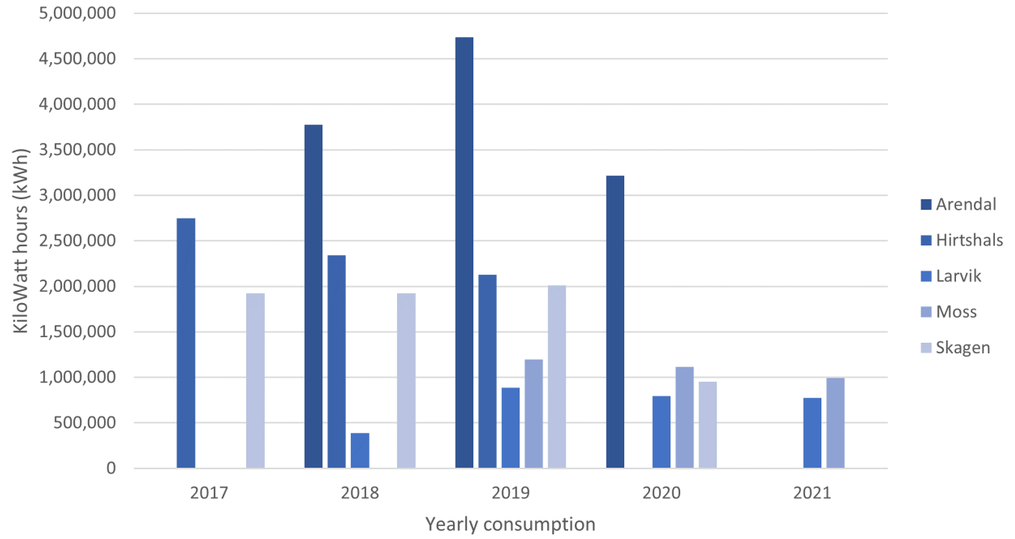


Foreign passengers in the applicable ports (in 1000).

Total energy consumption

For comparing energy consumptions among the ports, this is based on voluntarily submission, and presented in accordance with what has been provided, whether yearly, monthly, weekly or for some even on the hour. The ports included in this are Arendal, Hirtshals, Larvik, Moss, and Skagen. Ports not included are Grenland, Frederikshavn, and Sotenäs. The total energy consumptions measured across the partnering ports, reveal how Arendal (NO) and Hirtshals (DK) have the highest consumptions of energy. It is evident that despite the ports are considered similar, their energy consumptions are considerably different. This could be related to the ports not being accountable for the companies residing on the port area, meaning that they purchase their energy directly from energy utilities such as Orsted, Vattenfall, or Equinor. This comes apparent as the port of Moss introduced electrical ferries in the same period as these measures and their consumption is almost not changing. Hirtshals and Moss though both show a slight decrease of consumption over the years. For the port of Arendal their energy consumption is very likely to reflect that they provide shore power to all of its port calls and have a history of doing so, in comparison to the other participating ports.

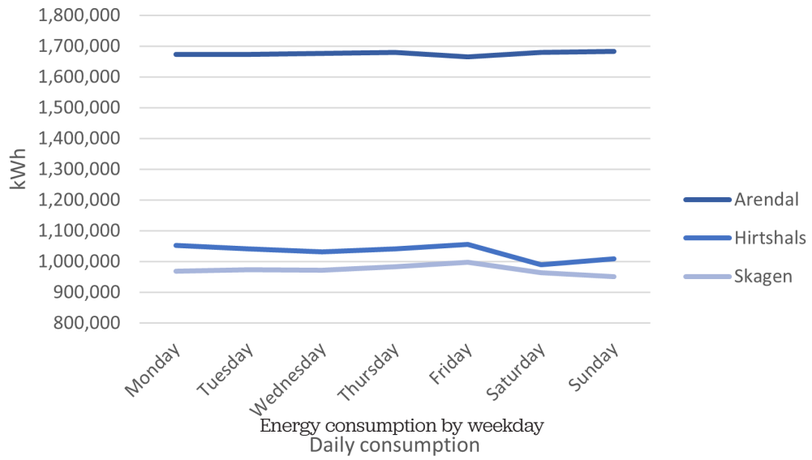
Arendal's (light blue bars) energy consumption increased notably from 2018 to 2019 but then decreased again November / December 2020. Where Hirtshals (dark blue bars) showed a slight decrease over the years. Larvik has a considerably lower energy consumption than any of the ports included.



Total energy consumption compared among ports

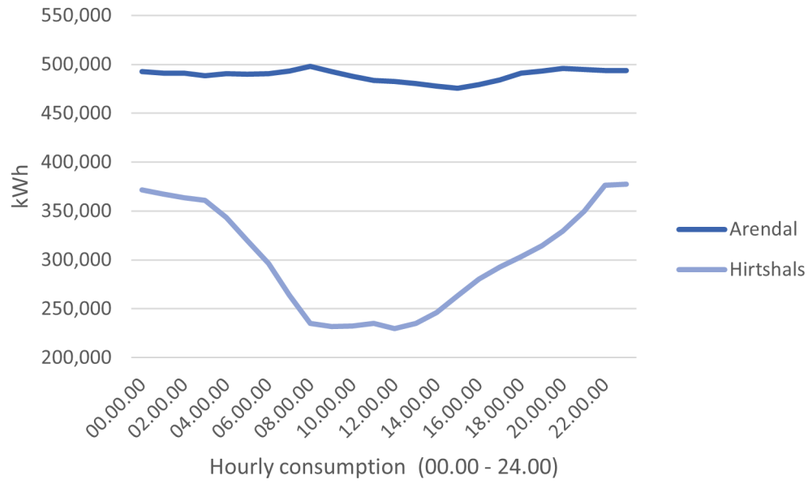
Total consumption by weekdays

Viewing the electricity consumption over a week in the figure, the trend over the week shows little or insignificant changes during the week. For Hirtshals (DK) (dark blue line) and Skagen (DK) (orange line) it is visible how there is a higher consumption on Fridays and lower on Saturdays. Arendal (NO) (blue line) shows a steady consumption throughout the week.



Total consumption by hour

The hourly consumption is not applicable for all ports, but for those where it is available different patterns are revealed. The figure shows how Arendal (NO) has a steady consumption throughout the hours of the day (blue line), while Hirtshals (DK) shows a significant decline in consumption during the day (purple line).



Energy consumption by weekday

Ports as part of the future Green Supply

The understanding of Green ports can be understood from various perspectives such as sustainable, low emission, environmental or habitat protection. Notteboom, van der Lugt [30] see the ports as part of a Green supply chain, defining the environmental concerns as integrated part of inter-organization practices for the supply chain as a whole. Outlining how they system should be designed to reduce its environmental impact through the different bullets here below, the a-e numbering is for referencing purposes only.

a. eco-design and green process engineering,
b. green procurement and purchasing
c. green production/remanufacturing and industrial ecology with minimum energy and resource consumption,
d. green energy mix, and the application of techniques for product recovery and waste management;
e. circular economy and reverse logistics, and models to share or use products instead of owning them outright,
f. environmental management systems (EMS) or “a collection of internal policies, assessments, plans, and implementation actions affecting the entire organization and its relationships,
g. green logistics, distribution and transportation

Larger ports have been following the green port bulletins for several years with various focus areas, reading Lam and Notteboom [31] will contribute to this, but also reveal how the ports in Europe and Asia are not so far apart in terms of what they consider to be a green port or its challenges. For Okada, Mito [32] a Green port means a place which maintains and protects it surrounding habitat, making sure that the eco-systems are intact. Preserving not only the water quality, but also the species living in the surroundings. But does not further expand on what that means in relation to the emissions. Part of reducing the emissions are related directly to reducing the vessel emissions while in port. This has also led to some ports and port users (vessels, brokers etc.) realising the potentials in shore power, considering how to provide enough available power from the grid side is what can become a challenge in the future also from a theoretical perspective [33]. Within the KASK region ferry owners domestically and regionally are also looking towards electrification [34], which means that some of the shore power consumptions are predictable as the time schedules provide insight to the number of port calls.

But important stakeholders in this transition will also be the utility companies, European Sea Ports Organisation [35], national and European regulators, Notteboom, van der Lugt [30] see regulators or governments as direct part of the Green supply chains transformation, holding an important role either as a potential catalysts strengthening the transition, or as a barrier in front of the green transition. Suggesting that they hold a role in informing the different actors of what is available now and in near future. From a SDG perspective, they highlight the following as relevant for the Green supply chain, Goal 7 (‘Ensure access to affordable, reliable, sustainable and modern energy for all’), Goal 12 (‘Ensure sustainable consumption and production patterns’), Goal 13 (‘Take urgent action to combat climate change and its impacts’), Goal 14 (‘Conserve and sustainably use the oceans, seas and marine resources for sustainable development’), and Goal 17 (‘Strengthen the means of implementation and revitalize the global partnership for sustainable development’).
The SETS project aimed towards understand what it would take for ports to move away from fossil fuels, towards alternative solutions such as electricity. From the Green port perspective, this affects the following topics; c), d), and g), while f) has been investigated from a research perspective, but is not seen implemented. Potential future projects for the ports could further investigate a), b), e), implementation of f), and g) which relates more to the vessels, ship brokers and owners.

Perspective on sustainability from partnering ports

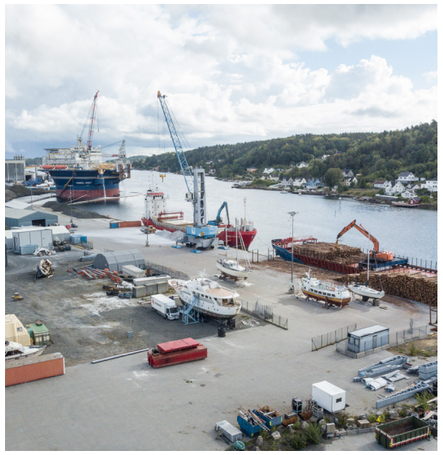
The perspectives on sustainability stems from the interviews conducted through out the SETSII project. The perspectives are provided as input or inspiration and should not be read or understood as deterministic opinions

PERSPECTIVE

Port of Arendal

Arendal Harbour has a goal to operate emissions free by 2030, and to achieve that goal, a strategy for the electrification of the port has been developed. Arendal has already achieved a step towards this goal by ensuring that shore power to all connecting ships is electric, which was achieved in 2017, becoming the first port in Europe to reach this goal. Arendal Harbour sees the business advantage as well as sustainable demand of electrification, which is one of the main motivations of the strategy. The port is also working on agreements with a factory to produce hydrogen and ammonia for visiting ships. Arendal Port has pushed the goals further compared to the city in which it is located and wants to be a fossil-free port by 2030. The port is publicly owned by the city and must consider the city's strategy towards becoming Europe's first zero-emissions city within the port's own goals and strategies. In Norway, public funds are available for organizations to become sustainable, which creates a high level of competition between cities and projects due to limited funds.

In the future, Arendal Harbour predicts that there will be local charges and fees for ships that do not connect to the shore power system, but that is only possible when more ships and ports are either electrified or operating on non-fossil fuels, while there are ships still operating on fossil fuels. Arendal Harbour has the mindset that no port will save the world alone, and all ports need to connect and have standardization processes for shore power. It is vital for all ports to be in agreement with electrification and zero emissions goals. It doesn't matter who the first emission-free port will be, but instead, it is important to know when the last port will be emission-free because that is what will save the world. Arendal Harbour is willing to take the first steps and see if the port can be the world's first emission free port. When that is said, it is important to mention that the transition will mean more expensive transportation now and in the future. The increasing cost of sea transport cannot be avoided, even if the electrification of world ports is not achieved. With the increasing cost of carbon pricing, not being green will cost ships, harbours, and businesses even more in the future. While the transition to green energy is an expensive and timely investment, the result of that investment after 2030 will be attractive to businesses and politicians.



The city leaders and national government are also supportive with the port's electrification. The city has the ambition of being the first green European city, which means the first city to operate with zero emissions. There is support is big for the green transition. Arendal Harbour acknowledges that the future is unknown, but there is a need to start the green transition early. Arendal Harbour has a system for the ships to get shore power. When a ship registers in the harbour's system, using their IMO number which acts as an identification number for the vessel and allows the port to know the exact needs of the ship every time the ship visits the port.

PERSPECTIVE

Port of Hirtshals

In recent years, Hirtshals Harbour has taken on an initiative to optimize the sorting and recycling of waste in order to reduce costs and add convivence for incoming ships. The waste that is collected and sorted includes food waste, operational waste, oil residues, fishing waste, and electronics. This green zone allows the port to recycle reusable material in daily port activities. Additionally, the harbour strives to minimize the emissions from daily processes even though there is not a big production. As the amount of waste increases with more harbour traffic, the waste and recycling procedures will be able to grow exponentially due to optimizing the current process as efficiently as possible. Fuels for the harbour vehicles now run-on Gas to Liquid Fuel which generate less CO2 emissions. Additionally, the harbour utilizes electricity generated by the solar panels that have been installed on top of onsite buildings. Hirtshals Harbour has focused on optimizing the harbour's own water and electricity consumption and has expanded that focus to other users of the port. The ongoing evaluation of consumption patterns is leading to the harbour being aware of usage patterns and can proactively reduce water and electricity consumption when excessive usage is identified.

Hirtshals Harbour has created shore power for smaller ships and is currently available in about half of the harbour. The next big project is to create shore power for the other half of the harbour to accommodate larger ships that use the port. To maximize the value of this transition, the harbour has a close working relationship with different types of vessels and shipping companies to discover precisely what is needed for shore power. The companies see value in creating a sustainable future, so the time and money invested into this transition is favoured amongst the harbour's partners. Hirtshals Harbour has started a company that will continue to development the transition to sustainable energy. The port has decided that it must be the greenest port and be able to use the resources that they have in the most effective and sustainable way.

Hirtshals Harbour is owned by the municipality, which has a strategy for how they want to develop the city and surrounding area. The harbour is part of that strategy despite being a self-governing port. The municipality in which the harbour is located has a long history of being sustainable and has created a culture around the surrounding nature.

PERSPECTIVE

Port of Grenland

The port of Grenland is located in the municipality of Bamble but is owned by three municipalities: Porsgrunn, Skien, and Bamble. All three municipalities are present at meetings concerning the port's activities. The three municipalities work together to elect the port's board of directors, which is comprised of members of the local community who work in finance and other businesses. Grenland Harbour has two terminals, one of which is Brevik Terminal. Since 2004, Brevik Terminal has been under one of Europe's strictest noise requirements.

Grenland Harbour intends to grow in size and capability in order to create a better framework for the industry, both regionally and industrial wide. In order to do this, the harbour is focusing on optimizing land use and infrastructure. As a result, the harbour has purchased and now controls Astalsstrand, an area near the harbour known for summer houses, totalling around 400 acres. This is only the start of the harbor's ambition to purchase more land and become an attractive area for international industry and commerce to invest. This is part of the Invest in Norway project, or Innovasjon Norge.

Since 2008, Grenland Harbour has been environmentally certified according to the ISO 14001 standard, which is one of three ports in Norway as of 2022. Due to this certification, the harbour is required to communicate with external parties about the various requirements of the harbour to maintain the certificate. As business and traffic in the harbour as increased over the years, so has communication between the harbour and associated businesses. This has resulted in a higher level of trust between the harbour and partners, leading to a positive reputation in which other ports see Grenland as a role model and often asks for advice about noise problem tactics at the terminals.

PERSPECTIVE

Port of Moss

The port generates their own income and does not receive funds from the government, an example of this is a business development firm "Moss Næringsutvikling AS" and Moss Harbour owns 1/8 of the company along with Sparebanken, Moss Municipality, and Våler Municipality. Despite having ownership in the business development firm, Moss Harbour does not have a defined role in business development in the area. Instead, the harbour provides infrastructure to the area in connection with the local railway, which allowed Europris to establish themselves in the area.

Due to the municipality involvement with the harbour, the harbour has different sustainability requirements set by the different municipalities. However, the businesses that are being establishing at the harbour also come with an interest in sustainability. Because of this, the harbour is convinced that electrification is essential and will soon lead to a competitive advantage in the area. When the harbour is able to generate enough electricity to cover all the equipment in a plot, the plot will become more attractive to businesses needing to establish themselves in the area. Despite Moss Harbour being situated on an area of over 520 acres, the harbour only owns 20 acres. Their angle is that there is no need for the harbour to own these areas in which the harbour is developed. The Harbour has decided that the owner of the land is not important, but instead, the value creation is the same and other plot owners benefit from its location near the port. Instead of focusing on owning and controlling land, the Moss Harbour is focusing those funds on other projects and letting private owners control that plot of land in the harbour area.

One of the features that is making Moss Harbour so attractive is their drone project for ASKO, which will allow goods to travel by drone around the fjords. In addition to the drones, the harbour is introducing electric trucks, which will possibly outcompete the Eastern European lorry industry by using public transport at sea and zero-emission transport on Norwegian land. The harbour believes that despite this costing more, the attractiveness of using sustainable transport will be enough to create the foundation for this venture.

Green conversion of commercial ports, summary and conclusion

In the course of the SETS-II project, electrification potentials were investigated and energy efficiency issues discussed with participating commercial ports. In general, it seems that the focus on energy consumption and energy management and thus the impact on the environment is weighted very differently between the participating ports. For instance, some of the ports are well advanced establishing environmental management systems according to international standards like ISO, while other ports seemed to have difficulties providing an overview of their own energy consumption on an annual basis in the initial phase of the project.

There is no doubt that participation in the SETS-II project collaboration has increased attention to the importance of some of the ports' fossil energy consumption and thus the impact on the environment, not only in the port areas, but also in the nearby urban communities.

The vast majority of SETS-II ports function as settlement port cities and many of the cities were originally created because of a port. There is therefore a strong interaction and an inseparable bond between the ports and the surrounding city, of which the port is an integral part. The cities are therefore heavily affected by having an active port as the nearest neighbor and there will be interdependence between city and port, when looking at potentials for green growth and sustainable development, including fossil-free community development.

Highlights from the SETS project

- Shore power is not only a question of port establishing the facilities, it requires grid connections, vessel applications and demand among vessel owners.
- The symbiosis projects showed us, how waste materials and processes can be transformed into valuable resources for not only individual businesses but for the community as a whole
- It is important to understand that the symbiosis is obtained through thrust, collaboration, and communication, enabling every stakeholder within the win-win network.
- This also testifies to the fact that neither community, cities nor the ports can achieve the green transition alone

The question that is generally raised is

- *How the cities live with their ports, and how the ports live with their cities? Both parts can have advantages and disadvantages, and by uncovering both problems, qualities and potentials, the goal is to be able to derive some concrete solutions and recommendations for the benefit of both city and port, regarding climate issues.*
- *How the Ports involve the companies that have chosen to be in the port areas in a fossil-free development, so that the port of the future becomes a unified green port as a geographical area.*

There is no doubt that the ports of the future will be fossil-free ports. Fortunately, the technologies needed to become an emission-neutral port are already present. Energy efficiency and electrification of the port's operations will play a more important role in the future both due to rising energy prices and the increasing pressure due to environmental demands from the ports' customers and the surrounding cities.

All of the country's participating national states, Denmark, Norway and Sweden, are signatories to the UN's Paris agreement on, among other things, keeping the global temperature increase to a maximum of 1.5 degrees Celsius. The countries also must ensure the resilience and adaptability of all countries in relation to climate-related hazards. In order to keep the global temperature rise to a maximum of 1.5 degrees Celsius, countries must make concrete efforts to reduce their greenhouse gases sharply, so that the countries can become emission neutral in 2050.

Parts of participating ports have integrated

the UN's Global Goals into their climate strategies, when it comes to port as a single cpmpany. A comprehensive climate effort should, however, be conducted in collaboration with other companies within the port area, external customers and service suppliers and, not least, public authorities. Some of the participating ports have already signed partnership agreements with the municipal councils of the nearby cities to act on the climate goals of the UN Paris Agreement.

Based on the above, it is strongly recommended that the other SETS-II ports enter into partnership agreements with their respective cities' municipal councils on how the ports and cities can jointly act on the UN Paris Agreement's climate goals in a credible, measurable and transparent manner.

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The partners behind SETS II work together to ensure a green transition and make the ports in the KATTEGAT / SKAGERAK region more competitive.

The project uses the environmentally heavy ports as positive examples and shows how they contribute with efficient and environmentally friendly solutions. By working together across borders in Sweden, Norway and Denmark, the can gain insight into each other's resources, knowledge and experiences in the field.

The goal is to significantly reduce CO_2 emissions from the ports participating in the SETS II project. Ambitious efforts are being made to develop an electrification strategy during the 3-year project period, which all ports can translate into concrete solutions and actions. The collaboration and the results of the project must be widely spread and be an inspiration to the outside world.

Read more about the project at
www.sets-kask.eu