Nordic Innovation

NEXT NORDIC GREEN TRANSPORT WAVE - LARGE VEHICLES

Zero Emission Tradelines – Potential barriers and mitigating measures

Deliverable 9.4
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Next wave - about the project

Electrification of the transport sector have begun and the Nordic countries, specifically Norway and Iceland, have taken major steps resulting in battery electric vehicles (BEVs) already accounting for a substantial percentage of the total sales. The world is looking towards the Nordics as they are providing global examples for success. However, little is happening regarding larger vehicles as battery solution still are not able to provide heavy-duty users the mobility they need.

Hydrogen vehicles can solve this. The Next Wave project focuses on providing infrastructure for a large-scale deployment of hydrogen vehicles and mobilising transport companies to use the vehicles. The goal is to further stimulate the global technological lead, which the Nordic countries have by stimulating the very first hydrogen infrastructure roll-out for larger vehicles while at the same time map how the infrastructure build-up needs to be done, so that the transition to hydrogen vehicles smoothly can take place. Such roll-out will also benefit the use of hydrogen for trains, aviation, and the maritime sector. Furthermore, in addition of sourcing the hydrogen as a by-product from the industry, in the Nordic region we have the unique opportunity to produce the hydrogen in a green manner exploiting renewable electricity production.

Nordic industries have taken international lead in the field of hydrogen and fuel cells and a unique cooperation exists between the national organisations, companies, and other key stakeholders, e.g., through the Nordic Hydrogen Partnership (NHP). Jointly they have marketed the Nordic platform for hydrogen and, at the same time, paved the way for vehicle manufacturers to deploy such vehicles in the Nordic countries. When it comes to hydrogen, the Nordics have globally leading companies both within the infrastructure, electrolysers, storages tanks, and the fuel cell business. The project therefore sets forward key mobility activities in a unique project where technical innovation and deployment strategies are intertwined.

The project builds on what have been done in the Next Wave phase I and II. In this third phase, the Next Wave project group has widened its scope to look further into how to get hydrogen trucks on the Nordic roads by stimulating also the development of infrastructure enabling zero emission tradelines, connecting the maritime sector with heavy-duty vehicles.

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Summary

Hydrogen is increasingly recognized as a zero-emission energy carrier with notable advantages over battery-based systems, particularly in terms of weight and refuelling efficiency, making it highly competitive for long-range and heavy-load transportation. Its rapid refuelling capability compared to battery electric solutions allows for greater operational efficiency and flexibility, potentially enabling the transport of more goods over longer distances in shorter times.

An evaluation of the flow of goods in Nordic countries has been conducted to determine the optimal ports and routes for initial hydrogen infrastructure development. The goal is to prioritise ports and specific roads for hydrogen bunkering and refuelling stations for zero emission tradelines between countries.

An analysis of barriers was conducted through the course of the project, with barriers such as high costs and lack of infrastructure mentioned as important ones, and suggesting mitigating measures through standardisation, piloting, collaboration, and economic incentives.

1. Background

Both electricity and hydrogen are regarded zero emission energy carriers. Due to the favourable weight characteristics of the hydrogen propulsion system versus battery-based systems, hydrogen can give a better range or payload competitiveness compared to electric vehicles and vessels. In addition, topping up the vehicle or vessel with hydrogen is a much quicker operation than i.e., recharging the equivalent battery-electric solution. As a result, hydrogen transport means has the potential of transporting more goods longer distances in a shorter time than its battery-based competitor.

As reported in the Next Wave Deliverable 5.1 & 5.2, ports are natural hotspots for deployment of hydrogen infrastructure as they are linking road transport and maritime applications. Another type of such a hotspot is logistic hubs that often can be found in the immediate vicinity of the ports. Furthermore, in addition to all the trucks arriving and departing, several transport operations are carried out locally by freight trucks or machineries, both in the closed harbour area as well as between the port and the eventual nearby logistic hub.

Being able to drive longer distances with heavier loads, while in addition requiring fewer and shorter refuelling stops, in general allows for more flexibility. However, there is a challenge in the infrastructure as there are few refuelling stations for trucks and no bunkering of hydrogen in ports in the Nordics. As a natural consequence, in this phase, the Next Wave project has a particular focus how zero emission tradelines can be established. That is, to explore the combined transport mode including truck transport to the port, transport by ship, and then again transport by truck to the customer, discovering what are the barriers and how a Nordic cooperation can contribute to reduce or eliminate them.

Photo: Leo Patrizi, iStock

2. Flow of goods

An evaluation of the flow of goods for each of the Nordic countries has been conducted in order to aid the recommendation for which ports and routes should be focused when making the move towards zero emission tradelines. The focus has been on evaluating which ports should be the first to accommodate for hydrogen bunkering. As a backdrop, in *Figure 1*, a map of Europe indicating the main transport corridors by road is shown.

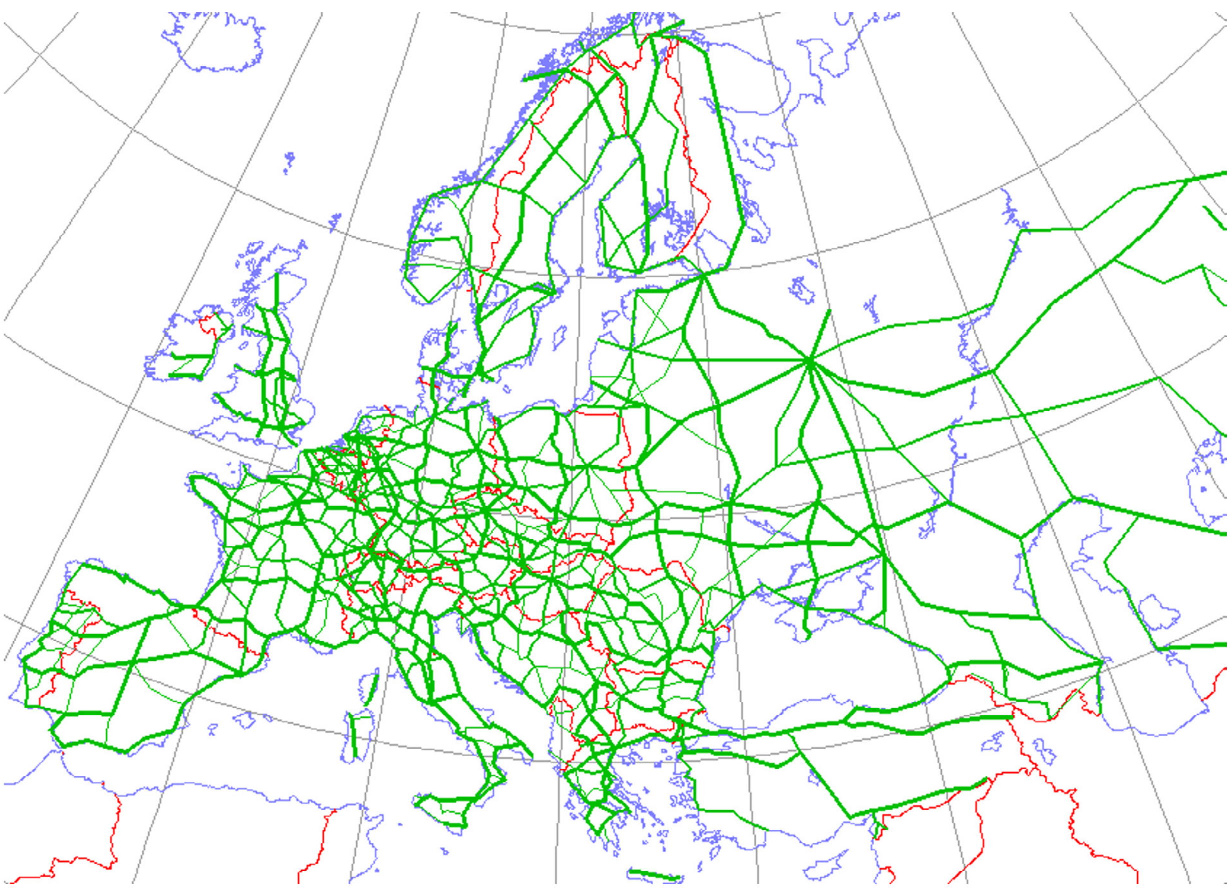

Figure 1. Map of Europe indicating the main transport corridors by road.

2.1 Iceland

As can be expected, most of the goods arriving in Iceland arrives by ship. Some products arrives by air, but that is a very low share of the total cargo. There are more than 1,500 ship calls from foreign ports annually. These are different types of ships, but the majority is cargo ships of various kinds. As an example, 250 ship calls arrives from Rotterdam being one of the key cargo shipping harbours in Europe.

The distance between Reykjavik and Rotterdam is just above 2,000 km. That is, a considerable distance to be covered. In this early stage of zero emission shipping, the main focus has been on short-sea shipping. Thus, the Reykjavik-Rotterdam cargo line is not expected to be among the first routes to be converted. It is, however, interesting to note that Iceland's second largest shipping company, Samskip, is into hydrogen ships.

While in the beginning, service probably will be shorter European routes, i.e., Rotterdam to Oslo. If these first ships work well (starting from 2025), further development might lead to ships that can come all the way to Iceland. Furthermore, other fuels such as ammonia and methanol might also be an option, but currently no e-fuel production exists in Iceland and no plans have so far been announced for zero (or low) emission ships to service Iceland with cargo.

Still, Iceland should not be that complicated to service. There are 3-4 main shipping harbours in Iceland so providing service/infrastructure should be less complex than for many other countries. Moreover, Iceland is an ideal location to create a zero emission cargo service on land. The ring road is ideal for hydrogen mobility, it's a bit up and down and could be a bit challenging during winter conditions, but its only 1,400 km long, *Figure 2*.

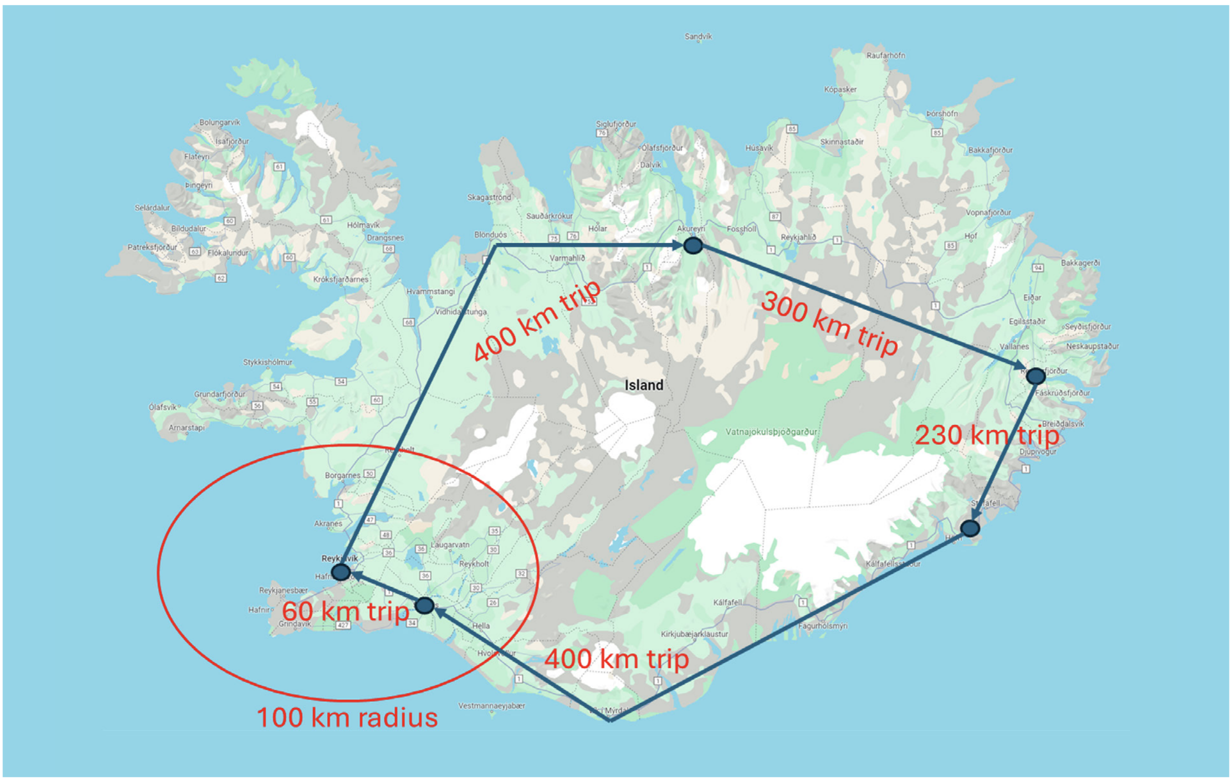

Figure 2. Map of Iceland with distances between key locations. Reykjavik is circled.

As shown in *Figure 2*, the distances between key locations in Iceland are rather short. The circle around Reykjavik indicates the largest distribution area where more than ⅔ of the Icelandic population is living.

Already today, battery electric and hydrogen solutions are being introduced in the truck segment in Iceland. Due to the limited distances, both technologies can provide the needed service without major investments in infrastructure. Hydrogen probably for the longer trips and heavier trucking operations, and battery electric trucks for the shorter, less energy demanding transport operations. In other words, zero emission solutions are available and it's up to the market development to decide which technology will be chosen based on cost, CAPEX and OPEX, availability and service, range, and available infrastructure.

It is of high importance that road and port authority work closely together and carefully follow the technology development both in the shipping and truck sector when preparing the future infrastructure. It is not certain that the same technology will be used in both cases, but when for instance shoreside electrical power for ships is considered - the installed capacity potentially also should include some charging capacity for trucks etc.

As indicated above, a zero emission tradeline involving Iceland is not expected in this decade. However, if the government is to stick to international emission agreements, such tradelines need to be established very soon.

2.2 Denmark

The flow of goods to and from Denmark is primarily done by road or sea. Due to the geographical location of Denmark, there is a long-standing tradition for maritime shipping. Being landlocked with Germany means that much of the freight transport by road from Denmark to both Germany and the rest of Europe crosses the Danish/German border. A substantial part of the export from Denmark to Sweden and the rest of the Nordic countries also is also by road via the Øresund Bridge connecting Denmark and Sweden.

As seen from *Table 1* and *Figure 3* to *Figure 5* below, there has been a slight decrease in total tonnage of export freight in recent years but maritime shipping and road freight to Sweden and Germany remains substantial.

Table 1: Outbound international freight from Denmark in 2023 (Danmarks statistik, n.d.)

Outbound international freight	
- from Danish ports	7,860,000 tonnes
- via Danish trucks	1,612,976,000 tonneskm[1]

[1] *Trucks with a total weight over 6 tonnes.*

Figure 3. Developments in truck transportation crossing the Danish-German border (Lastbiltrafik, 2024).

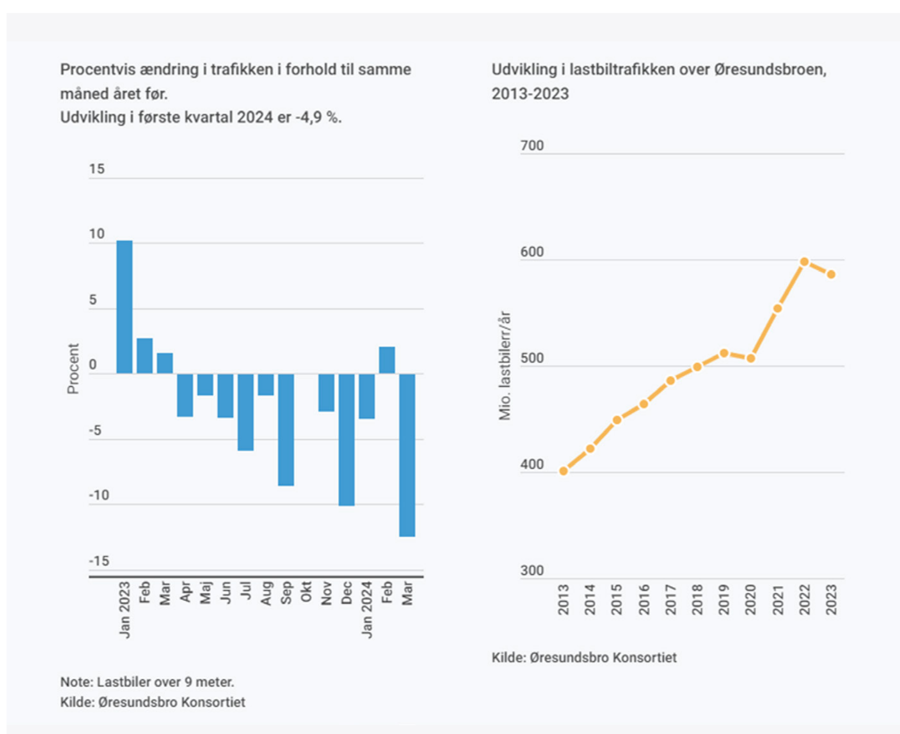

Figure 4. Developments in truck transportation crossing the Øresund Bridge (Lastbiltrafik, 2024).

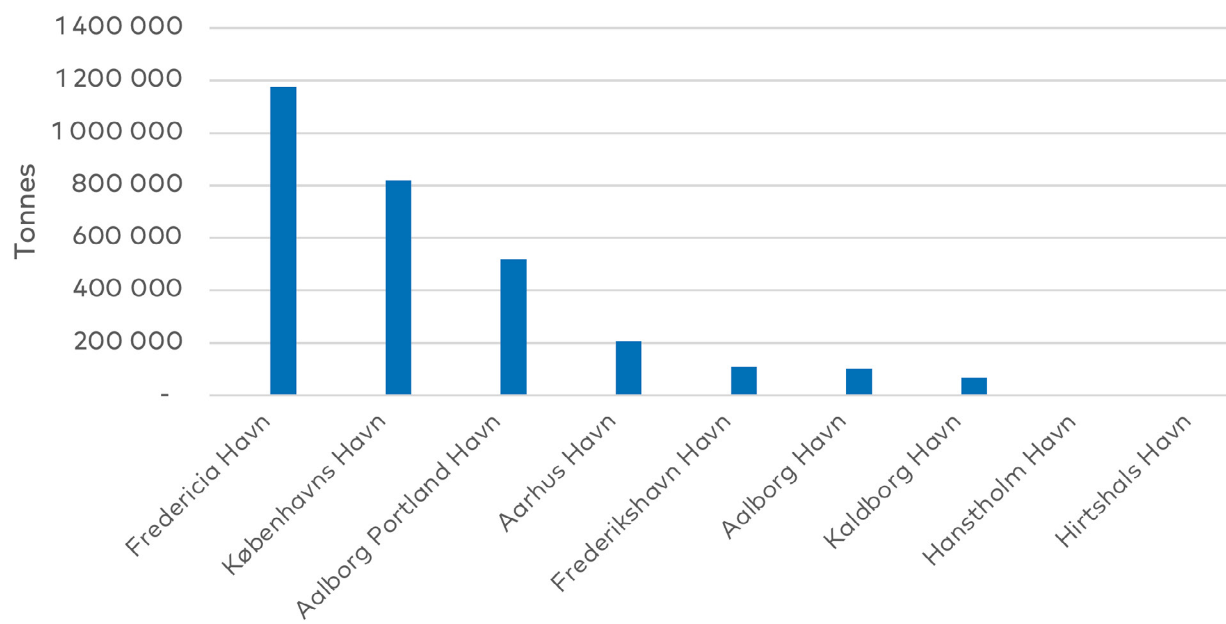

Figure 5. Outbound international freight from the largest Danish cargo ports, 2023 (Danmarks statistik, n.d.).

Note that: 1) while there is no outbound cargo from Hirtshals Havn, there was a total of 4,000 tonnes of inbound cargo through the port in 2023, and 2) outbound cargo from Hanstholm was 0 tonnes, but inbound amounted to 199,000 tonnes.

Transport nodes for zero emission solutions

The ports in Fredericia, Copenhagen, and Aarhus are the largest cargo ports in Denmark and represent key transport nodes that can serve as hubs for driving forward zero emission transport. As illustrated by the map in *Figure* 6, there is heavy transport[2] surrounding the port areas branching out to other routes for export by road. This indicates that there are vast opportunities for setting up hydrogen refuelling stations and using these routes for hydrogen transportation.

2 *Please note that "long vehicles" (>12.5 meters) may include long buses as well, this map does not exclusively denote truck transportation.*

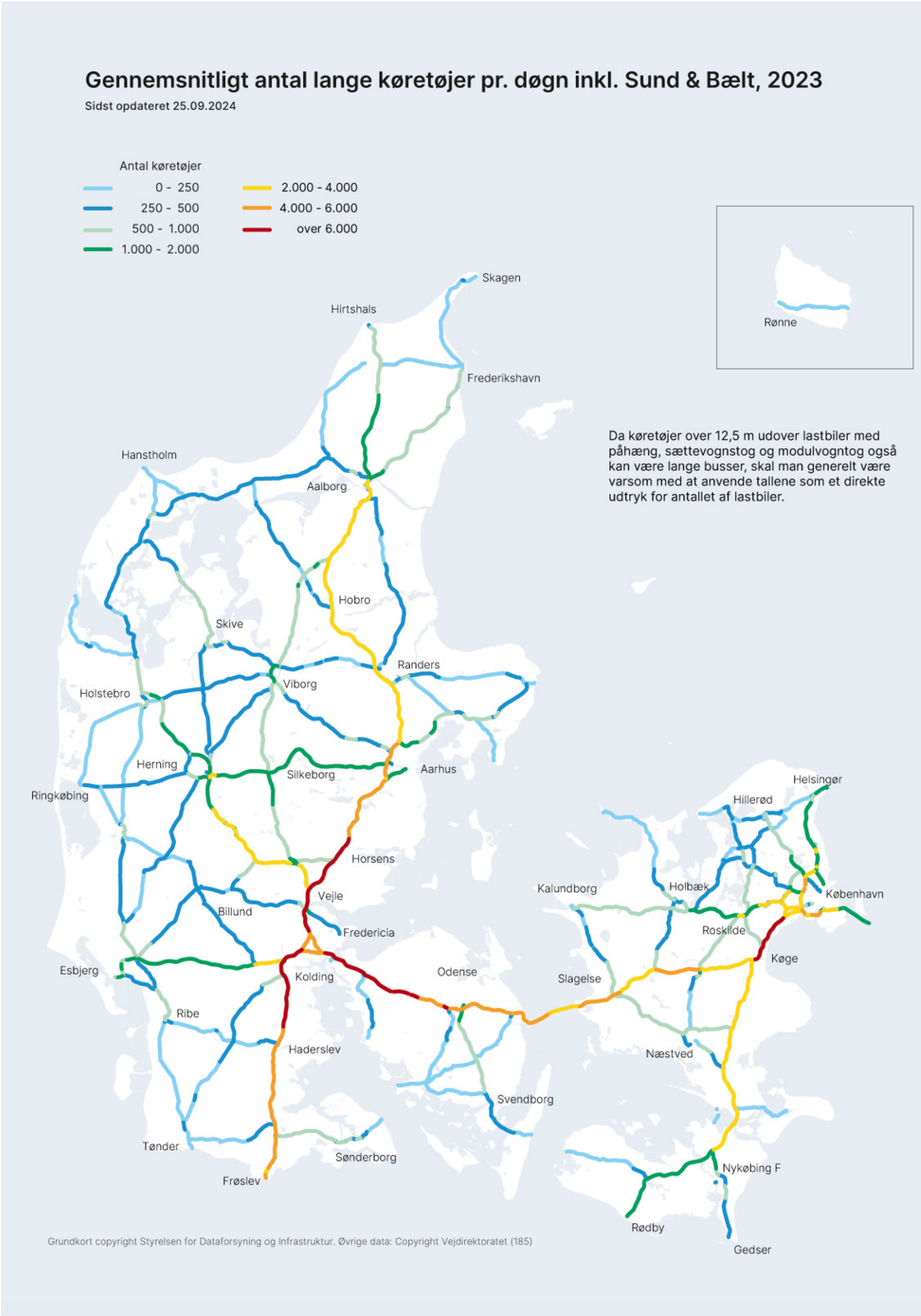

Figure 6. Average number of long vehicles per day including Sund & Bælt, 2023 (Vejdirektoratet, 2024).

Photo: Knud Nielsen, Adobe stocks

Expanding green corridors

The road transport density is further underlined by *Figure 7*, mapping out the existing gas stations and charging points along Danish motorways. As seen in *Figure 7*, there are hubs surrounding the Fredericia, Copenhagen, and Aarhus areas that could benefit from expanding the available zero emission solutions for transportation not least including hydrogen. In the northern part of Jutland there are motorway connections to the port cities of Hirtshals and Frederikshavn where much of the maritime shipping (in- and outbound) to/from Sweden and Norway happens. The outbound cargo from Hanstholm port amounted to 2,000 tonnes in 2023, but the inbound cargo was at 199,000 tonnes.

The motorway connections from Hirtshals and Frederikshavn run south through Aalborg where the Aalborg Port and Aalborg Portland Port are located and further down Jutland. While there is no motorway connection to Hanstholm and no outbound cargo at that port, the inbound cargo amounted to 4,000 tonnes in 2023 and would be an ideal point to set up a hydrogen hub. This is not only due to the freight transportation by road around the port, but also because this location would tie the north-western part of Jutland to the motorway path east and to the German border. There are only about 80 km from Hanstholm to Aalborg "as the crow flies", and just under 100 km by road. These distances make the area well-suited for hydrogen solutions - also because direct electrification is making slow progress in this part of the country.

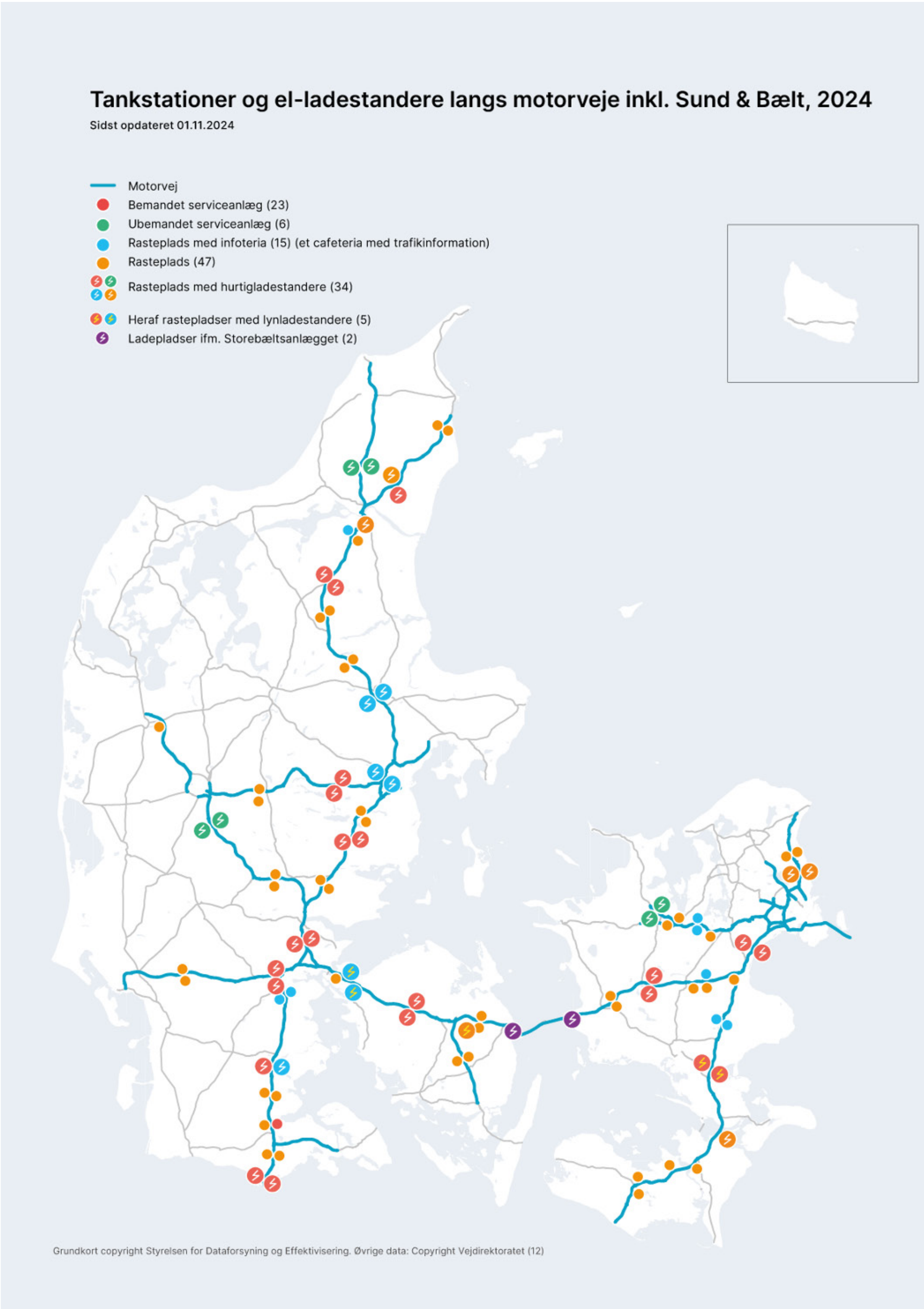

Figure 7. Gas stations and charging points along motorways including Sund & Bælt, 2023 (Vejdirektoratet, 2024).

2.3 Sweden

As the Swedish coastline extends more than 3,200 km, it is natural that the substantial flow of international goods in and out of Sweden is performed by shipping. Typically, shipped cargo volumes annually reaches a total weight of 160-180 million tonnes as presented in *Figure 8* below.

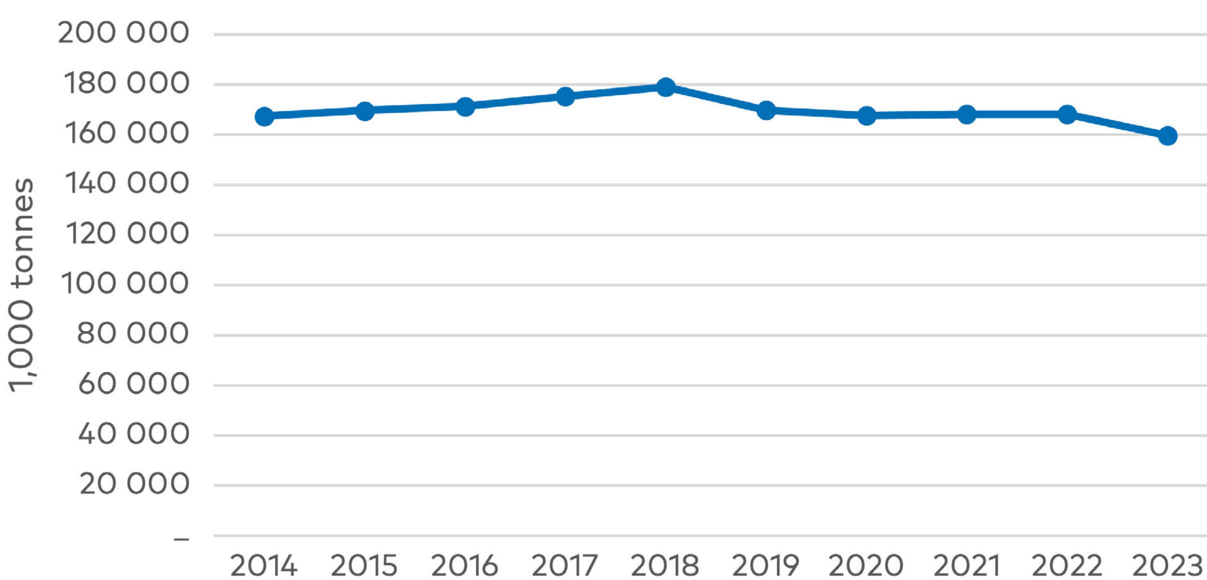

Figure 8. Total cargo volume in Swedish ports; foreign and domestic traffic (Jäder & Tano, 2023).

Flow of goods distribution analysis per port, *Figure 9*, shows that the three largest ports are located on the west coast of Sweden: Gothenburg, Trelleborg and Helsingborg. However, total cargo weight in all Swedish ports is quite evenly split between the west and east cost of the country.

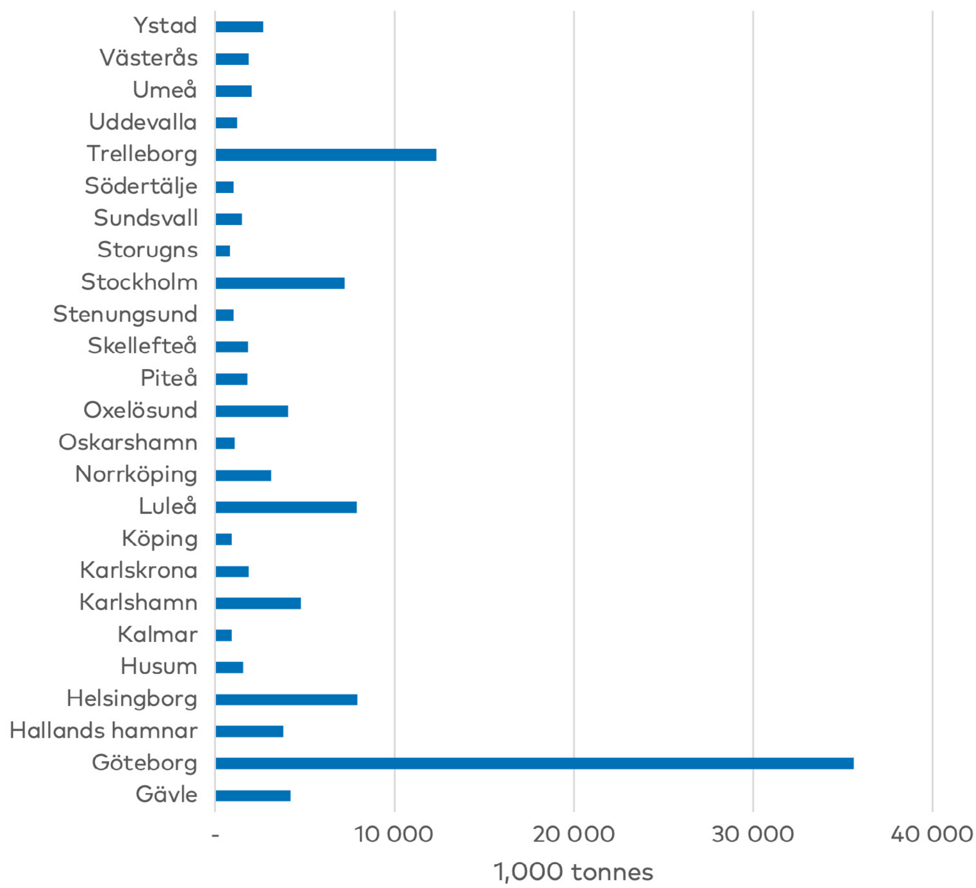

Figure 9. Cargo handling (over quay) in Swedish ports in 2023 (Jäder & Tano, 2023).

Export flow of goods

When it comes to foreign freight transport, two regions are responsible for most of the outgoing cargo weight, *Figure 10*. The largest cargo weights departing from Sweden to another country have their origin in the Norrbotten Region (33%), followed by Västra Götaland Region (24%). The main goods exported from Norrbotten is iron ore, followed by other mining products and forest industry products. Exports from Västra Götaland have different character and primarily include petroleum products.

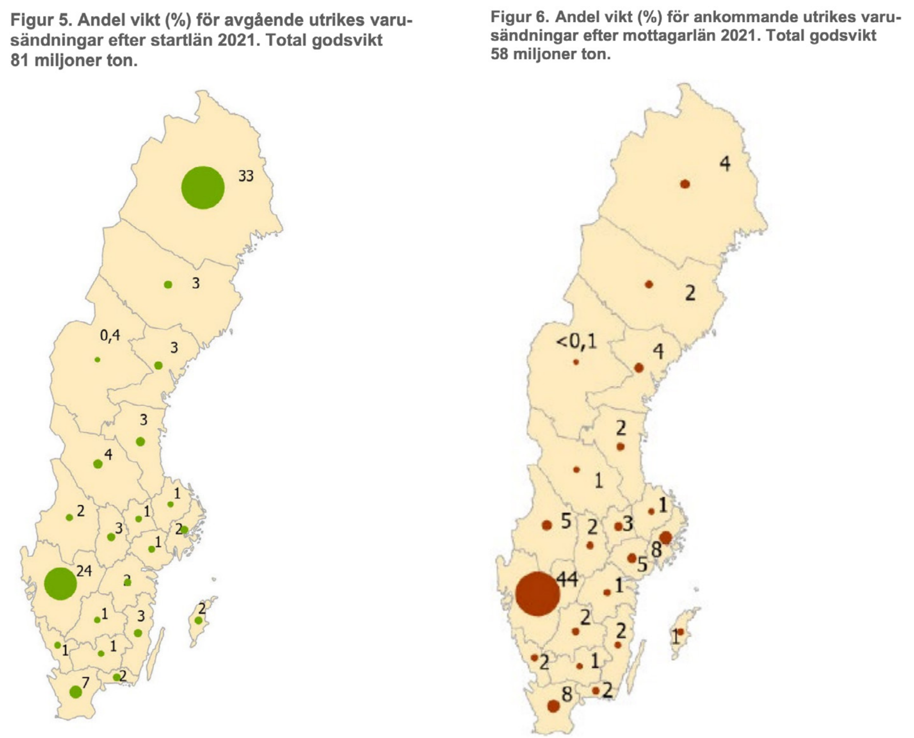

Figure 10. Percentage export (left) and import (right) cargo weights by origin. (Trafikanalys, 2021).

Import flow of goods

As seen from *Figure 10*, Västra Götaland Region is clearly the largest logistics location for freight import to Sweden (44%). The largest sending country in terms of weight is Norway (28% of the freight weight). About 46% of the cargo weight imported to Sweden has its origin in EU.

Investigating green corridors

The compilation of type of loads handled in Swedish ports presented in *Figure 11* suggests that a significant majority of the goods is transported from the ports to their final destination by road transports. Consequently, 83% of the 218 million tonnes constituting total domestic flow of goods in Sweden in 2023 was carried out by trucks.

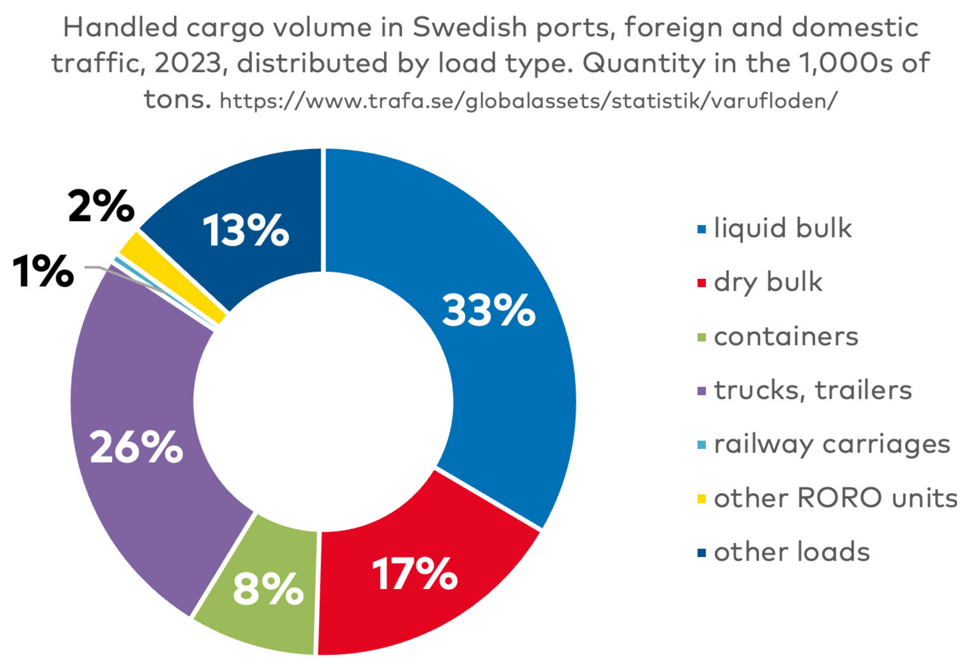

Figure 11. Handled cargo volumes in Swedish ports, foreign and domestic traffic, 2023, distributed by load type. Quantity in the 1,000s of tonnes.

As can be found from *Figure 12*, the main roads in Sweden are part of the EU TEN-T road network (Trans-European Transport Network) and are included in Scandinavian-Mediterranean Network Corridor stretching from Valletta in Malta to Riksgränsen in Sweden and further to Narvik in Norway. Through the two TEN-T categories *Core* and *Comprehensive* road network, they connect all the main port locations in the country. Furthermore, Copenhagen Malmö Port (CMP), Port of Gothenburg, Port of Luleå, Ports of Stockholm, and Port of Trelleborg have all been designated as Core ports by the European Commission.

Thus, in general, Sweden should be well equipped for several green corridors and zero emission tradeline opportunities. In fact, several governmental support programmes (Klimatklivet, Regional Electrification Pilots) stipulating rollout of refuelling infrastructure in Sweden have been launched in last two years. This results in establishment of new hydrogen refuelling stations (HRS) in numerous locations along the Swedish roads in TEN-T Corridors. The most recent information about hydrogen refuelling stations in Sweden is presented in *Figure 13*.

Figure 12: Core, Extended Core and Comprehensive Network Roads, ports, rail-road terminals and airports[3].

3 *https://webgate.ec.europa.eu/tentec-maps/web/public/*

Figure 13: Locations of hydrogen refuelling stations (HRS) in Sweden, January 2024.
Source: Vätgas Sverige.

Photo: Vilhelm, Adobe Stocks

2.4 Norway

In general, the maritime sector is an important vector in Norway. Recently, in order to kick-start the very first value chain for hydrogen as a fuel for maritime transport, Enova has granted support for five hydrogen production projects along the coast[4]. In addition, as 2024 turned into 2025, Enova announced their support for two hydrogen and seven ammonia ships through their investment support scheme for projects sourcing hydrogen fuel for maritime vessels[5]. This is in addition to the support for nine hydrogen vessels and six ammonia vessels that was granted by Enova in June 2024[6]. Through these and other grants, the recent Enova-support directed towards hydrogen as a fuel for maritime transport amounts to some 2.8 billion NOK clearly indicating the government ambitions deploying hydrogen and ammonia fuels in the maritime sector.

Flow of goods

Located at the very top of the Scandinavian peninsula, the transportation mode varies significantly between domestic and international trade in Norway. Domestically, most of the goods is transported on roads according to the main national transport corridors, *Figure 14*. In addition to the local transport of goods, this is usually also the case when part of an intermodal transport chain, where road transport often constitutes the domestic leg linking the start or the end of the chain.

4 *https://kommunikasjon.ntb.no/pressemelding/18309195/over-777-millioner-til-hydrogen-sikrer-forsyningen-langs-norskekysten.*

5 *https://kommunikasjon.ntb.no/pressemelding/18359169/stotte-til-14-nye-nullutslippsfartoy-i-norge.*

6 *https://kommunikasjon.ntb.no/pressemelding/18141539/12-enova-milliarder-til-gronne-skip-et-vippepunkt-for-maritim-industri.*

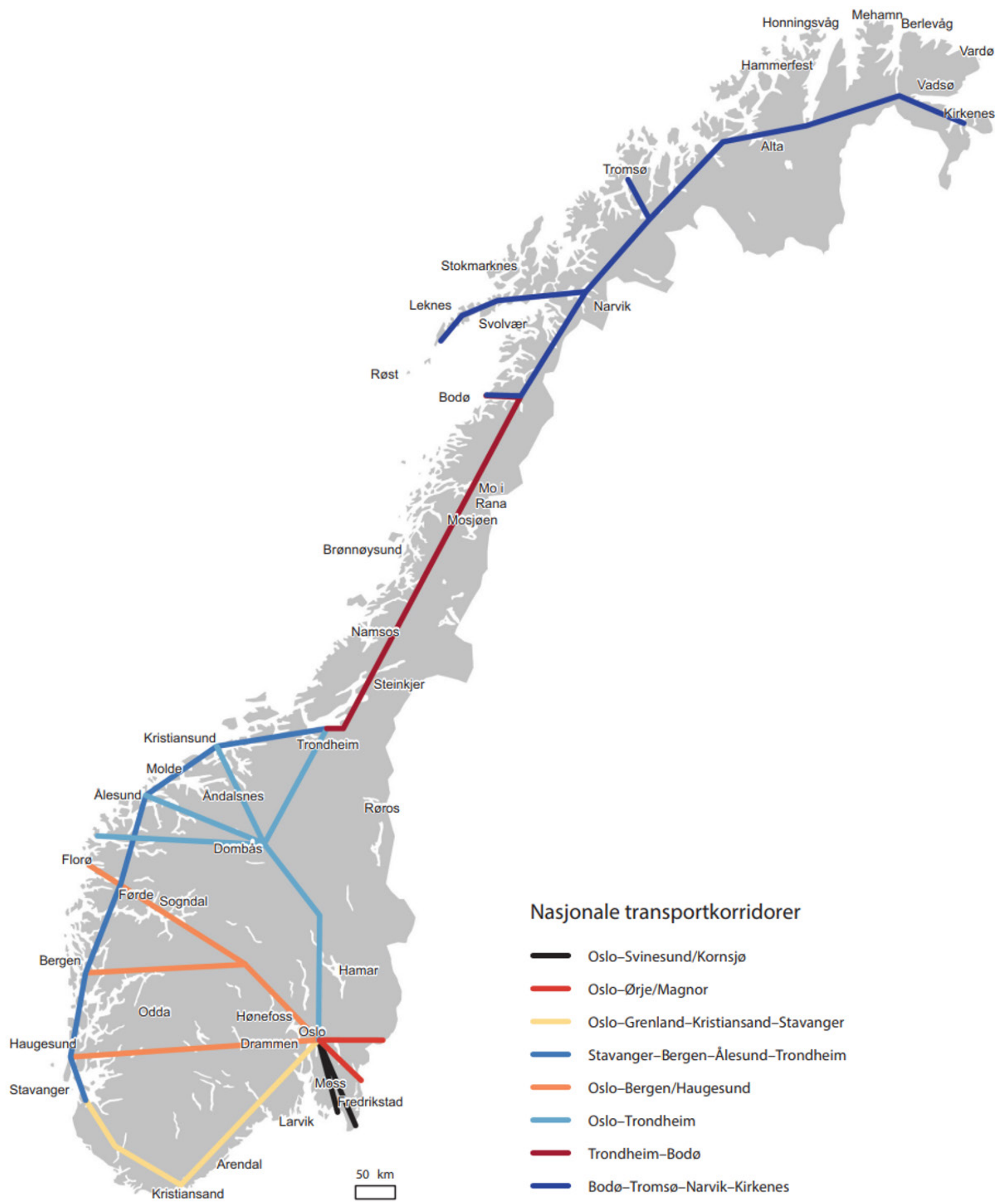

Figure 14: Main Norwegian transport corridors (Nasjonal transportplan 2025–2036, 2024).

In international freight transport, maritime transport is the dominating transportation method, accounting for 91%[7] of all goods transported to and from Norway. 80% of the goods being transported internationally is transported to and from countries around the North Sea and the Baltic Sea, *Figure 15*.

[7] *Measured in tonnes, 2022.*

Figure 15: North Sea and Baltic Sea around Norway.

Investigating green corridors

All roads that connect Norway to other European countries go through other Nordic countries. In *Figure 14*, the most important corridor for transporting goods on road between Norway and continental Europe is the Oslo-Svinesund corridor, closely followed by Oslo-Ørje/Magnor.

Within Norway, the corridors Oslo-Trondheim and Oslo-Stavanger is highly relevant. The corridor between Stavanger and Trondheim which goes through Bergen is also significant for international flow of goods by sea.

When it comes to ports, about 215 million tonnes of goods was loaded and discharged in Norwegian ports in 2022, 73% of the goods went to or from a foreign port, while the rest were transported domestically or to/from the Norwegian continental shelf.

The largest port in Norway is Oslo. It is, however, not the port that loads and discharges the most to foreign ports. Data from Statistics Norway show that Bergen og Omland is the port that loads the most goods to ship to foreign ports, as shown in *Figure 16*.

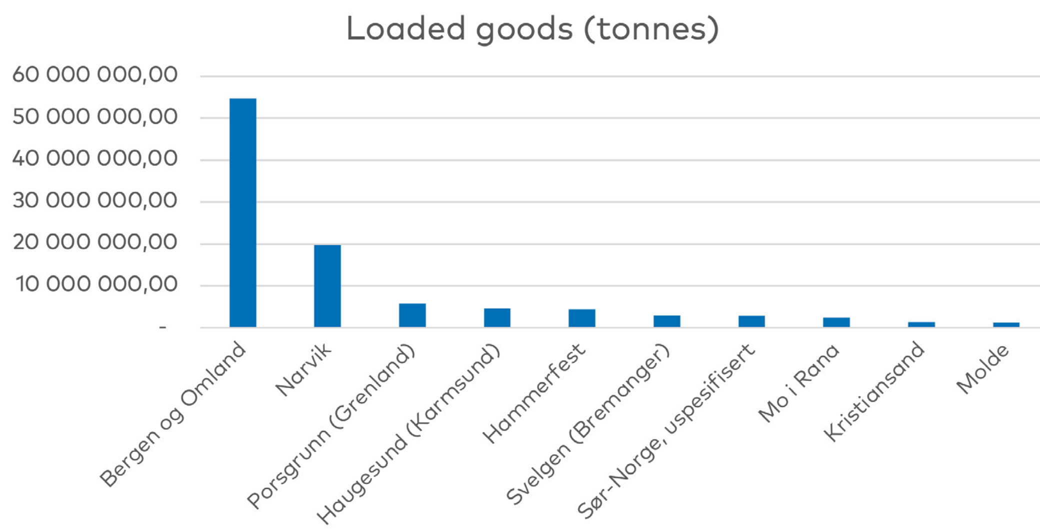

Figure 16: Loaded goods to foreign ports.[8]

The ports that discharge the most goods from foreign ports are Porsgrunn and Bergen og Omland, *Figure 17*. It should, however, be noted that four out of the top six ports shown in *Figure 17* are in the Greater Oslo Area.

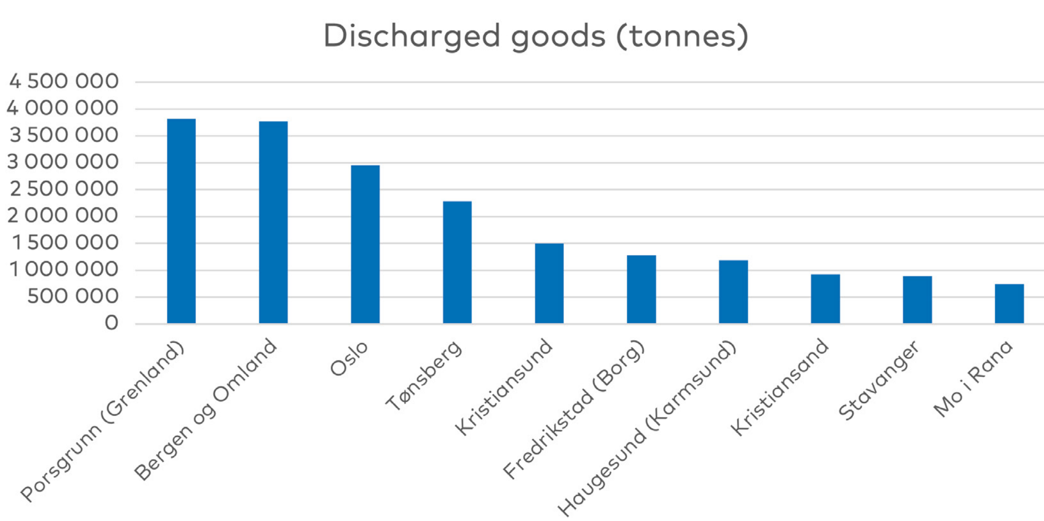

Figure 17: Discharged goods from foreign ports.[8]

8 *https://www.ssb.no/transport-og-reiseliv/sjotransport/statistikk/godstransport-pa-kysten/artikler/mindre-godstransport-mellom-norske-havner*

In 2022, the port facilities in Bergen and its surrounding area (Bergen og Omland) accounted for 27% of the overall (import/export and domestic) freight volume, mainly due to the loading of crude oil and petroleum products for export (Eli Almaas & Petersen, 2023).

2.5 Suggested routes for zero emission tradelines

Based on the above assessment on the flow of goods in **Norway** and the work done in previous phases of the Next Wave project, it is prominent that the Bergen port as well as the Greater Oslo Area are important locations in Norway for hydrogen infrastructure. Within Norway, the cross-border routes to Sweden as well as the connection from Oslo to the west part of Norway are good options for zero emission tradelines.

For **Iceland**, Reykjavik is the most important port, and maritime transport is key to decarbonise incoming cargo. While **Sweden** has several ports of importance, the two that dominate the Swedish freight transport are Norrbotten and Västra Götaland. As a large part of the Swedish road network is included in EU's TEN-T core network, that would be a natural corridor for green fuels.

Denmark is also a part of the TEN-T network, crossing from Germany to Sweden which also covers some core ports. Fredericia, Copenhagen, and Aarhus are the largest cargo ports and crucial for promoting zero emission transport, with potential for hydrogen refuelling stations. Northern Jutland's motorway connections to Hirtshals, Frederikshavn, and Hanstholm ports also present opportunities for hydrogen hubs, facilitating green transport corridors.

For all the Nordic ports, Rotterdam, Hamburg and a few others would be natural ports to constitute zero emission tradelines. An example is the maritime cooperation agreement between the cities of Oslo and Rotterdam to establish a green corridor that will help establish emission-free transport between the continent and Oslo[9].

[9] *https://www.oslohavn.no/en/news/handshake-for-a-green-corridor/*

3. Barriers and mitigating measures for zero emission tradelines

In order to develop actionable strategies for implementing zero emission tradelines, it is essential to identify and address the potential barriers and mitigating measures that may come into play. Several players within the Next Wave project are already closely connected to the topic. In addition, two events were hosted specifically to involve external stakeholders through the whole value chain. Firstly, a number of stakeholders were gathered at a workshop in Rotterdam hosted by Samskip in cooperation with the Next Wave group. Secondly, stakeholders representing the various Nordic institutes and a variety of companies were invited to attend an online workshop aiming to identify barriers and to suggest mitigating measures in order to remedy introduction of zero emission tradelines. This was to bring, specifically, the industry to the table, i.e., ship and harbour operators as they already are tackling some of the barriers and evaluate how to solve others.

For the sake of clarity, potential barriers were divided into six categories:

- Technological
- Economical and financial
- Market and supply chain
- Regulatory and policy
- Social and Cultural
- Operational and Logistical

After a short introduction, the different workshop participants (representing the national Nordic hydrogen member organisations, hydrogen production and distribution companies, hydrogen end users, type approval providers, as well as relevant technology suppliers and scientific organisations) were split into groups in breakout rooms freely discussing the barriers they have identified and experience in their work. Succeeding the discussion on barriers, a similar discussion on possible mitigating measures were conducted in groups before returning in plenum for a common summary of highlights and final remarks. The complete list of barriers and mitigating measures can be found in the Appendix of this report.

3.1 Identified barriers

Analysing the feedback from the various groups, some barriers were identified as more important as they were especially highlighted or repeated by several groups. These were connected to both cost, infrastructure, and standardisation. As the complete list of barriers can be found in the Appendix, the following is an overview of the main barriers identified during the workshop.

Regarding cost issues, different perspectives were presented throughout the groups. On one side, some groups mentioned that the cost of hydrogen is too high, both related to the need for upscaling and technological developments both resulting in lower hydrogen cost. On the other side, other groups phrased that the cost of fossil fuels or emitting CO_2 is too low, making hydrogen an expensive fuel competitor for zero emission tradelines.

The lack of infrastructure creating uncertainties regarding the availability of hydrogen was listed as an important barrier. Furthermore, due to the lack of committed plans for a dedicated infrastructure rollout, also the infrastructure developers struggle to upscale their activities needed in order to reduce costs. Also, the lack of financing of infrastructure was noted. Here, one group even pinpointed the lack of political ambitions and policies related to the AFIR requirements for cross-border infrastructure.

Standardisation was brought up as a barrier for the uptake of hydrogen for zero emission tradelines. As the need for standardisation comes in different parts of the value chain, one example is the need to standardise the bunkering/refuelling technology, while another is connected to the need to standardise the type of fuels for maritime and heavy-duty vehicles. As a result of the limited standardised solutions, the project and technology costs are higher than what could be expected in a well-defined and standardise regime.

3.2 Suggested mitigating measures

Clearly, most of the barriers identified are connected in some way or another, and mitigating measures can either target one specific barrier or take down several barriers simultaneously. Furthermore, for instance the hydrogen cost/pricing issue can be attacked from different angles, such as reducing the cost of hydrogen, or increasing the cost of fossil fuels.

During the workshop and the course of the project, several mitigating measures for the above barriers were identified. For the complete list, please consult the report Appendix.

Concerning the cost/pricing of hydrogen, the necessity for funding programs and incentives was highlighted. A very good example seems to be the funding programmes for maritime transport provided by Enova. By supporting both the production and use of hydrogen, the ambition is to develop the first functioning value chain in Norway. Enova provides up to 80% CAPEX support of additional costs both for production and procurement of vessels. The response from the market has been very good, and it now remains to be seen whether the allocations that have been made lead to final investment decisions.

The implementation of CO_2 taxes and other measures to increase the cost of fossil fuels or CO_2 emissions was recognized as crucial. Here, Contracts for Difference (CfD)[10] might be one such redemptive mitigating measure bringing economic viability to the early phase hydrogen market in general. The use of CfD has been discussed in Norway. The industry has argued the CfD is necessary to reduce risks, while Enova has argued that the market isn't ready for CfD, and that the CAPEX support for production and vessels will be enough to make hydrogen competitive to traditional marine gasoil (MGO).

Additionally, establishing and supporting more pilot projects was noted as a significant measure for cost reduction and standardisation. Once again looking at Norway, pilot projects has been important to stimulate market development. For maritime transport there are two relevant projects, both initiated by the Norwegian Public Roads Administration (NPRA). The world's first car ferry using liquid hydrogen, Hydra, was put into operation in 2023. In addition to the major technology development, the project was also important in order to develop rules and regulations to enable Norwegian passenger ships to run on hydrogen.

The second project initiated by NPRA is the Vestfjorden ferry connection, Norway's longest and most challenging ferry route from Bodø to Lofoten. The two ships that will operate the route are currently being built in Norway. The ferries will be the world's largest hydrogen-powered vessels and will feature the largest hydrogen installation ever installed onboard a ship, *Figure 18*. By demanding the use of hydrogen ferries, NPRA is driving innovation and technical as well as regulatory development, and at the same time stimulating the market. This is a very good example on how public procurement can be a driving force to foster the transition to zero emission transport. The example

[10] *Under the CfD the supplier of a new, high-cost commodity (e.g., green fuel such as hydrogen or ammonia) is paid the difference between a pre-determined reference price (e.g., the cost of fossil fuels) and a set fixed "strike price".*

should be followed by the other Nordic countries. Some countries will also benefit from large companies paving the way, such as for the example of the Gotland ferry, where Gotlandsbolaget has launched their hydrogen powered ferry, both Gotland Horizon and Gotland Horizon X.

Figure 18: The world's largest hydrogen-powered vessels are currently being built by Myklebust shipyard in Norway. Illustration: Myklebust/Torghatten Nord.

Implementing the very first hydrogen roll-out is not a one-entity show. Thus, collaboration emerged as a critical measure acknowledged by the industry, essential for developing infrastructure and establishing standards in this burgeoning sector. One particularly noteworthy mitigating measure is the potential development of a joint Nordic Hydrogen Strategy, leveraging the collective strengths of all Nordic countries. As an add-on to this mindset, a powerful mitigating measure in an early phase is to activate public organisations that can secure stable, long-term off-take of the produced hydrogen.

In summary, addressing these barriers through the aforementioned measures would significantly reduce risk and uncertainty among hydrogen producers and users paving the way for a viable early phase hydrogen market. Simultaneous actions throughout the value chain are a key to success. Luckily, we have Nordic companies and governments with the strength to carry out those actions, and ongoing initiatives like the committed infrastructure buildup in Sweden and the recent Enova grants in Norway, helping to reduce some of the identified barriers, while others – e.g., standardisation work – are more troublesome to overcome on a short-time basis. However, by implementing pilot projects, also these hurdles will be challenged speeding up the processes addressed by the Next Wave zero emission tradeline initiative.

3.3 Need for further work

To ensure the successful uptake and implementation of hydrogen as a viable energy source in the Nordic, there is a clear need for further work in implementation of pilot projects gathering experiences and pushing standards, as well as continuous monitoring and analysis of the evolving business environment.

Given the dynamic nature of technological advancements, regulatory changes, and market shifts, it is imperative to keep up to date with developments and recalibrate strategies accordingly. This ongoing assessment should keep up with updates to policies, standards, and infrastructure plans, thereby reducing uncertainties and fostering a more robust and resilient hydrogen economy.

For the next phase of the Next Wave project, these barriers and mitigating measures will be worked further on. Among other things, the project will aim to engage ports, goods-owners, and shipping companies in common efforts to reduce barriers for establishing zero emission tradelines.

Photo: Reise-und Naturfoto, Adobe Stocks

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Appendix

Workshop on barriers and mitigating measures

In order to develop actionable strategies for implementing zero emission tradelines, it is essential to identify and address the potential barriers and mitigating measures that may come into play.

Through the course of the project, we have conducted an online workshop aiming to identify barriers and to suggest mitigating measures in order to remedy introduction of zero emission tradelines.

Several players within the Next Wave project are already closely connected to the topic. In addition, external players through the whole value chain were invited to the workshop, as well as scientific organisations and industry associations.

Below, the complete list of potential barriers and suggested mitigating measures from the workshop is given.

For the sake of clarity, potential barriers were divided into six categories:

- Technological
- Economical and financial
- Market and supply chain
- Regulatory and policy
- Social and Cultural
- Operational and Logistical

Barrier	Category	Mitigating measure
Non-technical showstoppers (barriers)	Technological	Pilots and demonstrations are really needed to increase knowledge
Costly storage – higher uptime (for example HRS)	Technological	Pressurised H_2 intermediate solution. Will be liquid Liquid production is so important to expand project groups
Technical up-time must improve (HRS) increase confidence (this is the experience from the car industry)	Technological	Swapable solutions for ships will reduce the risk of uptime of HRS
Reliability	Technological	Reliability must be increased, redundancy and flexibility
Limited standardised solutions	Technological	Reliability is also very costly – but necessary
Lacking production capacity for electrolyser, and fuel cells etc. takes a long time if you order components today	Technological	Long lead time needs to be solved
Most ships will be hybrid solutions – therefore many of these barriers are not showstoppers!	Technological	If they don't get hydrogen, the vessel can still operate
Wide scope of standards: Wide variation of H_2 storage technologies in vehicles, 350 bar, 700 bar, liquid – difficult to prioritise the investment	Technological	Postpone the requirement on implementation of liquid hydrogen in road vehicles/HRS
Need for further technology development: Securing adequate technology. e.g., "refilling 700 bar @ 10 kg/min"	Technological	More research and innovation in technology development Collaboration projects between research/academia and commercial players Promote X-sectoral projects Run this parallel to building the market
Tax on H_2 ICE in Sweden –categorised as a gas truck and thus considered polluting	Technological	Never trust the Sweds!
Need for more aligned hydrogen transport solutions in the Nordics	Technological	Show differences among the countries and what the problems they cause to Nordic politicians
Bunkering needs to be developed and standardised	Technological	
Different kind of fuels for maritime. Is it possible to standardise?	Technological	Could we find a consensus about the type of fuel to be use?
Safety ventilation systems for hydrogen (when leakage occurs) might in some cases be difficult	Technological	Being investigated in several EU-projects such as HyTUNNEL etc.
Very costly in the beginning – lack of pilots	Economical and financial	Fossil fuel is too cheap. Higher fuel cost, CO_2 cost. Contract for Difference (CfD). Public procurement.
Cost efficient storage	Economical and financial	Liquefaction needs to be established. To be able to do so, we need a number of off-takers to make it economical viable

No economic incentive to participate in new projects/new fuels. There are some differences – very large ships/companies can do some things while more difficult for the smaller ones	Economical and financial	Funding mechanism to help small companies with small fleets. Need high % funding
Transport is very cheap – increasing transport cost has very little effect on the final price of a product	Economical and financial	Consumers must participate. Taxing of CO_2 is impacting
IMO is implementing new taxes starting 2027 and shipping is now in ETS	Economical and financial	
TCO: High pricing of all steps in the H2 value chain, resulting in a roadblock in market roll-out when it's compared with existing and commercially mature technologies	Economical and financial	Market volumes are key to get the unit prices down Support first movers with adequate financial support Activate public organisations as off-takers Create mechanisms that promote clean technologies before fossil tech
Weak sense of urgency to change	Economical and financial	Appropriate support schemes and policies to drive the change
Still not enough drivers /benefits to replace currently established technologies – choosing the cheapest option is still baseline choice	Economical and financial	Joint Nordic H_2 strategy
Lack of incentives for hydrogen stations for trucks - at least in some countries	Economical and financial	Get proper national funding schemes/support mechanisms in place
Cost in general – both CAPEX and OPEX. Companies/end users are surprised about the costs (vehicles and vessels, transport solutions etc.)	Economical and financial	Apply for grants – European and domestics. Need funding programs and incentives End users should be willing to pay a premium for zero-emission transport Have to make the whole value chain understand the importance of making a change – the customers customer Show what we are doing and that it's something good. Storytelling, communication CO_2 price should increase. It must be more expensive to pollute. Important if the whole fleet is to be transformed Contract for difference is necessary Reduce uncertainties of investments. Need of long-term security of the investment. Authorities need to stick to adopted plans
Financing of infrastructure: Need to have commitment for a large number of trucks to make the investment decision. The same for maritime use	Economical and financial	Mobilize the big companies to be early movers / commit for use of hydrogen – and paying the prize. Mobilise the different parts of the value chain to commit and take coordinated action Financial institutions are important
Waiting game to see if projects in pipeline actually will fly. A handful of projects are highly disseminated, and all other stakeholders are waiting to see if they become successful	Market and supply chain	Higher funding and more long-term public commitment might push more projects to move

Might completely fail if uptime of HRS is very low and no redundancy available	Market and supply chain	
Mobility as a service	Market and supply chain	Risk sharing. Potential role of government
Market footprint of H_2 technologies: Low number of options for finding suppliers and partners, resulting in uncertainty of investments	Market and supply chain	Expand H_2 applications to market segments with naturally high volumes, e.g., vehicles to get costs reduction benefits due to industrial scale
Lack of commercially available H2 vehicles: A key to create off-take at HRS	Market and supply chain	Unique aspect of Nordic countries, being a quite limited market with unique requirements (cold climate), compared to continental Europe: utilise the strength of working together in Nordics rather that 5 separate countries Different truck standards in Nordic countries compared to continental Europe: standardisation
Coordination and investments. Engage different parts of the value chain at the same time to do investments simultaneously	Market and supply chain	Mobilising different players from the whole value chain, applying for funding that can fund the whole value chain Hydrogen Valley program in EU Try to harmonise European funds with national funds Takes a lot of efforts just to educate people. Inform both users and the government who have set targets without knowing how to get there
Producers of hydrogen have to make big investments. So, commitment from users is important – this is difficult	Market and supply chain	
Difficult for small companies to be able to buy trucks in the early phase – OEMs focussing on larger companies / consortiums	Market and supply chain	
Are customers willing to pay the extra cost for use of hydrogen trucks?	Market and supply chain	
Certification - Ships out of class – don't get operation license. It is almost impossible to implement new technology on board non-classed ships as government authority demand class or standard rules	Regulatory and Policy	
Each project needs to be classed	Regulatory and Policy	New rules – are updated for each project. More pilots will help to get final rules
Classification societies don't want to give final rules, so they don't block innovation	Regulatory and Policy	More demonstration projects are necessary to help with preparations of final rules and regulations
Companies and government must support each other	Regulatory and Policy	Government must contribute to get the new rules established, directly/indirectly
Lack of Nordic H_2 strategy	Regulatory and Policy	Joint vision and strategy on H_2 in Nordics

Lack of clarity of hydrogen's role in future society, opening space to big variation on suggested implementation measures, e.g., industry, energy, transports etc.	Regulatory and Policy	Strengthen the statements/clarity in H_2 strategies
Lack of political ambitions and policies, both national and across borders	Regulatory and Policy	The landscape is not clear for producers or users: Lack of clear political ambitions Incentives are suddenly removed Cross-border: Pipelines are postponed, results in more uncertainties AFIR requirements for cross-border infrastructure is a political responsibility for the member states Should be addressed by Nordic politicians and further Next Wave collaboration
Lack of available areas for stations, including permissions for regulation and use	Regulatory and Policy	
Lack of harmonised regulations across borders, i.e., transport of hydrogen (ref. Next Wave report)	Regulatory and Policy	Show differences and resulting problems to Nordic politicians and authorities
Certified drivers needed for transport of hydrogen (ADR). Makes cost of transport for hydrogen very expensive	Regulatory and Policy	
Regulation for transport of hydrogen in tunnels. Do we know what will be allowed?	Regulatory and Policy	Being investigated in several EU-projects such as HyTUNNEL etc.
Afraid of toxicity and explosions (gaseous hydrogen)	Social and Cultural	Education – still general education is missing
Geopolitical instability is negative for the new fuels. Range, of ships, will be less - so more frequent refuelling. Might have negative impact when disturbances in the world (wars) impact routes	Social and Cultural	Higher efficiency at least one solution. Focus on inland, short sea and fishing (possible solution). But then there are mainly small companies – difficult to execute pilots etc.
H_2 reputation in news flow: Volatility in the investors market results in some H_2 projects being delayed or cancelled bringing doubts in public view	Social and Cultural	In communicating hydrogen, bring more of big picture of advantages from hydrogen in future society Enhance focus on good news
Public acceptance of hydrogen stations in city centres might be difficult	Social and Cultural	
Traditional ships have very large fuel storage – and refuel where it is the cheapest. This will be different with the new fuels - as one will have to refuel more frequently	Operational and Logistical	Operation profiles need to be revisited and rethought
Need for infrastructure: Absence of solid plans for large scale transmission and distribution needed to reduce costs Absence of storage capacity which would be necessary to lower the costs	Operational and Logistical	Collaboration between players across the entire value chain, and across various geographic locations


Photo: Jaroslav Pachý Sr., Adobe Stock

Next Nordic Green Transport Wave - Large Vehicles

Deliverable 9.4

Zero Emission Tradelines – Potential barriers and mitigating measures

Version 1.0

2025