

# NEXT NORDIC GREEN TRANSPORT WAVE - LARGE VEHICLES

Deployment of hydrogen trucks and infrastructure  
in the Nordic  
- Status, ambitions, and recommended actions to  
stimulate the demand

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# Next wave - about the project

Electrification of the transport sector already began 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 (e.g., buses, trucks, and lorries) the mobility they need.

Fuel cell electric vehicles using hydrogen as a fuel can solve this. The project focuses on providing infrastructure for a large-scale deployment of trucks, buses, and lorries. 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 can happen smoothly. Such roll-out will also benefit the use of hydrogen for trains 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.

Already, Nordic industries have taken international lead in the field of hydrogen and fuel cells and a unique cooperation exists between "hydrogen companies" via the Nordic Hydrogen Partnership (former Scandinavian Hydrogen Highway Partnership, SHHP) cooperation. 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 and the fuel cell business. The project therefore sets forward four key activities in a unique project where technical innovation and deployment strategies are intertwined.

The project will deliver an analysis on large-scale transport of hydrogen with mobile pipeline, a description of the innovation and business potential for a roll-out of FC-buses in the Nordic region, as well as a coordinated action plan for stimulating the FC truck demand and a prospect for utilising hydrogen in heavy-duty equipment. Finally, the project will contribute to national and Nordic hydrogen strategy processes even providing input to a possible Nordic Hydrogen Strategy.

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# Terms and abbreviations

In this report we use the term **hydrogen truck** about trucks using hydrogen either to produce electricity in a fuel cell or as a fuel in a combustion engine. The first is also called a Fuel Cell Electric Truck. For short we do not distinguish between these two variants here.

| Term / abbreviation      | Explanation                                                                                                                                                                                                                                                                                              |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ACEA</b>              | The European Automobile Manufacturers' Association.                                                                                                                                                                                                                                                      |
| <b>AFID</b>              | Directive 2014/94/EU on the deployment of alternative fuels infrastructure.                                                                                                                                                                                                                              |
| <b>AFIR</b>              | EU Regulation for the deployment of alternative fuels infrastructure, currently in process for adoption. A further development of AFID.                                                                                                                                                                  |
| <b>BEV</b>               | Battery Electric Vehicle.                                                                                                                                                                                                                                                                                |
| <b>CAPEX</b>             | Investment expenses.                                                                                                                                                                                                                                                                                     |
| <b>CfD</b>               | Contract for Differences. An agreement between two parties whereby one party agrees to pay the other party the difference between the actual value of a commodity at a point in time – the market price – and a value which the parties agreed at the point the CfD was entered into – the strike price. |
| <b>EV</b>                | Electric Vehicle.                                                                                                                                                                                                                                                                                        |
| <b>FCEV</b>              | Fuel Cell Electric Vehicle.                                                                                                                                                                                                                                                                              |
| <b>Fuel Cell</b>         | A fuel cell uses the chemical energy of hydrogen (or other fuels) to produce electricity. Hydrogen from a tank and oxygen from an air inlet produces electricity, heat, and water vapor.                                                                                                                 |
| <b>HRS</b>               | Hydrogen Refuelling Station(s).                                                                                                                                                                                                                                                                          |
| <b>LNG</b>               | Liquefied Natural Gas.                                                                                                                                                                                                                                                                                   |
| <b>Hydrogen truck</b>    | A truck that uses hydrogen either to produce electricity from a fuel cell or as a fuel in a combustion engine.                                                                                                                                                                                           |
| <b>MW</b>                | Megawatt.                                                                                                                                                                                                                                                                                                |
| <b>NHC</b>               | Nordic Hydrogen Corridor project.                                                                                                                                                                                                                                                                        |
| <b>OEM</b>               | Original Equipment Manufacturer. Used as a term for truck manufacturers.                                                                                                                                                                                                                                 |
| <b>OPEX</b>              | Operational expenses.                                                                                                                                                                                                                                                                                    |
| <b>TCO</b>               | Total Cost of Ownership.                                                                                                                                                                                                                                                                                 |
| <b>TEN-T</b>             | The Trans-European Transport Network.                                                                                                                                                                                                                                                                    |
| <b>VAT</b>               | Value Added Tax.                                                                                                                                                                                                                                                                                         |
| <b>350 bar / 700 bar</b> | Term for the maximum pressure of compressed hydrogen in storage tanks. 350 bar is used in some buses and trucks, while 700 bar is used in passenger vehicles and some trucks as well.                                                                                                                    |

# Summary

The Nordic countries have set ambitious targets for CO<sub>2</sub> reduction from transport. So has the Nordic truck operators, and the transition to zero and low emission solutions has begun. Hydrogen trucks are currently being developed by several OEMs, and at the same time several companies are ready to produce hydrogen and to operate hydrogen stations.

Infrastructure and trucks should be deployed in a coordinated way, so that the stations are available before the trucks arrive. National and regional authorities should stimulate the development by providing the necessary incentives. This is especially important in the early phase when costs for trucks and infrastructure is relatively high.

In this report we describe the status for hydrogen trucks and stations, as well as elaborates on the possible barriers that can hinder the use of hydrogen in heavy-duty transport. Availability of trucks is one important barrier. We discuss how Nordic regions and countries can become attractive for the early deployment of trucks, and the necessary incentives to speed up this deployment. The report describes national targets and ambitions for reduction of CO<sub>2</sub> emissions in the Nordics, together with the relevance of hydrogen usages in other segments.

Finally, we present our vision for the deployment of trucks in the Nordics by 2025 and 2030, together with the necessary cross-border infrastructure. We find that there is a great potential for the Nordics to pave the way for zero-emission heavy-duty transport, as the countries have done for passenger vehicles. We estimate that 740 Hydrogen trucks are deployed in the Nordics by 2025 and 12,550 by 2030. This equals 19% of the estimated total number of hydrogen trucks in Europe in 2025, and 13% in 2030.

Several trucks cross the Nordic borders each day. The countries should cooperate to facilitate development of stations making this transport with hydrogen across the borders possible. Early deployment of trucks and infrastructure will provide good opportunities for the Nordic hydrogen industry to take positions on the global market. However, this requires ambitious policies and good framework conditions from the authorities. The Next Wave partnership will continue the work to achieve this in the extension of the project during 2022-2023.

Photo: Kelly Lacy, Pexels





Photo: Josh Sorenson, Pexel

# 1. Background

Mistakenly, for way too long, the transformation from fossil fuels to hydrogen have been portrayed as a *chicken-or-the-egg-problem*. That is not a fruitful approach for change. Thus, to be clear right from the beginning:

**By implementing the infrastructure first – the vehicles will come!**

Obviously, there must be a balance. Infrastructure should be developed in line with the demand, but in such a way that it is not a barrier to deployment and development of vehicles. A hydrogen fuelling network needs to be in place before hydrogen trucks will find their way to the market.

To get the business case right, it is important to come at scale as quickly as possible. Heavy-duty vehicles (e.g., buses, trucks, lorries, and machineries) as well as maritime applications are potential large consumers of hydrogen as a fuel making it possible to come at scale if coordinated actions are made. Hence, it's key to locate the main hotspots.

Heavy-duty road transport is a combination of city logistics, as well as regional and long-haul operations. Thus, in a Nordic perspective, outlining a first hydrogen infrastructure both includes the local hotspots where the vehicle density or number of transport operations are high, as well as the strategical refuelling spots allowing for cross-border operations.

A natural hotspot for heavy-duty vehicles is ports. Obviously, this is where the road transport and maritime applications meet. Furthermore, and in addition to all the trucks arriving and departing, several transport operations are carried out locally by freight trucks or machineries. Another type of hotspot is logistic hubs that usually can be found outside or in the neighbourhood of larger cities, ports, and airports, or industrial hubs serving industries such as the fishing, mining, process, or forest industry.

Strategical refuelling spots are locations along the main transport corridors allowing for long-haul operations connecting the Nordic countries internally and towards our neighbouring countries such as Germany and the Baltics.

Here, regional national and transnational projects will be important initiatives for deployment of the first stations and trucks. The H2 Truck<sup>1</sup> project, the EU co-financed Nordic Hydrogen Corridor<sup>2</sup> and the GREATER4H project<sup>3</sup> are important initiatives and front runners.

In addition, there are a few fledgeling national and commercial hydrogen heavy-duty infrastructure initiatives currently being explored. Recently, the hydrogen providers Everfuel and Hynion has launched their plans for developing the initial network of refuelling stations in Norway, Sweden, and Denmark. Several other hydrogen providers are planning to establish hydrogen stations in these countries as well.

## 1.1 BEVs - a success-story to learn from

Battery Electric Vehicles (BEVs) have successfully been introduced in the Nordic countries, though the largest success has been in Norway and Iceland. To come to this winning position, a mix of economic and convenience incentives were put in place applying both to the car owners and the companies constructing the first charging infrastructure.

Deployment of Fuel Cell Electric Vehicles (FCEVs) has taken longer. Only a couple of hundred vehicles are in service in the Nordic countries today, mainly in Norway and Denmark but also Iceland is picking up momentum in the hydrogen segment. The low market share is due to a limited number of models and vehicles available, together with very limited infrastructure.

Now it is about time to lift the good market acceptance for zero-emission passenger car into the larger vehicle segment. Recent years, OEMs have started to launch some larger BEV models (mainly distribution trucks) broadening the potential use and market for BEVs but also further increasing the demand for an even more widespread infrastructure.

The constraints of the battery powered vehicle become more evident when pushing into the larger vehicle segment as when energy consumption goes up it becomes more and more difficult to fulfil the market needs for charging time and range. OEMs developing and building larger vehicles, such as vans, trucks,

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<sup>1</sup> The H2 Truck project's main goal is to deploy the first 100+ hydrogen trucks in the Oslo Region, together with the associated infrastructure, starting from 2022. Partners are leading companies in Norway representing the whole value chain, including hydrogen producers, station providers, transport users and purchasers of goods, as well as regional authorities. Learn more at [www.h2truck.no](http://www.h2truck.no).

<sup>2</sup> Nordic Hydrogen Corridor is a study with pilot deployment for the introduction of eight new hydrogen refuelling stations (HRS), one hydrogen production unit, and fuel cell electric vehicles (FCEV) along the TEN-T core network in Sweden in the period 2017-2022, enabling zero emission transport between the capitals of the Nordic countries with fuel cell electric vehicles (<http://www.nordichydrogenpartnership.com/nhc/>).

<sup>3</sup> STRING is a geographical area and a political member organisation in Northern Europe amongst others working strategically to assure sustainable transport connectivity from Hamburg to Oslo (<https://stringnetwork.org/about/>). The GREATER4H project is currently being developed, aiming to deploy refuelling stations and trucks from 2023-2024.

and other equipment have therefore looked more closely towards hydrogen as the primary fuel for such vehicles. A variety of solutions are under development and testing – specifically in the van and truck category.

Now it is time to mobilize transport users to engage in the transition to zero-emission in this segment as well. To do so, the industry must cooperate throughout the value chain in order to:

- 1 Build competence in the whole value chain.
- 2 Build confidence among transport users that hydrogen for heavy-duty transport is a viable solution.
- 3 Build confidence among infrastructure developers that the transport users will use hydrogen trucks.
- 4 Create an ecosystem that is attractive for OEMs when deploying their early trucks.
- 5 Ensure that infrastructure is developed in line with the deployment of trucks so that stations are in place when trucks arrive.
- 6 Show the public actors that there is a common interest to use hydrogen for transport and communicate which framework conditions are needed.

Photo: Bruno Van Der Kraan, unsplash



## 2. Status

In the following sections we present the status for fuel cell heavy-duty vehicles and plans for hydrogen infrastructure development in the Nordic countries. Things are currently developing fast both with respect to vehicle development and infrastructure deployment. Thus, the status described below is to be seen as a snapshot as of December 2021.

### 2.1 Hydrogen truck development picking up speed

Development of hydrogen trucks is now really picking up speed. There are several reasons for this:

Socially, the Paris agreement has started to take effect:

- Announcement/implementation of ambitious international, national, and local regulations to drastically reduce road transport emissions already within a few years are important drivers for customers starting to demand zero-emission vehicles in general.
- “Green” technologies are being debated with respect to scarce material resources, the ethics in the way these materials are made available, and the fact that the huge demand for batteries requires a considerable amount of such very limited resources. Thus, even if some believe batteries will be the answer to everything, there is an international political recognition and willingness to explore multiple pathways as realizing different technologies and diversified exploitation of resources will be needed for the green shift within transport to happen.

Technologically, advantages and disadvantages of the battery electric vehicles (BEVs) and the fuel cell electric vehicles (FCEVs) in the heavy-duty transport segment are highly evident:

- For energy intensive vehicles like trucks, it is far simpler to store the required amount of energy by means of hydrogen compared to batteries.
  - As a result, the payload of a hydrogen truck is comparable to the diesel equivalent, while for the battery version the payload typically is reduced only for the purposes of energy storage. That is not an option for an industry where payload is essential for total cost of ownership (TCO).
  - This trade-off between the payload and the weight of the energy storage limits the range of the battery electric trucks.
- Refuelling a hydrogen truck is a similar experience to refuelling a conventional truck topping up the vehicle in some 15 minutes. For BEVs, charging time will depend very much on the on-site charging capacity but up to 90 minutes should be expected.
- Charging hubs with on-site mega chargers (~1 MW chargers) for BEVs requires strong transmission lines and an add-on capacity normally not readily available in most grids without notice. For FCEVs, on-site hydrogen production is an option but as for conventional fuels hydrogen can be transported to the energy station.

## 2.2 Vehicles

A variety of solutions are under development and testing – specifically in the van and truck category. OEMs from Asia (Hyundai) and the US (Nikola via Iveco) now entering the European market, giving the traditional European brands a tough competition. OEMs are establishing new partnerships to develop core technology for their hydrogen trucks, like cellcentric, the joint venture of Volvo and Daimler developing fuel cells. Retrofit of trucks with hydrogen and fuel cell systems becomes available, and some OEMs are exploring the possibilities for using hydrogen in a modified internal combustion engine.

The most ambitious investment in hydrogen trucks in Europe so far is taking place in Switzerland. Hyundai will deliver 1,000 XCient trucks until 2023. The first 46 are already in operation. The large number of pilot projects now taking place in several European countries will probably deploy hundreds of trucks by 2025. *Figure 1* shows some of the trucks which are expected also on Nordic roads within the near future.

Hydrogen trucks is still a very young market, and only the first steps have been taken. However, the prospect for such vehicles is large and cost is expected to drop relatively fast since technological advancement from bus and passenger vehicle development can be taken directly into the truck program. The costs are still high, just as at the onset of BEV and FCEV introduction some years ago. Already BEVs are closing the cost gap but the FCEVs have a slightly longer time until fully competitive.

## 2.3 Infrastructure

Hydrogen stations have up to recently been built to distribute hydrogen for passenger vehicles. Now, the focus is more on the commercial vehicles. This is of great importance for how the further establishment of hydrogen stations will take place. Hydrogen will be delivered to vehicles where the demand is and based on a viable business model. Several important issues need to be considered:

- 1 Where should stations be located?
- 2 Who are the users?
- 3 Should the station serve both passenger and commercial vehicles?
- 4 What sort of hydrogen should be delivered; 350 bar, 700 bar, or liquified hydrogen?
- 5 What capacity is needed, and how can it be increased in line with the demand?

*Figure 2* shows the current locations of hydrogen refuelling stations in Europe. Most of the hydrogen stations are dedicated to passenger vehicles and can only deliver hydrogen at 700 bar. Some stations are dedicated to buses, dispensing hydrogen at 350 bar. Germany is leading the way in Europe, with 91 stations in operation by December 2021. The total demand at these

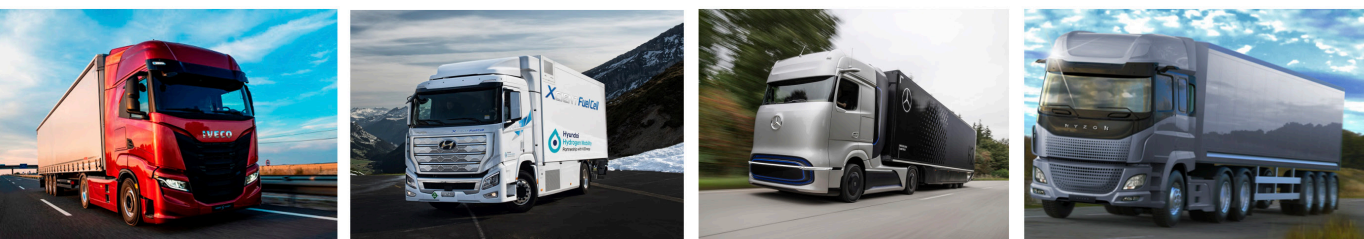


Figure 1. Some of the hydrogen trucks that soon are expected to the Nordics. From left Iveco S-Way (Nikola Tre), Hyundai Xcient, Mercedes-Benz GenH2 and Hyzon. Photo: Iveco, Hyundai Hydrogen Mobility, Daimler, and Hyzon.

stations were 21.7 tonnes in November 2021<sup>4</sup>. Commercial hydrogen vehicles can refuel at six 350 bar stations in Germany<sup>5</sup>. From 2021, hydrogen stations in Germany are set up primarily where demand for commercial vehicles is expected in the short term and where a public refuelling station would make sense for a growing network of refuelling stations for passenger cars as well. This seems to be the approach that most operators now use when establishing stations. Thus, use of hydrogen in heavy-duty transport will pave the way for use in other segments as well in the years to come.

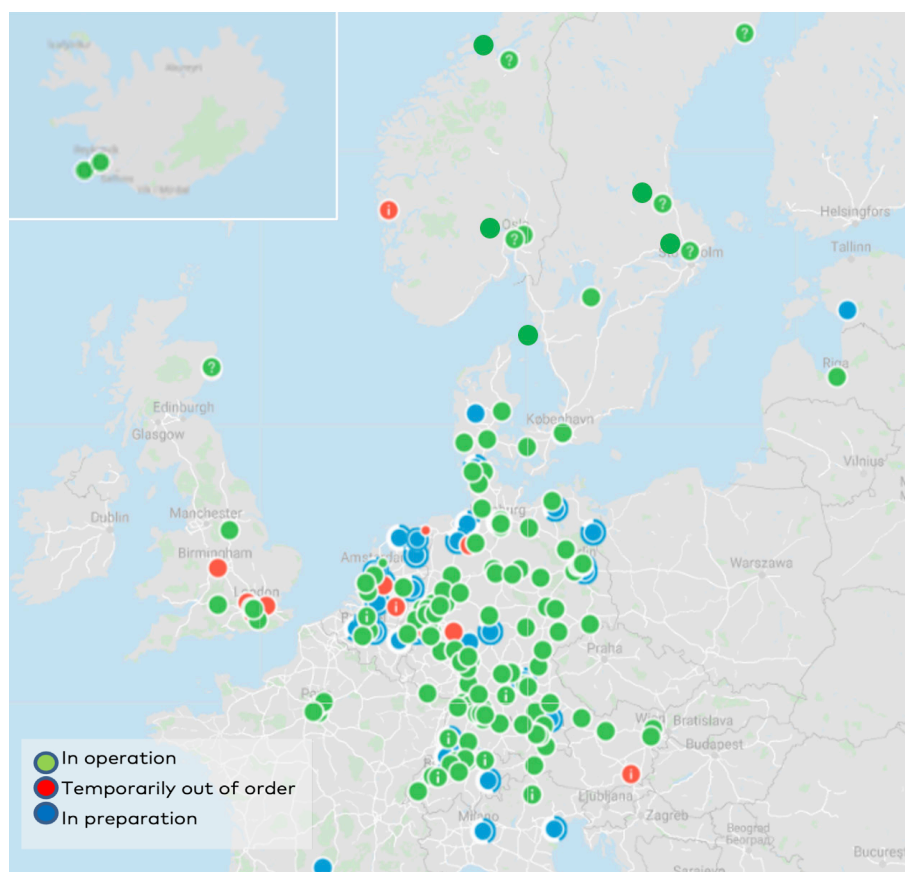


Figure 2. Hydrogen stations in Europe by December 2021. Source: <https://h2.live>.

<sup>4</sup> <https://h2.live>

<sup>5</sup> <https://h2.live/en/netzausbau>

### 2.3.2 Modular development of hydrogen refuelling stations

Hydrogen refuelling stations (HRS) are built on a modular basis so that capacity can be expanded as demand increases. Capacity utilization is an important factor in gaining profitability. At the same time, large volumes are a way to reduce unit costs. The price per kilogram to produce hydrogen is normally lower at higher volumes. Thus, in the early phase it is important to find the balance between capacity of the station and the expected increase in demand.

Figure 3 shows an example of how a HRS can be expanded in a modular way. The first step is a station with a dispensed hydrogen capacity of 300 kg/day, which is then expanded stepwise to a daily capacity of 2,100 kg, 4,200 kg, and 7,800 kg, respectively. In this example, the station at the final stage includes 12 dispensers for refuelling at 350 bar and nine dispensers for refuelling at 700 bar.

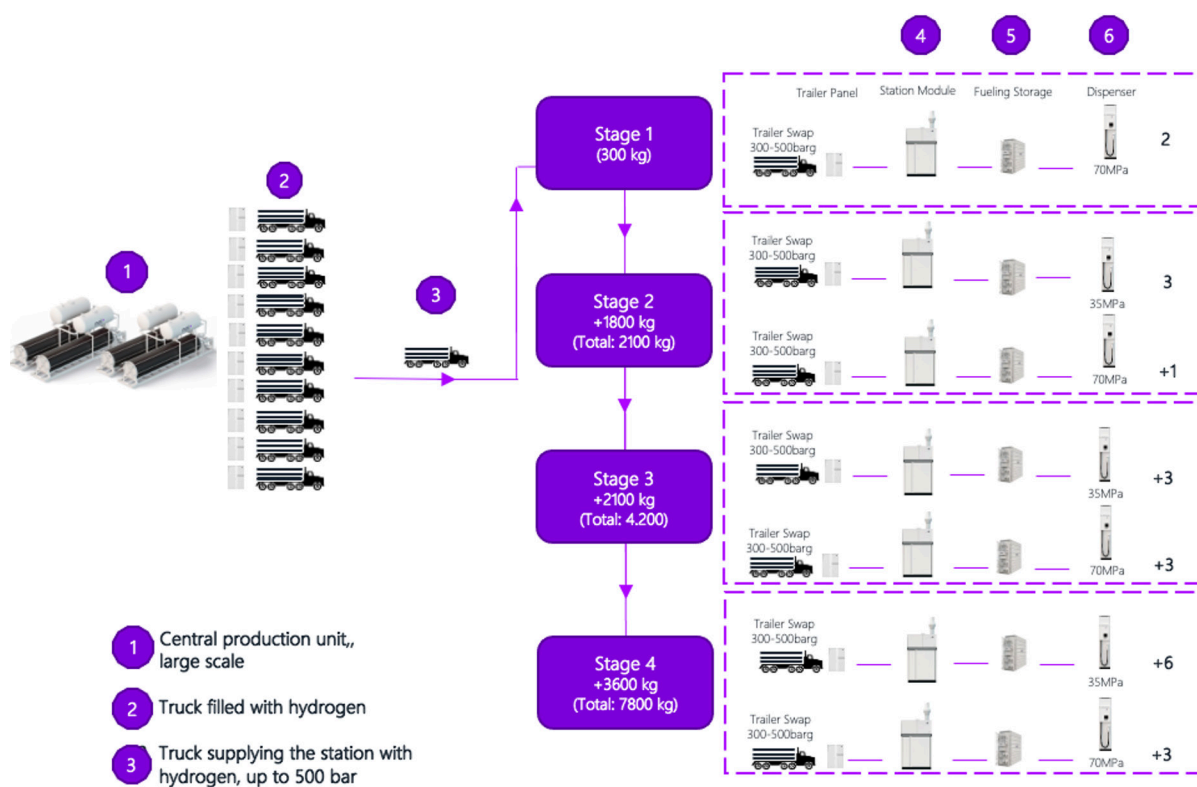


Figure 3. The principle of a hydrogen refuelling station, and an example of how the station can be expanded step by step in line with an increasing demand. Source: Nel Hydrogen.

### 2.3.3 Hydrogen refuelling station cost

The HRS in *Figure 3* distribute hydrogen produced at a central, large scale production unit. Hydrogen may also be produced by electrolysis at the station. This eliminates transport costs but may at the same time increase the investment (CAPEX) and operational costs (OPEX) per kg hydrogen. Large-scale production with distribution to several stations seems to be the preferred solution for development of hydrogen refuelling stations in the Nordics<sup>6</sup>.

The cost of a hydrogen station depends on production method and several other elements. Everfuel<sup>7</sup> has provided the following cost estimate based on the example given in *Figure 3*:

- Station with one 350 bar or one 700 bar dispenser, including one transport panel, storage tanks, station module, and installation: approximately 1.5 M€.
- Electrolyser with a capacity of 4 tonnes of hydrogen per day: approximately 8 M€.

The cost is expected to decrease as the number of stations increase.

### 2.3.4 How many vehicles can one station serve?

The capacity of a hydrogen station depends on several issues, as the total amount of hydrogen available, capacity of storage tanks at different pressure levels, capacity of compressors, number of dispensers, and cooling capacity. In *Table 1*, an estimated number of vehicles that can be refuelled from various sizes of stations are shown assuming only one type of vehicle uses the station, i.e., not a multi-purpose station. For passenger cars, information is adopted from Hynion AS, while for taxis, buses, and trucks, the estimates are based on the expected on-board hydrogen storage capacity of these vehicles and their usage patterns. The demand for hydrogen will not be evenly distributed throughout the day. Therefore, the station must be dimensioned also for operational peaks during the day. Simultaneous capacity during rush-hours, for instance in the morning, is a main challenge for station dimensioning.

Passenger cars is a challenging segment when it comes to infrastructure development. There is little loyalty to a station among car owners, you can refuel the vehicle wherever there is a station. It is difficult for the operator to schedule for the demand, with a high risk of limited capacity utilization resulting in low profitability. For buses, the situation is different. They travel fixed routes and refuel at the depot, giving a predictable volume. Many trucks also run fixed routes; starting and ending at the depot. Thus, buses and trucks are preferred segments when developing infrastructure, giving a greater opportunity for profit.

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<sup>6</sup> Other Next Wave-reports related to this topic available from <http://www.nordichydrogenpartnership.com/nextwave/rapporter/> are: 1) Available by-product hydrogen in the Nordic countries, 2) Large-scale hydrogen use in Nordic industry 2020 – 2030, 3) Nordic transport regulations for large-scale hydrogen transport, and 4) Perspectives and potentials for hydrogen & fuel cell buses in the Nordic region.

<sup>7</sup> Everfuel Norway, November 2020.

Table 1. Estimated number of vehicles that can be refuelled based on the hydrogen station capacity assuming an average number of kg per refuelling for the various vehicles (Source: Evig Grønn AS<sup>8</sup> and Hynion AS)

| kg per fuelling →          |  |  |  |  |
|----------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Station capacity (kg)<br>↓ | 3.4                                                                               | 6                                                                                 | 30                                                                                  | 30                                                                                  |
| <b>150</b>                 | 25                                                                                | 25                                                                                | 5                                                                                   | 5                                                                                   |
| <b>500</b>                 | 147                                                                               | 83                                                                                | 16                                                                                  | 16                                                                                  |
| <b>1,000</b>               | 294                                                                               | 166                                                                               | 33                                                                                  | 33                                                                                  |
| <b>2,100</b>               | 617                                                                               | 350                                                                               | 70                                                                                  | 70                                                                                  |
| <b>4,200</b>               | 1,234                                                                             | 700                                                                               | 140                                                                                 | 140                                                                                 |

### 2.3.5 Hydrogen production

The market price of electricity in the Nordics, in large arriving from renewable sources, is relatively low. Thus, hydrogen production by electrolysis can become a viable green near-term option for replacing current fossil fuel-based hydrogen production. In addition, the possibility of increasing renewable electricity production, especially wind power, opens possibilities for new industry based on green hydrogen in all Nordic countries.

The use of larger hydrogen vehicles, not only in heavy-duty distribution and transport, but in buses, vans, lorries, and the like, would demand a considerable amount of hydrogen. Economically, large-scale production is vital for hydrogen as scale has massive impact on CAPEX and OPEX when it comes to hydrogen production. Use of hydrogen in heavy-duty applications will therefore stimulate potential large-scale production of hydrogen and make the cost of such production competitive to fossil fuel in most of the Nordic countries. Hydrogen can therefore become cost competitive today with fossil fuel if it is at scale. The opportunities for the Nordic countries to boost the use of green fuels in heavy-duty transport are therefore unique both from an environmental as well as an economical point of view.

Finally, the existing hydrogen industry itself in the Nordic countries must be considered, one which is world leading in the construction of hydrogen infrastructure, production, storing, and refuelling.

<sup>8</sup> Statusrapport for hydrogen, December 2020. <https://www.eviggronn.no/statusrapport-for-hydrogen-inkludert-mulighetsstudie-vestfold-og-telemark/>

## 2.4 Barriers and incentives

Hydrogen represents an industrial opportunity for Nordic companies. So far, however, there has been lack of clear political signals that provide long-term perspective and security for the many actors who are ready to invest in and use hydrogen. There are also several possible barriers along the value chain, as described in *Table 2*.

*Table 2. Possible barriers and challenges for use of hydrogen in heavy-duty transport*

| Part of Value Chain  | Barrier / Challenge                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Production</b>    | 1. Cost per kilogram hydrogen produced decreases when production volume increases. The need for hydrogen in land transport should be considered in connection with other segments, especially industry and maritime transport, so that synergies with these can be utilized.                                                                                                                                                   |
| <b>Distribution</b>  | 1. The costs of transporting hydrogen from a central production site to a hydrogen station.<br>2. CAPEX per station.<br>3. Lack of network of stations.<br>4. Lack of demand for hydrogen.                                                                                                                                                                                                                                     |
| <b>Trucks / OEMs</b> | 1. Limited availability of trucks.<br>2. Cost of trucks.<br>3. Cost of operating trucks.                                                                                                                                                                                                                                                                                                                                       |
| <b>Use of trucks</b> | 1. Service and maintenance for the trucks must be established.<br>2. Limited knowledge of technical solutions and which drivetrains should be pursued.<br>3. New/unfamiliar brands are the first available. Limited trust among users.<br>4. Confidence in that hydrogen is a viable drivetrain (long-term policy, availability, technology, resale value).                                                                    |
| <b>Others</b>        | 1. Municipal regulatory processes can be time-consuming.<br>2. Areas for hydrogen stations are hard to find, especially in urban areas.<br>3. The need for holistic solutions to trigger action throughout the value chain is a significant barrier - the actors in each part of the value chain must be confident that there will be simultaneous solutions in other parts of the value chain to be able/confident to invest. |

Infrastructure for hydrogen refuelling is a particularly important barrier. Currently, only a few stations are available in the Nordics. In addition to support from public sector, there is a need for stronger coordination among future users, related to what a basic refuelling network should look like.

Vehicles also constitute a particularly important barrier. High cost in the initial stage makes the hydrogen trucks 3-5 times more expensive than today's diesel trucks, and the resale value of a hydrogen truck is highly unclear. Efforts must be made in each part of the value chain, from hydrogen production and distribution to service and maintenance of trucks, to make the TCO competitive.

A fragmented company structure in the transport industry, together with only a handful of large players, makes the financial barrier even more demanding. In Norway for instance, 7 out of 10 transport companies operates less than five

trucks<sup>9</sup>. It should be an important goal for the Next Wave project and other early initiatives to ensure that all players in the transport industry have the same opportunity to use zero-emission trucks - not only the large companies.

### 2.4.1 Framework conditions and instruments

The EU regulation on CO<sub>2</sub> emissions for heavy-duty vehicles (2019/1242) entered into force on August 14, 2019. From 2025 onwards, OEMs will have to comply with the targets set for fleet-wide CO<sub>2</sub> emissions to be reduced by 15%, and from 2030 onward by 30%, compared to the reference period 2019/2020. These requirements are so ambitious that they will not be met through the efficiency of the internal combustion engine alone. Zero-emission vehicles are given an extra advantage in the emission calculations, so that manufacturers have an extra motivation to develop such vehicles. It is the heaviest trucks that have the largest emissions, and it is in this segment that hydrogen is most relevant. This emphasizes the need to facilitate the use of hydrogen. The CO<sub>2</sub> targets for heavy-duty vehicles are currently on public consultation, and the Commissions adoption is planned for fourth quarter 2022<sup>10</sup>.

Along with the standards for the OEMs, other directives and standards also put pressure on EU/EEA Member States to facilitate emission-free transport. *The Alternative Fuels Infrastructure Directive* (AFID), now being transformed to a regulation (AFIR), the *Renewable Energy Directive* and the *Energy Taxation Directive* will further strengthen the focus on emission-free transport. Figure 4 shows some of the relevant standards and directives.

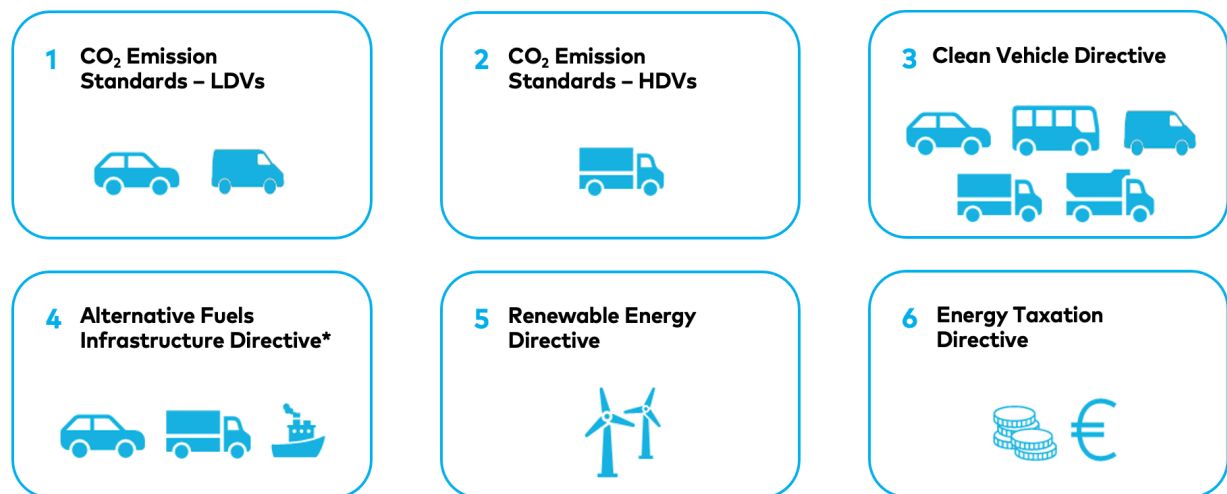


Figure 4. Some standards and directives in the EU that are important for the development and use of zero-emission vehicles in Europe. The *Alternative Fuels Infrastructure Directive* is now transformed to a regulation. Source: Hydrogen Europe.

<sup>9</sup> Sigrun Gjerløw Aasland, CEO Zero, at Zerokonferansen 2021, November 24, 2021.

<sup>10</sup> [https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13168-Reducing-carbon-emissions-review-of-emission-standards-for-heavy-duty-vehicles\\_en](https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13168-Reducing-carbon-emissions-review-of-emission-standards-for-heavy-duty-vehicles_en)



Photo: hpgruesen, Pixabay

## 2.4.2 Alternative Fuel Infrastructure Regulation (AFIR)

*Directive 2014/94/EU on the deployment of alternative fuels infrastructure (AFID)* sets out a framework of common measures for the deployment of such infrastructure in the EU. It requires Member States to set up national policy frameworks to establish markets for alternative fuels and ensure that an appropriate number of publicly accessible recharging and refuelling points is put in place, particularly also to enable free cross-border circulation of such vehicles and vessels on the TEN-T network.

An evaluation of the directive carried out by the Commission in 2021, showed that a comprehensive and complete network of alternative fuels infrastructure does not exist across the EU. It was concluded that the Directive is not well-adapted to the purpose of serving the increased climate ambition for 2030. Targets for infrastructure for hydrogen was optional in the Directive and was not part of the national policies for several countries.

This has led to the creation of a new *Regulation for the deployment of alternative fuels infrastructure (AFIR)*. A proposal for the regulation was up for public consultation during the autumn of 2021<sup>11</sup>. The proposal is part of the overall set of interlinked policy initiatives under the "Fit for 55" package. According to the proposal, the Member States should notify a national policy framework for the development of the market as regards alternative fuels in the transport sector and the deployment of the relevant infrastructure by January 1, 2025.

<sup>11</sup> [https://ec.europa.eu/info/sites/default/files/revision\\_of\\_the\\_directive\\_on\\_deployment\\_of\\_the\\_alternative\\_fuels\\_infrastructure\\_with\\_annex\\_0.pdf](https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf)

The proposal sets these targets for hydrogen refuelling infrastructure of road vehicles (Article 6):

- 1** Member States shall ensure that, in their territory, a minimum number of publicly accessible hydrogen refuelling stations are put in place by 31 December 2030.  
To that end Member States shall ensure that by 31 December 2030 publicly accessible hydrogen refuelling stations with a minimum capacity of 2 t/day and equipped with at least a 700 bars dispenser are deployed with a maximum distance of 150 km in-between them along the TEN-T core and the TEN-T comprehensive network. Liquid hydrogen shall be made available at publicly accessible refuelling stations with a maximum distance of 450 km in-between them.  
They shall ensure that by 31 December 2030, at least one publicly accessible hydrogen refuelling station is deployed in each urban node. An analysis on the best location shall be carried out for such refuelling stations that shall in particular consider the deployment of such stations in multimodal hubs where also other transport modes could be supplied.
- 2** Neighbouring Member States shall ensure that the maximum distance referred to in paragraph 1, second subparagraph is not exceeded for cross-border sections of the TEN-T core and the TEN-T comprehensive network. The operator of a publicly accessible refuelling station shall ensure that the station is designed to serve light-duty and heavy-duty vehicles.
- 3** In freight terminals, operators or owners of these publicly accessible hydrogen refuelling stations shall ensure that these stations also serve liquid hydrogen.

The regulation also sets requirements about payment methods, prices, and price information. The regulative is expected to be adopted by the Commission within the first half of 2022.

### 2.4.3 Current incentives in the Nordics

Cities and regions are frontrunners in taking actions for clean fuel deployment. For several years, the City of Oslo has been committed to reduce emissions from passenger vehicles. Per 2020, 62% of all new registries of passenger vehicles in Oslo were battery electric. The city is now aiming for a similar transition for the commercial vehicles where the project Pilot City for Zero Emission Heavy-Duty Transport is the main action. The city will use its purchase power to demand zero-emission transport, facilitate areas for infrastructure, use different incentives and cooperate with the industry to achieve the goals. The same leadership is seen in other Nordic cities and regions as well.

Another example is the guidance to common environmental requirements for developers<sup>12</sup> made by The Swedish Road Administration together with Stockholm, Gothenburg, and Malmö aiming at reduced emissions during construction work within the cities.

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<sup>12</sup> [https://tekniskhandbok.goteborg.se/wp-content/uploads/Vagledning-till-gemensamma-miljokrav-for-entreprenader\\_2021-04.pdf](https://tekniskhandbok.goteborg.se/wp-content/uploads/Vagledning-till-gemensamma-miljokrav-for-entreprenader_2021-04.pdf)

Incentives for hydrogen in transport in the Nordics per December 2021 are shown in *Table 3*.

*Table 3. Incentives for hydrogen in transport in the Nordics per December 2021*

| Incentives: hydrogen for transport | NO                                                                                                               | SE                                                                                                                                   | DK                                                                                                                     | FI                                                            | IS                                                                                                        |
|------------------------------------|------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| <b>Purchase of trucks</b>          | Enova: No specific program, but possible to get 40% of additional cost                                           | Energimyndigheten: 20% funding of investment                                                                                         | No specific subsidy for trucks. Can be a part of larger demo.                                                          | No specific subsidy for trucks. Can be a part of larger demo. | 100% depreciation in year 1. No VAT. Reduced annual fee. No excise tax for ZE trucks. No current funding. |
| <b>Purchase of buses</b>           | Same as for trucks                                                                                               | Energimyndigheten: 20% funding of investment from 2022.                                                                              | Same as trucks – but public tenders almost all ZE                                                                      | Same as for trucks                                            | Same as for trucks                                                                                        |
| <b>Hydrogen stations</b>           | Enova: No specific program, but possible to get 40% of cost. Must be related to purchase of trucks               | Naturvårdsverket – Klimatklivet: up to 70% funding of investment                                                                     | No specific subsidy but tender for ZE infrastructure 72 mill DKK and 225 mill DKK underway                             | No specific subsidy for HRS. Can be a part of larger demo.    | No incentives.                                                                                            |
| <b>Annual CO<sub>2</sub> tax</b>   | Annual tax is 0, - for ZEVs and only 378 NOK for HD diesel trucks. CO <sub>2</sub> -tax is 159, - NOK/ton (2021) | Currently 107 SEK/g CO <sub>2</sub> for range 90-130 g/km and 132 SEK/g for emissions above 130g/km according to official test cycle | Part of fuel tax – no general CO <sub>2</sub> -tax but underway as part or "green tax reform" to be negotiated in 2022 | No annual car tax since 1.10.2021                             | Gasol + diesel 11,75 ISK/L<br>Gasoline 10,25 ISK/L<br>Fuel oil 14,45 ISK/kg<br>Fossil gas 12,85 ISK/kg    |
| <b>Toll roads</b>                  | Exemption                                                                                                        | No exemption based on emissions                                                                                                      | CO <sub>2</sub> -based MAUT for trucks planned in principle from 2025                                                  | No toll roads in Finland                                      | Full payment                                                                                              |
| <b>National ferries</b>            | Exemption                                                                                                        | No exemption based on emissions                                                                                                      | Program underway – tender completed but not yet public                                                                 | Not relevant                                                  | Full payment                                                                                              |
| <b>Zero emission zones</b>         | Being considered in some large cities                                                                            | No zones yet                                                                                                                         | Legal framework on its way through parliament                                                                          | No such zones in Finland                                      | N.A.                                                                                                      |

## 2.4.4 What measures are needed?

Instruments are usually considered for separate parts of the value chain. Individually, these can be optimized. However, it is equally important to look at the totality. In the end, the total cost of ownership (TCO) is the most important to the users of hydrogen trucks. Incentives in different parts of the value chain may all have a positive effect on TCO.

The same situation was the reality a decade ago during the introduction of BEVs in the Nordic countries. With coordinated efforts from industry and governments, it was possible to overcome all these barriers in a short time. Governments created incentives, utilities participated in building the infrastructure which together caught the attention of the car producers which in return provided the Nordic countries with more BEVs than most other market areas. As a result, Norway and Iceland lead the sales of pure BEVs in the world today.

Now, the same must be done for larger vehicles. Incentives need to be put in place to lower the TCO to attract customers. With increasing demand, the infrastructure will be built. Building the hydrogen infrastructure will not be too hard as that industry is actually situated in the Nordic countries. And, since heavy-duty vehicles have high energy demand, the economics of such stations make sense even with a modest fleet of some 20+ large vehicles parish to it. Below, some of the most relevant measures are elaborated:

## **1 The national authorities should show long-term ambitions for use of hydrogen for heavy-duty transport**

The National and local ambitions for reduction of greenhouse gas emissions in the transport sector are high in all Nordic countries. The ambitions must be followed by actions and support schemes in the policy instruments. Authorities must show a long-term commitment to facilitate the use of hydrogen in the transport sector.

The public can also contribute by introducing standard demands for use of zero-emission transport or biogas for all public procurement in the vehicle segments where this is available. A good example is the standard requirements that the City of Oslo has introduced, requiring fossil-free and zero-emission transport in all tenders. This should apply both to the purchase of own vehicles, and to deliveries of goods and services to the public sector, including construction assignments.

## **2 Funding must be granted for the acquisition of the first hydrogen trucks**

Public funding should be offered for the acquisition of hydrogen trucks at an early stage. Leasing of trucks is widely used, and the pay-per-km model seems to be relevant in the early stage of deployment of hydrogen trucks. Funding schemes should reflect this. Public funding should also be available for commercial vans and passenger cars used in fleets, e.g., for taxis and courier cars. These are segments that will help increase the use of the stations and make them more profitable. Several users in these segments are also dependent on hydrogen as a fuel to achieve the necessary range and operational continuity that the practice of the profession requires.

Germany has notified a federal aid scheme for the acquisition of light and heavy commercial vehicles with alternative, climate-friendly propulsion systems and ancillary EV charging facilities<sup>14</sup>. The scheme offers a premium of a maximum of 80% of the price difference between a commercial vehicle with an electric or hydrogen drivetrain, and a maximum of 80% of the investment costs for charging and refuelling facilities for these vehicles.

## **3 Long-term benefits must be established for use of hydrogen trucks**

The larger vehicle incentives will have to be different than for passenger (private) vehicles as for instance revoking VAT will not have the same impact. With the right incentives, OEMs building these trucks will prioritize the Nordic market, knowing also that the hydrogen used in the region is green. Within 5-10 years, the same can be evident for hydrogen-powered larger vehicles as is evident when it comes to sales of BEVs today.

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<sup>14</sup> [https://ec.europa.eu/competition/elojade/isef/case\\_details.cfm?proc\\_code=3\\_SA\\_59352](https://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=3_SA_59352)

Examples of relevant measures:

- Exemption on road toll and national ferries until 2030, and then a maximum of 50% of regular fee.
- Access to bus lanes or zero-emission lanes, reserved parking, and reserved and timely favoured delivery of goods.
- Increased annual fee for diesel trucks.
- Differentiated depreciation between zero-emission and fossil fuelled trucks.
- Introduction of zero-emission zones.

#### **4 Increased CO<sub>2</sub> tax sourced to fund acquisition of zero-emission vehicles**

The *polluter-should-pay* principle is crucial for the introduction of zero-emission road transport. The CO<sub>2</sub> tax should be increased, and the tax facilities should be considered for reversing the increased CO<sub>2</sub> tax in the transport sector to climate measures in the industry.

#### **5 Support should be granted for an initial network of hydrogen stations**

National funding agencies should support programs for the establishment of a network of hydrogen stations. This must apply to stations in urban regions, taking into account where the heavy-duty transport hotspots are located, and in corridors between cities (typical logistics routes). Such a program will provide the necessary security for both infrastructure players and truck users to make costly investments at an early stage. Nordic funding instruments could be used to ensure that the infrastructure enables cross-border transport. This would further stimulate the transport companies to use hydrogen.

#### **6 Production of hydrogen should be supported at an early stage**

Combined large-scale hydrogen production sites for industrial and maritime use as well as road transport is an interesting approach to come to scale and thus reduce the production cost. However, in the early phase, production must also be established within a limited distance to the hydrogen stations. These production facilities will have to start with a moderate capacity and then increase in line with the demand. The facilities should receive support in the establishment phase, and the grid companies should be regulated to offer «industrial large-consumer» grid rent.

Contract for Difference (CfD) seems to be a good alternative to ensure that green hydrogen becomes competitive. This is now considered as an instrument in several European countries.

#### **7 Coordinated deployment and competence building should be supported**

It is important to bring together the players in the entire value chain for a coordinated investment in hydrogen for heavy-duty transport. The first trucks and the early infrastructure need to be deployed hand in hand, and in a public-private partnership.

Funding must be offered to support the coordination and for cross-cutting issues such as dissemination of knowledge, mobilization of users, and cross-border development of corridors. This will help the

smaller players in the transport industry to switch to hydrogen trucks more quickly. The *Next Nordic Green Transport Wave - Large Vehicles* project is a good example of such activity.

Joint approach by Nordic governments – providing similar incentive packages could create a major momentum. If the Nordic countries approach the truck manufacturers jointly to deploy a larger number of vehicles, we will be strong enough to gain interest from the OEMs, and the price of the trucks will drop fast. Already there is an example of this from Switzerland where governmental incentives have created a hub for Hyundai to deploy 1,000 zero-emission hydrogen trucks over the next 2-4 years<sup>15</sup>. Breaking these barriers has been done before and can easily be done again, drastically stimulating the use of green hydrogen instead of fossil fuel in a heavy polluting transport segment.

Photo: Wolfgang Hasselmann, Unsplash



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<sup>15</sup> See for example: <https://fuelcelltrucks.eu/hyundai-ships-first-hydrogen-trucks-to-switzerland/>

## 3. The Nordic Countries - status and ambitions

### 3.1 Norway

Road transport represents 17% of the total CO<sub>2</sub> emissions in Norway in 2020<sup>16</sup>. Transport in total represents 32% of the CO<sub>2</sub> emissions, *Figure 5*.

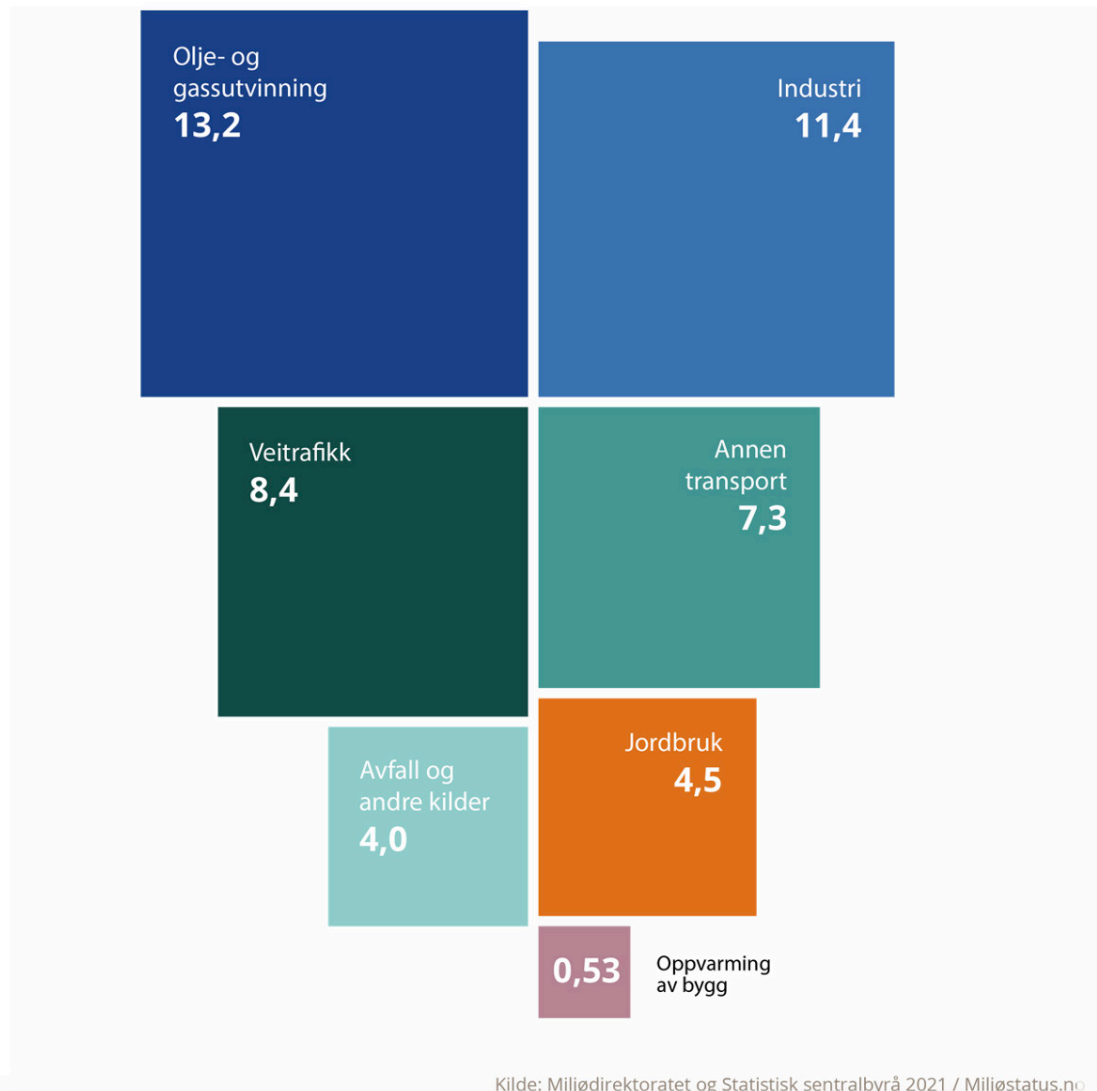


*Figure 5. CO<sub>2</sub> emissions in million tonnes CO<sub>2</sub>-equivalents in Norway per 2020. Road transport represents 17%. Source: Environment Norway.*

<sup>16</sup> <https://miljostatus.miljodirektoratet.no/tema/klima/norske-utslipp-av-klimagasser/klimagassutslipp-fra-transport/>

### 3.1.1 National targets

The most relevant national targets with respect to zero-emission transport in general, and hydrogen ambitions specifically, can be summarised as follows:

|                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>National Transport Plan 2022-2033 (adopted June 2021)</b>   | <b>Some relevant zero-emission targets</b> <ul style="list-style-type: none"> <li>• 2025: <ul style="list-style-type: none"> <li>– 100% of new passenger cars, light-duty vehicles, and city buses should be zero-emission.</li> </ul> </li> <li>• 2030: <ul style="list-style-type: none"> <li>– 100% of new heavy distribution vans,</li> <li>– 75 % of new long-distance buses, and</li> <li>– 50 % of new heavy-duty trucks should be zero-emission.</li> </ul> </li> <li>• New car ferries and high-speed passenger ferries to use low- or zero-emission technology when technology is ready for use.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Roadmap for hydrogen (presented June 2021)<sup>17</sup></b> | <p><i>Until 2030, heavy-duty transport by road based on hydrogen may become more relevant if trucks with a high total weight (&gt;50 tonnes) and a long range (&gt;500 km) becomes available.</i></p> <p><b>Ambition in the short term, until 2025:</b><br/> Support technology development through piloting and demonstration projects for the production and use of clean hydrogen in maritime transport, heavy-duty road transport, and industry. The projects contribute to early market introduction and market development and facilitate the development of geographical hydrogen hubs. The government will facilitate that:</p> <ul style="list-style-type: none"> <li>a) Five hydrogen hubs for maritime transport are established, with opportunities for the development of associated road transport solutions based on hydrogen.</li> <li>b) One or two industrial projects with associated production facilities for hydrogen are established, with the intention of demonstrating value chains with global dispersal potential.</li> <li>c) Five to ten pilot projects are established for the development and demonstration of new and more cost-effective hydrogen solutions and technologies.</li> </ul> |

<sup>17</sup> The roadmap is part of governments report to the national assembly: Energi til arbeid – langsiktig verdiskaping fra norske energiressurser  
<https://www.regjeringen.no/contentassets/3d9930739f9b42f2a3e65adadb53c1f4/no/pdfs/stm202020210036000dddpdfs.pdf>

### 3.1.2 Transport corridors

A schematic overview of the main transport corridors of Norway is given in *Figure 6*.

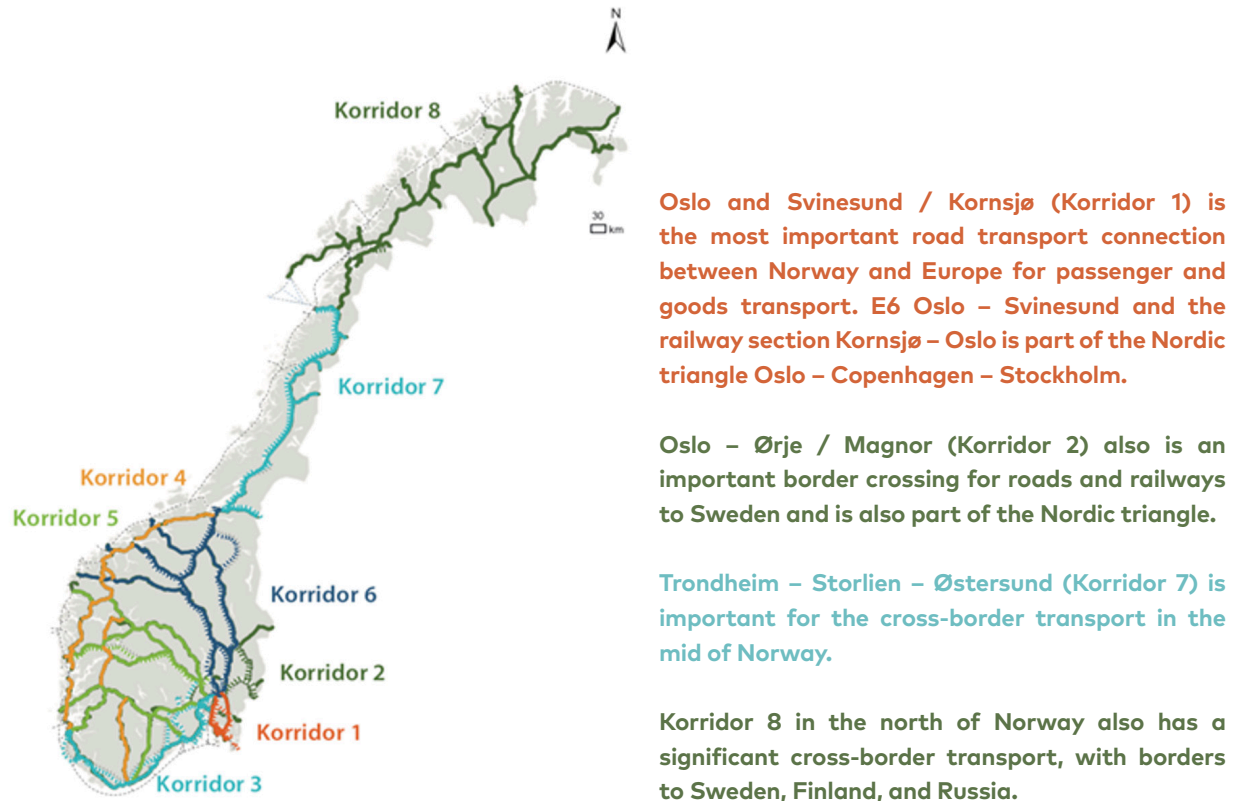


*Figure 6. Schematic of the main and international transport corridors of Norway. The colour of the text represents the corridors in the figure. Source: National Transport Plan 2022-2033<sup>18</sup>.*

Except within wood and mining/quarry industry, cross-border rail transport of freight is marginal, and even if the maritime freight transport to and from Norway is increasing, domestic maritime freight transport is almost non-existing. As a result, heavy-duty road transport in Norway continues to increase. In fact, almost every seventh vehicle on Norwegian roads is a heavy-duty vehicle (vehicle  $\geq 5.6$  meter)<sup>19</sup>. The total number of light- and heavy-duty trucks in Norway per 2020 was 70,670<sup>20</sup>.

The Institute for Transport Economics (TØI) assumes that there will be a growth in freight transport work in Norway of 32% from 2018 to 2040. The highest growth is expected to be in the road network and in ferry traffic, with a growth of 45% and 59%, respectively. Road traffic with heavy-duty vehicles is increasing more in the Oslo region than in the rest of the country.

<sup>18</sup> <https://www.regjeringen.no/no/dokumenter/meld.-st.-20-20202021/id2839503/>

<sup>19</sup> <https://www.osloregionen.no/wp-content/uploads/Gods-og-logistikk-i-Osloregionen-rapport-fra-arbeidspakke-1.pdf>

<sup>20</sup> <https://www.ssb.no/statbank/table/11823/>

Infrastructure for cross-border transport should be developed in line with the deployment of the first trucks. The axis Oslo – Gothenburg, further down to Hamburg, and to the rest of Europe is the most important and should be developed first. This makes up a good match between the H2 Truck project and the two most relevant international projects for Norway: the Nordic Hydrogen Corridor and the GREATER4H projects. The further development of cross-border infrastructure will depend on where the first trucks will be operating.

### 3.1.3 Relevant initiatives

Everfuel and Hynion are operating hydrogen stations in Norway. Both companies have ambitious plans for establishing several stations making up the initial network in the country. The H2 Truck project<sup>21</sup> brings together more than 20 partners from the complete value chain, including the largest transport users and purchasers of goods and services. The aim is to bring the first 100+ hydrogen trucks on the road in the Oslo region, together with associated infrastructure.

MoZEES (Mobility Zero Emission Energy Systems<sup>22</sup>) is a research centre hosted by Institute for energy technology (IFE) and including the leading Norwegian institutes and universities for transport research, such as SINTEF, Institute for Transport Economics (TØI), and Norwegian University of Science and Technology (NTNU). The partners have extensive competence on hydrogen, batteries, energy systems, and the societal aspects of introducing zero-emission transport. In total, MoZEES comprise some 40+ partners including national and international industry companies throughout the value chain.

The Norwegian Hydrogen Forum is secretariat for the Hydrogen County Network which includes 9 out of 10 counties in Norway as well as some municipalities<sup>23</sup>. This cooperation could be valuable for the regional development of hydrogen infrastructure and deployment of trucks in Norway.

### 3.1.4 Other segments that can be relevant

The government's roadmap for hydrogen focuses on maritime transport and the industry. These are important segments for development of hydrogen-based road transport as well. Several maritime pilot projects are being developed. The use of hydrogen in ports is of special relevance and will probably be important for accelerating the use in heavy-duty transport.

As reported in the *Next Wave Deliverable 2.1*, in Norway, a large amounts of by-product hydrogen are produced within a few defined industries such as refineries and chemical industries. Earlier, for instance, the HRS in Porsgrunn was fed fuel cell-grade hydrogen from the INOVYN's VCM-factory at Rafnes. If economically viable, in the future we may again see industrial by-product hydrogen finding its way to the refuelling dispensers.

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<sup>21</sup> <https://www.h2truck.no>

<sup>22</sup> <https://mozees.no>

<sup>23</sup> <https://www.hydrogen.no/norsk-hydrogenforum/medlemmer/>



Photo: Schwoaze, Pixabay

## 3.2 Sweden

The greenhouse gas emissions within Sweden are shared between the different sectors according to *Figure 7*. In 2019, the transport sector counted for 32% of the total emissions.

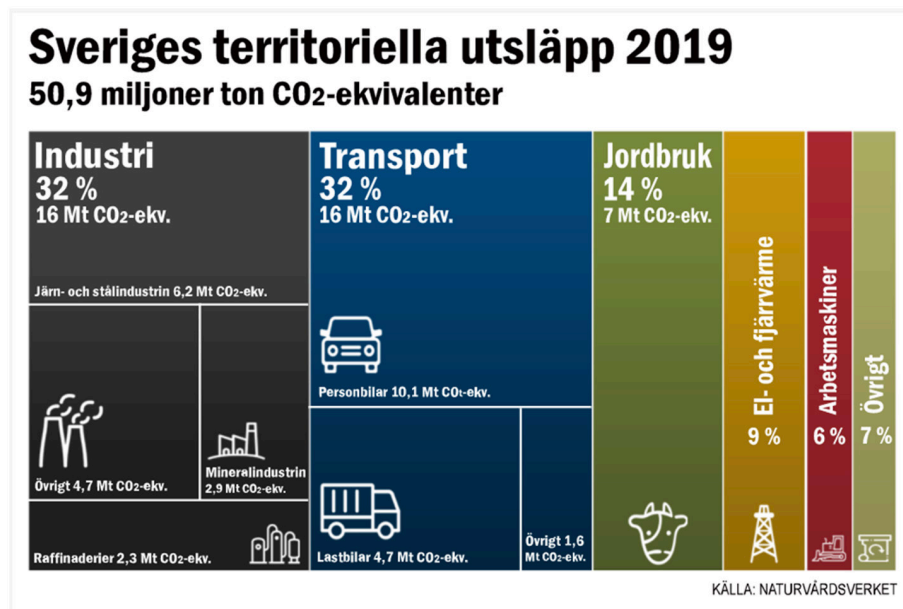


*Figure 7. Distribution of the Swedish greenhouse gas emissions with respect to the different sectors. Source: Naturvårdsverket.*

Now, trucks counted for 29% of the transport sector's emissions, whereas heavy trucks have 2.5-3 times higher emissions than light trucks in total. During 2020, heavy trucks drove 8,314.1 million kms on Swedish roads. In *Figure 8* below, the total transport emission's split between different transport sectors can be seen. There has been a small decrease in the emissions since 2007.

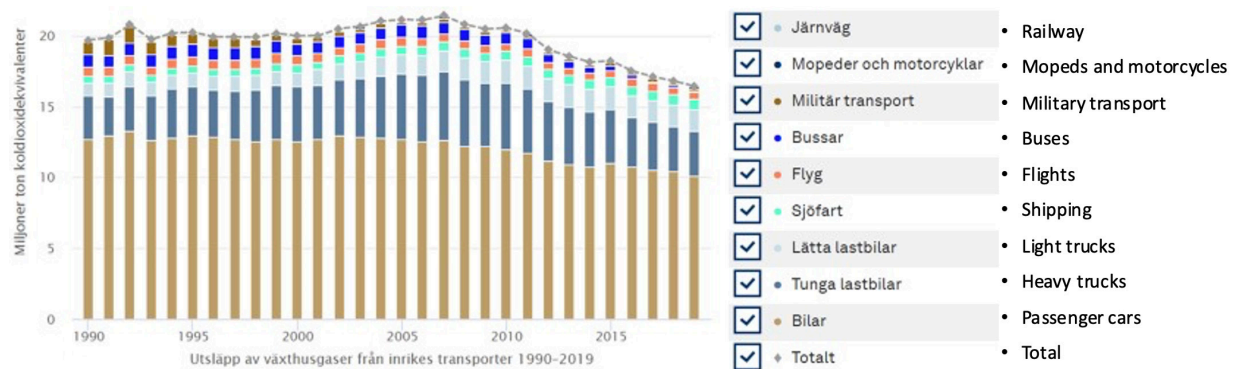


*Figure 8. Total transport emission's split between different transport sectors.*  
Source: Naturvårdsverket 2019.

### 3.2.1 National targets

As seen above, transportation within the country is responsible for about 1/3 of the Swedish greenhouse gas emissions, whereof road transportation counted for the main part of these emissions.

Sweden has committed to targets to reduce emissions from the transport sector with 70% by 2030 and to reach net zero emissions by 2045. Sweden seldom makes milestones to reach these long-term targets, instead there has been a focus on supporting the first step of roll-out of zero-emission vehicles. The bonus-malus system was implemented in 2018. It was based upon the French bonus-malus system but fitted to Swedish conditions. It's an incentive giving bonus to zero- and low-emission vehicles and giving malus (penalty) to emitting vehicles. Higher emissions give higher malus. The system is now evaluated to find if the settled limits need to be adjusted. There are ongoing discussions also to make a bonus-malus system for trucks and heavy vehicles, but no decisions have been made yet.

Sweden has focussed on making current fuels greener by blending in ethanol and other biofuels into the fossil fuels, rather than setting clear targets for number of zero- and low-emission vehicles into the roads.

| <b>Transport emission targets</b> | <ul style="list-style-type: none"> <li>-70% in 2030 (ref. year 1990).</li> <li>Net zero in 2045.</li> </ul>                                                             |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Vehicle targets</b>            | <ul style="list-style-type: none"> <li>80% of sold passenger cars in 2030 should be chargeable.</li> <li>50% of sold trucks in 2030 should be zero-emission.</li> </ul> |

### 3.2.2 Transport corridors

The TEN-T corridors have been covering just a part of Sweden and therefore just being able to support partly the build-up of infrastructure for alternative fuels. In the new programme period, the corridors are extended and the core corridor together with the comprehensive corridor cover much better the relatively large area of the country. The map in *Figure 9* shows the new version of the corridors.

Synergies between different transport modes along the corridors is a goal for several stakeholders. Refuelling stations located so they also can serve road transport, trains, and the transport within and around ports would make better conditions for getting the infrastructure in place with better economic conditions.



*Figure 9. The TEN-T corridors in Sweden and neighbouring countries. Source: TEN-T.*

#### AFIR

The regulatory for alternative fuels (AFIR) propose a maximum of 150 km between HRS for compressed hydrogen and maximum 450 km for liquid hydrogen. Sweden have today five HRS positioned over the country, and within the two-three coming years there are plans for approximately 30 more. Using the TEN-T map and considering the distance requirement in AFIR, a proposal for a wanted positioning of the upcoming station could be like the scenario described in *Figure 10*. This would also support some of the cross-border transports expected from neighbouring countries.

#### The Nordic Hydrogen Corridor (NHC)

The Nordic Hydrogen Corridor project (NHC) is financed by Connecting Europe Facility (CEF) and part of the TEN-T-corridor ambitions. NHC aim to install eight HRS and procure at least 100 fuel cell vehicles in Sweden until December 2022. Additionally, the project will deliver an electrolyser that can produce hydrogen for at least the eight stations. The project is expected to provide insights into technology and business models for the further expansion of hydrogen mobility.

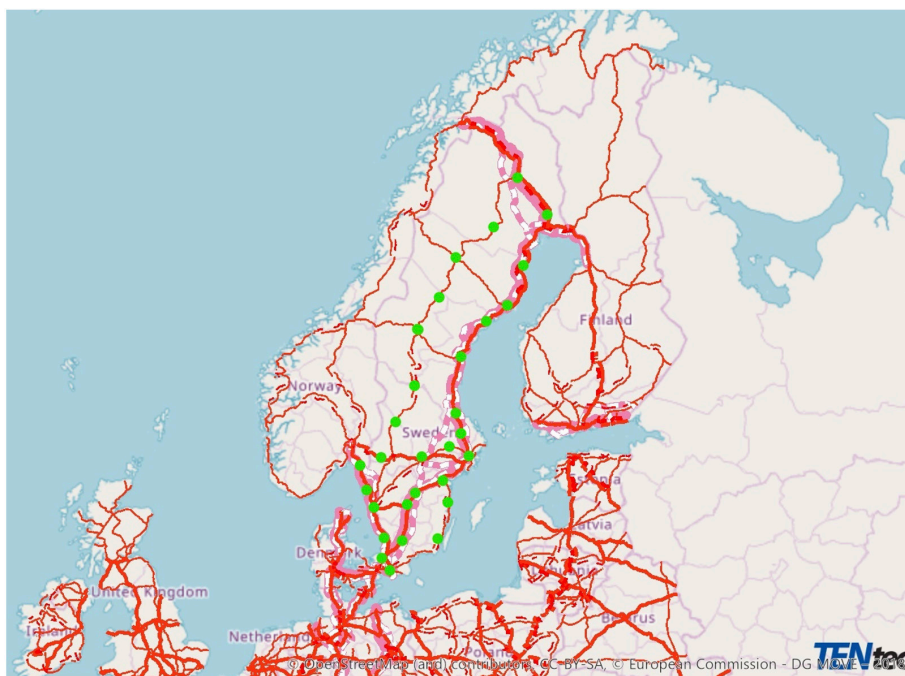


*Figure 10. A proposal for a wanted positioning of the upcoming hydrogen stations based on the TEN-T map also considering the distance requirement in AFIR.  
Source: TEN-T map modified with proposed HRS locations.*

### **Hydrogen refuelling station infrastructure in the STRING region**

In an effort to decarbonise the EU transport system, STRING is in the process of establishing a hydrogen corridor with refuelling stations for hydrogen heavy-duty vehicles from Hamburg to Oslo – along the EU ScanMed TEN-T corridor.

Heavy-duty vehicles are currently responsible for 27% of CO<sub>2</sub> emissions from road transport in the EU. Simultaneous, heavy-duty vehicles are a key player in ensuring a competitive trading system that provides the STRING region with exports, jobs, and a healthy economy.

Hydrogen remains one of the most promising new technologies in this field. The EU plans to invest up to 470 billion euros into hydrogen technology, estimating that hydrogen will create up to 1 million direct related jobs until 2050. This is a window of opportunity for the STRING region to establish itself as a frontrunner and a test bed for hydrogen technology. Therefore, STRING now takes the first step towards becoming a global hydrogen frontrunner by establishing a hydrogen corridor from Hamburg to Oslo. The project is called GREATER4H.

The hydrogen corridor project aims at deploying a minimum of 12 HRS in the STRING region. The project is planned as an EU co-financed project with a public-private partnership uniting stakeholders along the entire hydrogen value chain. By setting targets for what percentage of trucks that should be zero-emission, the emission reduction potential can be calculated. According to Daimler they foresee that from 2030, more than 50% of their long-haul trucks will use hydrogen.

NHC and GREATER4H is partly overlapping on the Swedish south and west coast. A dialogue between the two projects is established.

### 3.2.3 Relevant initiatives

The two Swedish truck producers AB Volvo and Scania have started their activities with fuel cell trucks and two Scania truck are now in operation in Gothenburg running as waste collection trucks. AB Volvo announced during 2021 the cooperation with Daimler truck, resulting in the joint venture cellcentric. AB Volvo has stated that approximately 50 HRS would cover their need for refuelling within Sweden. Within the Volvo Group also Volvo Construction Equipment (Volvo CE) has started the development of fuel cell integration into different vehicles<sup>24</sup>, and they are building the first refuelling station at one of their sites.

From the Swedish authorities, it's possible to apply for funding for fuel cell trucks in the Swedish Energy Agency's Electrical truck programme. Here, funding of up to 20% of the investment is possible. It's also possible to apply for funding for hydrogen refuelling stations, supporting fuel cell trucks, in the Swedish Environmental Protection Agency's program *Klimatklivet*. Here, funding of up to 50% of the investment for the HRS is possible.

### 3.2.4 Other segments that can be relevant

The cross-sectorial potential is yet to be more explored, analysed, and communicated. When the heavy industry shifts to use hydrogen in larger scale, we will face a number of challenges, but also possibilities. There will be a big need of renewable energy, and by that, a need of local/regional energy storage units. In this scenario, we see the strong connection between the energy sector and the industry, and once we have large amount of hydrogen available, it's a natural next step to also use hydrogen as a fuel for the transport sector. Vehicles that will distribute the products made by the industry using hydrogen within its processes.

Photo: Ulrike Leone, Pixabay



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<sup>24</sup> <https://www.volvoce.com/global/en/news-and-events/press-releases/2021/volvo-ce-takes-big-step-towards-a-carbon-neutral-future-with-hydrogen-fuel-cell-test-lab/>



Photo: Sven Brandsma, unsplash

## 3.3 Denmark

### 3.3.1 National targets

There are set no targets for CO<sub>2</sub> reductions for the transport sector specifically but there are general national climate targets. Naturally, the transport sector is a significant part of these efforts and several parallel initiatives have been set in place to combat emissions from transportation harmful for both climate and air pollution.

In September 2021, the Danish government presented a road map for the climate policy areas that need to be visited and continuously revisited on the way to the national goals of a 70% reduction in 2030 and climate neutrality in 2050. This plan maps out both priorities and timeline that are to ensure that all necessary decisions are made, and initiatives set in motion in 2025. This includes the transport sector where the timeline includes e.g., strategy for the transition of heavy-duty road transport (including infrastructure) in 2022.

|                                     |                                                                                                                                |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>National climate target 2025</b> | A political agreement has set an obligation to reach a 50-54% CO <sub>2</sub> -reduction in 2025 – as compared to 1990-levels. |
| <b>National climate target 2030</b> | A political agreement has set an obligation to reach a 70% CO <sub>2</sub> -reduction in 2030 – as compared to 1990-levels.    |

### 3.3.2 Transport corridors

As a part of the TEN-T programme, *Figure 11*, transport corridors will be established in all areas of transportation: air, rail, road, and maritime/inland waterway. The geographic location of Denmark makes the country an essential link between Scandinavia and the European continent. An expansion of the hydrogen refuelling network is necessary not only for road transport but also for air and maritime transport, as well as for shipping and maritime logistics.

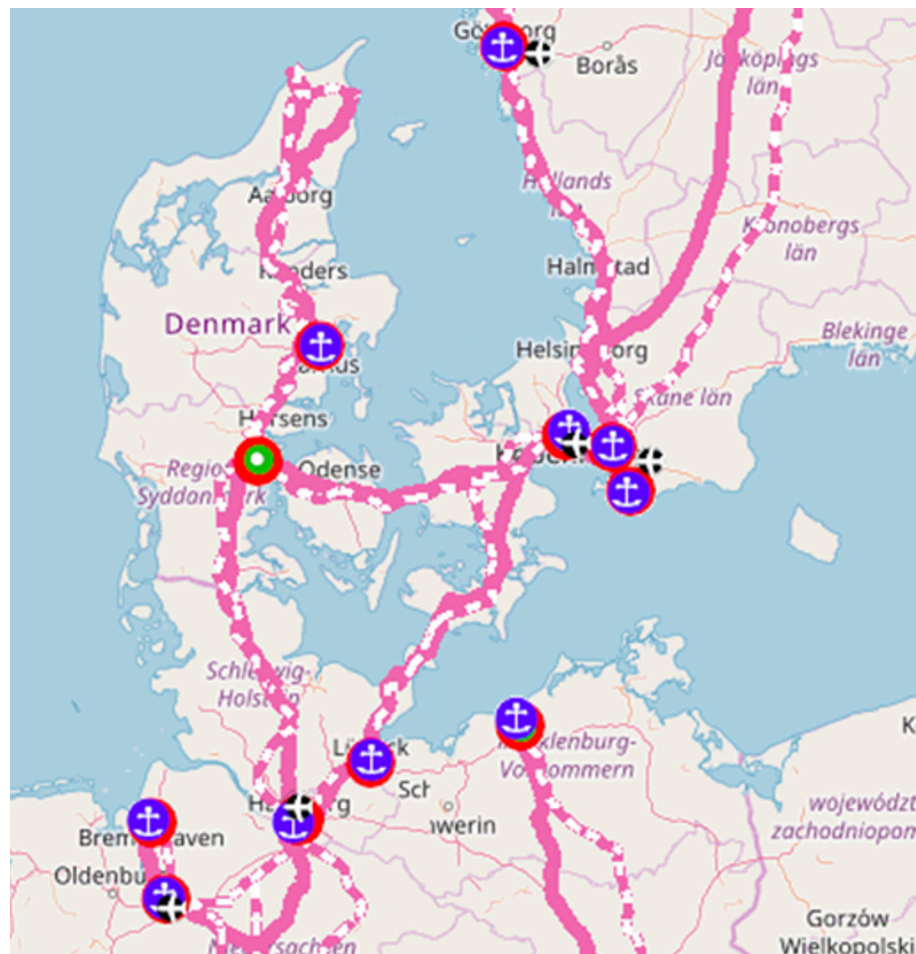


Figure 11. TEN-T Corridor, Denmark. Source: TENtec Interactive Map Viewer<sup>25</sup>.

### 3.3.3 Relevant initiatives

A number of initiatives regarding the deployment of both FCEVs and hydrogen refuelling infrastructure are in motion in Denmark. Politically there are two current initiatives of significant importance for the implementation of hydrogen solutions for transportation:

<sup>25</sup> <https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html>

## 1

### **Financial reserve for green transportation (2021-2022)**

- 475 million DKK have been allocated for initiatives that will further develop zero-emission transport.
- 2021: This includes 72 million DKK in 2021 for subsidising the expansion of green fuel infrastructure for commercial transport, including hydrogen.
- 2022: 50 million DKK for subsidies for the procurement of green heavy-duty transport.

## 2

### **National Hydrogen and Power-to-X strategy**

The Danish government published a national hydrogen strategy on December 15th 2021. The strategy is ambitious both in regard to the scale of hydrogen production and subsequent implementation of hydrogen technologies in transport and other sectors. The Government aims for at least 4-6 GW electrolyser capacity in 2030. It will provide better access to the electricity grid and enable direct connections between renewable energy and hydrogen production. The main focus for use of hydrogen is heavy-duty transport and production of liquid fuels for aviation and shipping, and to some extent road transport. The strategy also has an aim for construction of hydrogen infrastructure and connection to Germany and potentially Sweden. The strategy will be negotiated in Parliament in the beginning of 2022.

Green hydrogen is rapidly becoming a central piece in both Danish domestic climate action and in international efforts to ensure global action. Hydrogen and Power-to-X are also areas of great interest to international trading partners, and thus, a critical part of Danish green export initiatives.

### **3.3.4 Other segments that can be relevant**

Denmark has the potential to produce an abundance of renewable energy – much more than can be integrated directly into the Danish energy system. This is largely because of the enormous capacity for wind power, not least off-shore. Denmark is already at the forefront of development and deployment of renewable energy which also represents a significant part of Danish export. Hydrogen is a natural continuation of this tradition, and the transport sector is an obvious consumer. Denmark already has an established hydrogen industry covering all parts of the technological value chain for transportation - i.e., electrolysis, fuel cells, refuelling stations, and more. This growing industry is also why hydrogen has become such an important political priority both in facilitating the domestic climate ambitions and as a new export market.

As mentioned above, the geographic location of Denmark makes the country an imperative transit point between Scandinavia and the European continent. Therefore, it is of vital importance that the hydrogen infrastructure is aligned with the developments of the other Nordic countries. This will ensure the strategic deployment of the refuelling infrastructure necessary for the success of the business cases for the stations as well as supply stable infrastructure for the fleets deployed.

## 3.4 Finland

### 3.4.1 National targets

In Finland, there is a very recent (May 2021) roadmap for fossil-free transport. Concerning use of hydrogen in traffic, the latest study and plan is from year 2017 when Finland decided how to fulfil the requirements in the *Alternative Fuels Infrastructure Directive* (DAFI, Directive 2014/94 / EU):

|                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Roadmap to fossil-free transport:<br/>Government resolution on reducing domestic transport's greenhouse gas emissions (May 2021)<sup>26</sup></b> | <b>Some relevant zero-emission targets</b> <ul style="list-style-type: none"> <li>• According to the Government Programme, by 2030 Finland will reduce emissions from domestic transport by at least 50% compared to the 2005 level. The aim is to achieve an entirely fossil-free transport sector by 2045.</li> <li>• CO<sub>2</sub> from road transport in 2005 were about 12.5 million tonnes, which means that in 2030, the emissions should total only about 6.25 million tonnes. In 2019, the total emissions were about 11 million tonnes, which means that the need for additional emission reductions is still around 4.75 million tonnes.</li> <li>• For the entire fleet, the goal is that in 2030 there will be some 700,000 electric passenger cars and some 45,000 electric vans, of which at least half are all-electric cars.</li> <li>• In heavy-duty vehicles, the corresponding targets are about 4,600 electric vehicles.</li> </ul> |
| <b>Distribution network for alternative transport fuels. Finland's national plan (March 2017)<sup>27</sup></b>                                       | In 2030, the total number of hydrogen refuelling stations (HRS) in Finland would be 20.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

Concerning hydrogen, there are no binding or other near-term targets in the 2021 Roadmap to fossil-free transport and most of the discussion is focused for the period 2030-2045. As an example, the following parts can be found in the roadmap:

*The traffic use of hydrogen in Finland has not progressed on market terms. If the situation were to change and there would be more demand for hydrogen in the future, the use of hydrogen in transport would also require a new distribution infrastructure. For this reason, the demand for hydrogen must be carefully monitored and possible measures must be taken in the event of a change in demand.*

*It is possible that it would be most sensible to direct hydrogen in transport to areas where there is no need for a nation-wide distribution network (e.g., maritime ports).*

<sup>26</sup> <https://julkaisut.valtioneuvosto.fi/handle/10024/79530>

<sup>27</sup> <https://julkaisut.valtioneuvosto.fi/handle/10024/79530>



Photo: Lex Valishvili, Unsplash

### 3.4.2 Transport corridors

In practice, at least 13 HRS are needed for Finland to fulfil the requirement in the new AFIR proposal, of a maximum of 150 km distance between hydrogen stations along the TEN-T core network, while the national non-binding target is 20 HRS. The TEN-T core network and comprehensive network in Finland are shown in *Figure 12*. In these maps, proposals for 13 and 33 HRS are added. 13 would be the minimum AFIR proposal, while about 33 would be sufficient to cover all main routes of heavy transport in Finland. The estimate is based on heavy traffic statistics in Finland<sup>28</sup> and analysis by WSP Finland.

These maps are based on TEN-T networks and cover all forms of transport. TEN-T is important concerning the fulfilment of the requirements in the AFIR proposal. As an example, appropriate number of LNG stations for heavy-duty vehicles should be placed along the TEN-T core network.

While the TEN-T network is guiding the locations of LNG stations, there are other aspects, that should be taken into account when hydrogen refuelling stations for heavy-duty traffic are planned in Finland.

One important aspect is cost of hydrogen. It seems that lowest cost of hydrogen can be achieved when hydrogen is produced in centralised manner and distributed to HRS using compressed tube trailers. This is the case at least, when the amount of dispensed hydrogen is small or moderate (<1,000 kg/day). For very large HRS, local production is the preferred option. The best cases are, when mid- or large-scale hydrogen production for industry can be combined with hydrogen production for transport purposes. Due to this, hydrogen supply options for transport are briefly studied in the following.

<sup>28</sup> <https://vayla.fi/vaylista/aineistot/kartat/liikennemaarakartat>

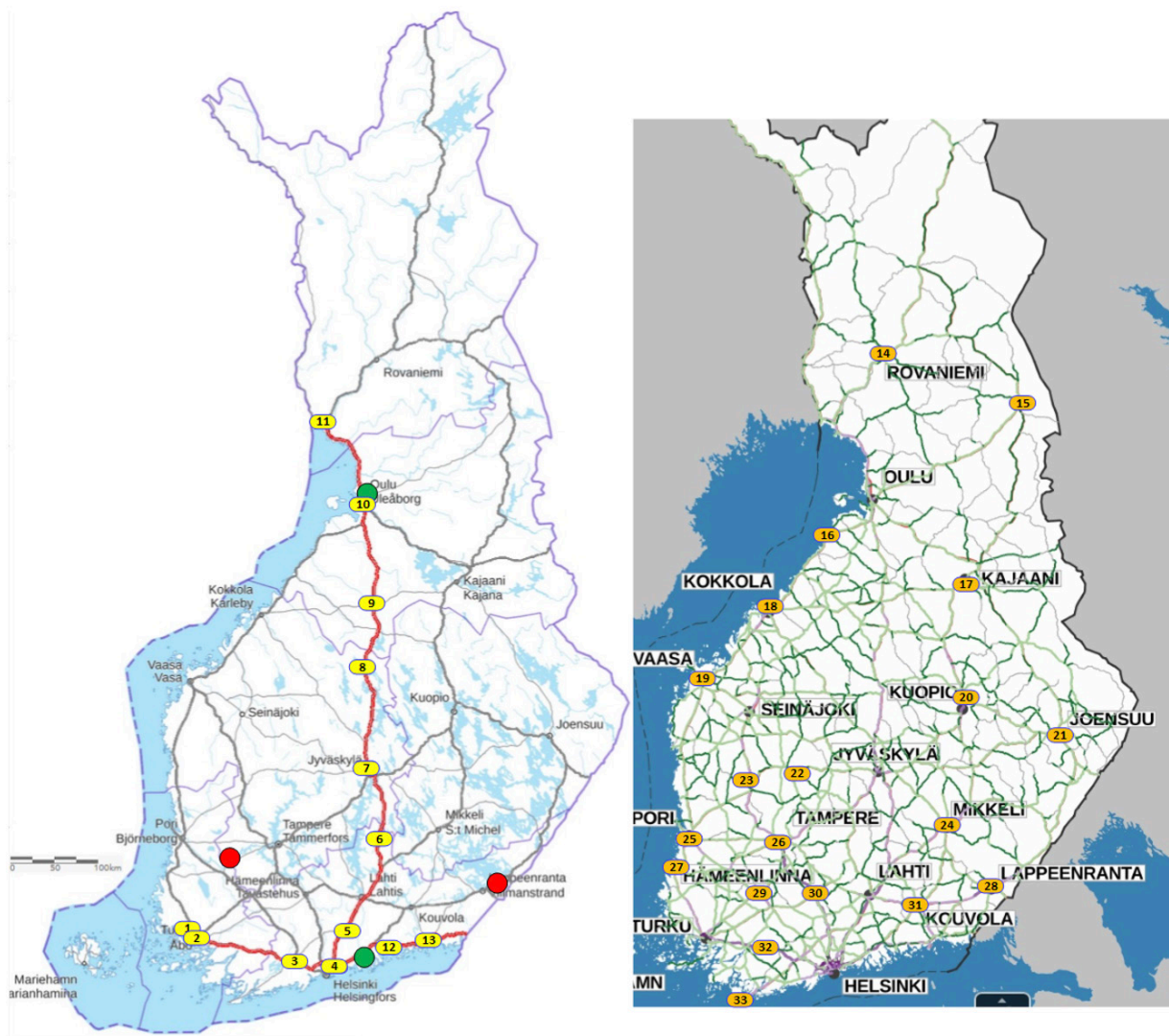


Figure 12. The core network and comprehensive traffic network in Finland, with proposed location of 13 (left) and 20 additional (right) hydrogen refuelling stations added<sup>29</sup>.

### Hydrogen production sites in Finland

In Finland there are one very large (>300 tonnes/day) and 4 mid-size (20-30 tonnes/day) hydrogen production sites/areas as well as two smaller production sites, where significant amount of hydrogen is produced either as dedicated production for industry or as a by-product. These sites are listed in *Table 4* and shown in *Figure 13* below.

As can be seen in *Figure 13*, there is no industrial hydrogen production in northern or central Finland. Thus, these areas cannot easily be served by existing hydrogen production facilities. The distance from the largest site producing by-product hydrogen (Lappeenranta) to suitable HRS site (Jyväskylä/Äänekoski/

<sup>29</sup> <https://vayla.fi/en/transport-network/transport-system/ten-t>

Viitasaari) is 200-300 km. Similar distances goes for several other hydrogen production sites (Sotkamo, Kokkola, Oulu, Kouvola, Porvoo). When comparing *Figure 13* with the TEN-T core network in *Figure 12*, it is obvious that one or more HRS in central Finland may need a local electrolyser, when the demand is sufficient.

*Table 4. Hydrogen production and consumption hotspots in Finland*

| City/Area          | Companies                                           | The scale of daily dedicated or by-product hydrogen production (tonnes/day) |
|--------------------|-----------------------------------------------------|-----------------------------------------------------------------------------|
| Porvoo             | Neste and Linde                                     | > 300                                                                       |
| Lappeenranta       | UPM Biofuel and Kemira Chemicals                    | 40-50                                                                       |
| Kouvola            | Solvay Chemicals and Kemira Chemicals               | 20-30                                                                       |
| Äetsä & Harjavalta | Kemira Chemicals and Linde                          | 20-30                                                                       |
| Oulu               | Kemira Chemicals, Eastman Chemical Company, Nouryon | 20-30                                                                       |
| Sotkamo            | Terrafame                                           | 10-20                                                                       |
| Kokkola            | Voikoski                                            | 3-5                                                                         |



*Figure 13. Hydrogen production and consumption hotspots with 150 km (Porvoo) and 100 km (all other) radius.*

### Industrial heavy-duty transport

TEN-T core network focuses on international trade and the most important connections, hubs, and corridors for that. Therefore, the picture for Finland is far from complete as there are massive amounts of industrial transport in Finland. In Finland, there are good statistics for industrial heavy-duty traffic. Until 2017, there were even statistics for different industry segments<sup>30</sup>.

Transportation volumes in Finland for different industry segments has been collected and illustrated by WSP<sup>31</sup>. The total transportation volume and transportation volumes for forest industry are illustrated the study of WSP. In Figure 14 heavy traffic volumes per day (from <https://vayla.fi/vaylista/aineistot/kartat/liikennemaarakartat>) are shown together with existing hydrogen production points as well as potential hydrogen consumption hotspots. In addition to selected industrial sites, also some ports (Helsinki/Vuosaari, Kotka-Hamina, Rauma ports, Oulu ports) are included.

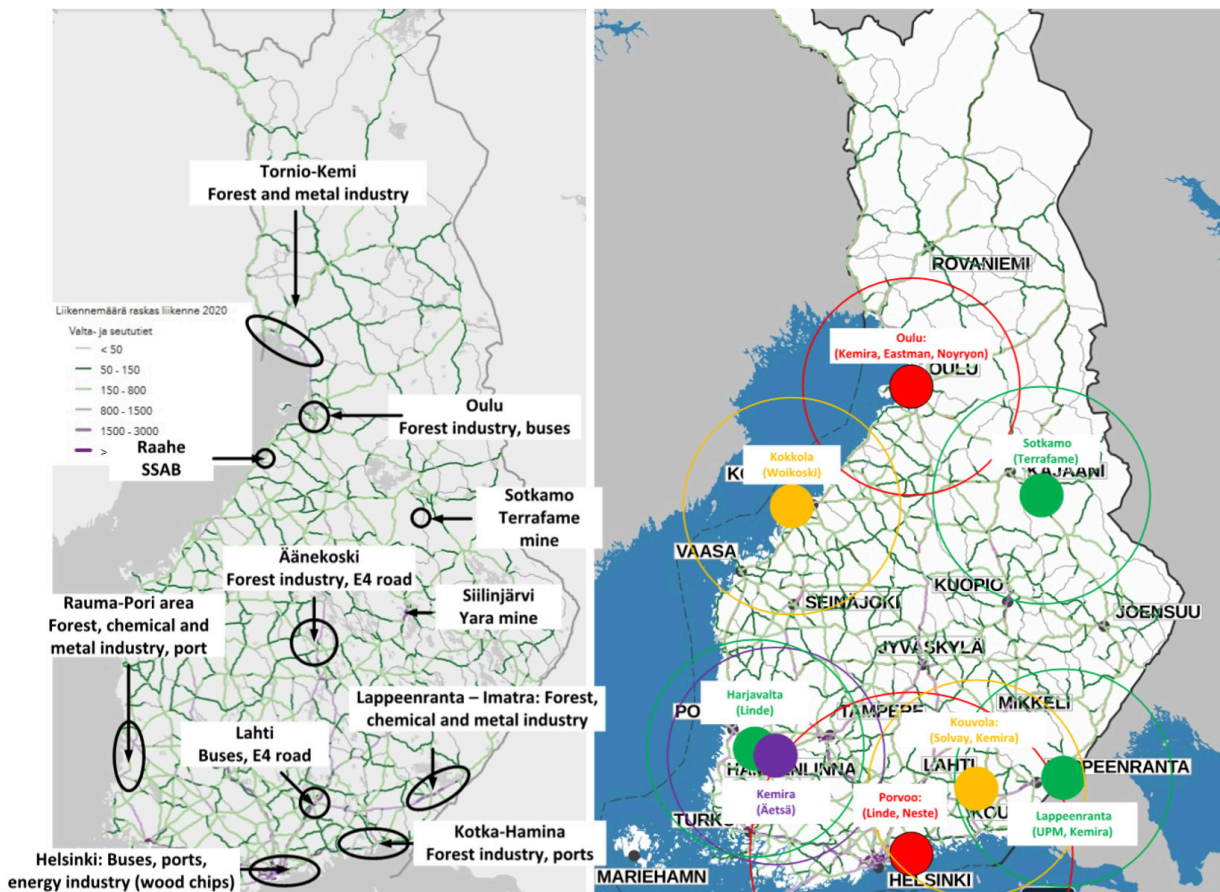


Figure 14. Transportation volumes in Finland, hydrogen production sites, and potential hotspots for hydrogen usage in road transport and traffic in industrial areas.

<sup>30</sup> [http://www.tilastokeskus.fi/til/kttav/2017/kttav\\_2017\\_2018-04-26\\_tau\\_010\\_fi.html](http://www.tilastokeskus.fi/til/kttav/2017/kttav_2017_2018-04-26_tau_010_fi.html)  
[http://www.tilastokeskus.fi/til/kttav/2017/kttav\\_2017\\_2018-04-26\\_tie\\_001\\_fi.html](http://www.tilastokeskus.fi/til/kttav/2017/kttav_2017_2018-04-26_tie_001_fi.html)  
<sup>31</sup> Elinkeinoelämän kuljetukset tieverkolla -volyyymi-ja arvoanalyysi, WSP Finland (2017)  
[https://julkaisut.vayla.fi/pdf8/lr\\_2017\\_elinkeinoelaman\\_kuljetukset\\_web.pdf](https://julkaisut.vayla.fi/pdf8/lr_2017_elinkeinoelaman_kuljetukset_web.pdf)

The average distance travelled by heavy-duty trucks between destinations can be retrieved from 2017 statistics<sup>32</sup>. Based on these data, a rough estimate can be given that every normal factory visit is done after driving 300 km to the destination and back.

The corresponding 150 dm<sup>3</sup> diesel fuel consumption, translates into a 30 kg hydrogen consumption if served by a hydrogen truck. For all ports, the same fuel consumption is assumed (25 kg H<sub>2</sub>/visit), while it is recognised that different ports have different profiles.

It is also interesting to notice that the average road transport distance for basic industrial chemicals was 201 km, even if a large part of the transport routes are expected to be at very short distances.

These figures show that there are in the range of 20-30 ports or industrial areas, where local production of hydrogen for heavy traffic could be motivated, if 2 tonnes per day is considered as minimum amount of production for on-site production of hydrogen.

### **Market potential for hydrogen as fuel for heavy-duty transport in Finland**

Emissions from road traffic amounts about 10.4 million tonnes CO<sub>2</sub>-equivalents in Finland every year<sup>33</sup>. Transport of goods accounts for a bit more than 30% of that, and buses less than 5%.

Truck traffic for forest, metal, chemical, and energy industries is responsible for about half of the total goods traffic emissions – corresponding to a consumption of some 100,000 tonnes H<sub>2</sub>/year (274 tonnes H<sub>2</sub>/day) if served by hydrogen vehicles.

Since the traffic is mainly concentrated in a few areas, the transportation needs of these industries forms excellent hotspots for hydrogen vehicles. The external traffic of the largest single industry sites would correspond to a consumption approaching 10 tonnes H<sub>2</sub>/day, while the external traffic of the largest port and industry areas would correspond to a consumption of some 40 tonnes H<sub>2</sub>/day, or even more.

The total emissions of city buses corresponds to 184,000 tonnes CO<sub>2</sub>-equivalents, which is only 11% compared to heavy-duty truck traffic for forest, metal, chemical, and energy industries. Assuming a diesel consumption of 34 dm<sup>3</sup>/100 km and 2.67 kg-CO<sub>2</sub>/dm<sup>3</sup>, this corresponds to about 200 million km, which is close to the figure reported by Traficom when total km are used<sup>34</sup>. Traficom reports totally 176.1 million line-km for large and mid-sized cities.

### **3.4.3 Relevant initiatives**

In Finland, there are no publicly known initiatives for commercial hydrogen traffic. There are subsidies available for LNG trucks (€12,000) and CNG trucks (€5,000) for the purchase or long-term rental, but not yet for hydrogen trucks.

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<sup>32</sup> [https://www.stat.fi/til/kttav/2017/kttav\\_2017\\_2018-04-26\\_tau\\_010\\_fi.html](https://www.stat.fi/til/kttav/2017/kttav_2017_2018-04-26_tau_010_fi.html)

<sup>33</sup> [https://www.aut.fi/files/2196/Liikenteen\\_tiekartta\\_Tiivistelmaraportti\\_2020.pdf](https://www.aut.fi/files/2196/Liikenteen_tiekartta_Tiivistelmaraportti_2020.pdf)

<sup>34</sup> [https://www.traficom.fi/sites/default/files/media/file/julkisen\\_liikenteen\\_suoritetilasto\\_2018.pdf](https://www.traficom.fi/sites/default/files/media/file/julkisen_liikenteen_suoritetilasto_2018.pdf)

### 3.4.4 Other segments that can be relevant

In Finland, there are few sites with significant amount of industrial traffic. The three most important sites are probably: (a) Yara Siilinjärvi mine, (b) Terrafame mine in Sotkamo, and (c) SSAB industrial site in Raahе. These are illustrated in *Figure 14* and more details are given in *Next Wave – Deliverable 3.1*<sup>35</sup>. In addition to these three sites, there is an open pit mine in Kevitsa, Sodankylä<sup>36</sup>. In case the trucks that services the mines would use hydrogen in the future, the same hydrogen production site could supply the eastern Lapland with hydrogen.

The Saimaa deep-water channel is also part of Ten-T network<sup>37</sup>. The location of that channel, as well as the location of the Saimaa canal, would be excellent concerning the use of hydrogen for maritime applications. In case use of liquid hydrogen becomes common as maritime fuel, it would be highly potential fuel for the vessels travelling from Saimaa deep-water channel to the ports along the coastline and rivers in central Europe.

Photo: Ludovic Charlet, Pixabay



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<sup>35</sup> Next Wave report: Prospectus of using hydrogen in heavy-duty equipment, including non-road mobile machinery, <http://www.nordichydrogenpartnership.com/nextwave/rapporter/>

<sup>36</sup> <https://www.boliden.com/fi/operations/mines/boliden-kevitsa>

<sup>37</sup> <https://vayla.fi/en/transport-network/transport-system/ten-t>

## 3.5 Iceland

Reduction in greenhouse gas emissions due to transport fuel is more important to Iceland than many other countries. Today, road transport is responsible for 20% of the total greenhouse gas emissions. Out of this, larger vehicles accounts for 44%. The Icelandic 2020 goal of 10% share of renewable fuels in road transport will be reached, mainly through combination of green fuels and BEVs. However, to reach Iceland climate targets set out in the Paris Agreement will be very challenging. Greening of heavy-duty transport could play a very important role regarding fulfilling Iceland's 2030 climate targets.

### 3.5.1 National targets

The most relevant national targets with respect to zero-emission transport in general, and hydrogen ambitions specifically, can be summarised as follows:

|                                            |                                                                                                                                                                                                                                                                    |
|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>National transport declared targets</b> | <b>Some relevant zero-emission targets</b> <ul style="list-style-type: none"><li>• 2030 ban on sales of fossil fuel passenger vehicles. No specific goals for larger vehicles.</li><li>• All new governmental owned ships should use eco-friendly fuels.</li></ul> |
| <b>Roadmap for hydrogen</b>                | During the latter part of 2021, the government has been drafting a roadmap for hydrogen and electrofuels. The goal is to launch the roadmap by the end of 2021 or early 2022.                                                                                      |

### 3.5.2 Transport corridors and the market

Most goods in Iceland are transported with trucks, but due to its population Iceland is not a major market for any OEM (cars or trucks). At the beginning of 2020, a total of 13,100 trucks were registered in Iceland, with roughly 7,000 trucks above 12 tonnes. This transport category alone is responsible for a large percentage of the fuel consumption as they are driven considerable distances. Even though they are not very many, the sector was responsible for 10% of the total transport emissions in 2017, while vans and non-road mobile machinery are responsible for 6% and 7% of the emissions, respectively. An overview of the CO<sub>2</sub> emission from heavy-duty transport in Iceland is given in *Figure 15*.

The largest truck companies<sup>38</sup> do carefully follow the development of alternative fuels for trucks. In general, truck operators are very interested in reducing their CO<sub>2</sub> emissions and are very open minded towards new technologies. A general consensus is evident among the key stakeholders, that fuel cell and hydrogen technologies look the most promising to replace fossil fuel. Even with the current development of batteries, it would be unlikely that batteries alone could solve the energy demand, range, harsh terrain etc. for trucks. Batteries

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<sup>38</sup> Icelandic New Energy has hosted meetings with key truck operators to examine their view on alternative fuels (new technologies) during the course of the Next Wave project to collect the market view.

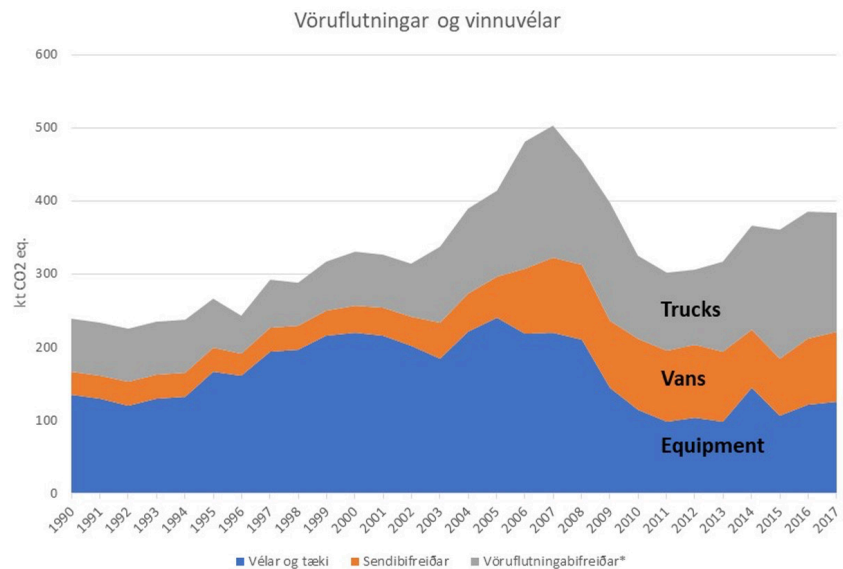


Figure 15. CO<sub>2</sub> emission from heavy-duty transport in Iceland.

could though be a potential solution for inner city delivery vans and/or small trucks. Most stakeholders have been following the development of hydrogen trucks and see a great potential. So, the general view is that hydrogen as a fuel is the most promising and with highest likelihood of replacing fossil fuel in trucks. However, there are a few key points that need to be in place so that they can start operating such vehicles:

### 1 Service

Truck operation is a very demanding business, and service and maintenance schemes must be in place at the onset of projects. Stakeholders raises concerns regarding lead time for spare parts, i.e., if new technology is being introduced.

### 2 Infrastructure

Access to fuel is very important and that redundancy is provided for fuelling. Providing such can though be simpler for trucks than conventional vehicles as many of them drive the same route every day and the focus could be on providing infrastructure on the busiest routes in the beginning.

### 3 Total Cost of Operation (TCO)

This is probably the most important concern. Even though the interest in zero-emission trucks is very high and there will be "market" benefits of becoming "green", there is a general consensus that:

| TCO higher than comparable fossil fuel vehicles | Truck company actions toward investing in zero emission vehicles                                  |
|-------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <10%                                            | Easy to justify investment – high interest                                                        |
| 10-30%                                          | Potential demonstration activities, specifically if cost reduction is foreseen in the near future |
| >30%                                            | Almost impossible to justify a project. Would create a market difficulty                          |

## 4 Aftermarket

The possible re-sale value of vehicles is unknown when new technologies are introduced. This raises some concern, and possibly, companies will have to add cost to the TCO as the re-sale value or aftermarket value might be low or near zero. Here, the vehicle warranty might heavily influence the potential aftermarket value.

Stakeholders agree that a "single (or very few) unit demonstration" is more difficult than the initial introduction of BEVs as many of the key issues listed above can only be solved if a reasonable fleet is introduced simultaneously. A joint effort by industry, infrastructure providers, and government intervention could break this barrier for market introduction. With increased availability of vehicles forecasted during the coming years, this could happen fast if a joint coordinated action can be put in motion.

### The ring road (Iceland's corridor)

Actual data on the truck movement around the island is not collected. However, the island road system is relatively simple, i.e., there is a ring road which sustains over 95% of the heavy-duty traffic (not counting traffic inside the Reykjavik boundaries). Most trucking companies as well as the government are now exploring potential pathways in utilizing green (zero-emission) solutions. As mentioned above, the truck traffic is responsible for a very high percentage of the total emission from transport. Thus, to be able to reach the 2030 climate goals, part of the fleet must become zero-emission in the coming years.

Mapping out the whole island, it can be easily seen erecting a hydrogen infrastructure for the heavy-duty fleet is not very complicated. Furthermore, being an island makes it even simpler as Icelandic trucks stay within that boundary. As can be found from *Figure 16*, only a handful of stations could cover a complete setup for a hydrogen truck infrastructure.

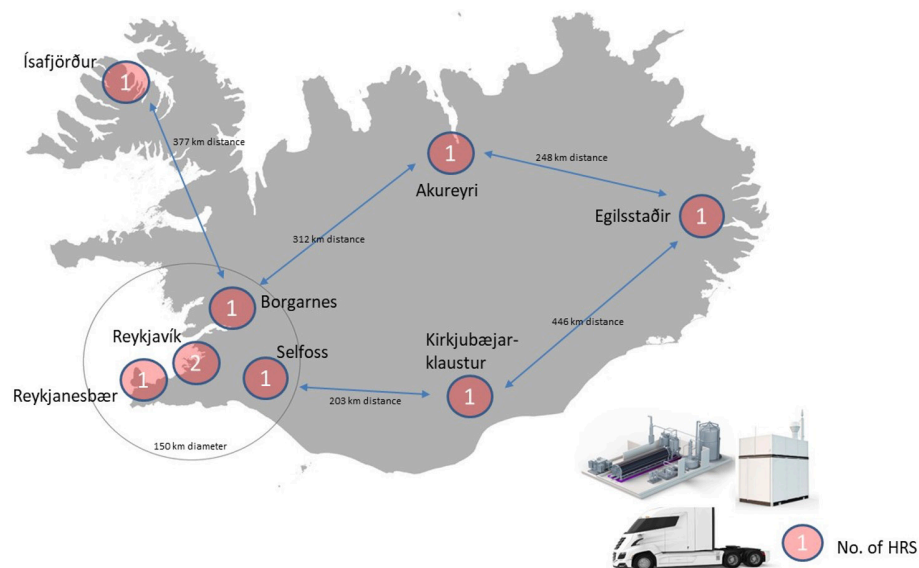


Figure 16. Iceland ring road (by the coastline).

### City buses

The city bus fleet is small. In Reykjavik, there are about 100 buses, but at other locations the bus fleet is very small; generally <5 buses in each community, as for instance in both Akureyri and Reykjanesbær. There is though a bus service from Reykjavik to many communities around the island, which is in-large the same driving way as trucks would do. Infrastructure built for heavy-duty activities in and around Reykjavik could therefore also be utilized for buses.

Already, there are a number of battery electric buses<sup>39</sup> in operation in Reykjavik. If zero-emission is to be reached, it is unlikely that batteries will be able to fulfil all different bus routes. Therefore, hydrogen buses could be part of the solution for zero-emission bus operation utilising the same infrastructure. This is even more relevant when looking at the bus routes linking communities around the island together.

### The most promising point-to-point hydrogen transportation routes

The route between Akureyri and Reykjavik accommodates the heaviest heavy-duty traffic in Iceland. The route is just a little less than 400 km long and should be ideal as an initial route for hydrogen trucks as they should easily make the route on a single filling – minimizing the infrastructure cost, i.e., with stations in both ends.

As mentioned above, there is no actual data available regarding truck traffic around the island. However, most products and goods are transported via land, including fish. During the last few years there has been a steady growth in fish farming, specifically in the Westfjords<sup>40</sup>. A large portion of that production is transported from the Westfjords to Reykjavik, or Keflavik airport, and that is a second point-to-point route which easily could be covered without major infrastructure investment.

### Government actions to stimulate uptake of zero-emission trucks

As described above, a key early adoption barrier is TCO. The main incentive which stimulated the uptake of zero-emission passenger vehicles was revoking VAT. This will not have an effect when it comes to trucks. For Iceland, stakeholders have mentioned a few potential pathways for the government to stimulate the first movers:

- Investment grants
  - Both for trucks and infrastructure
- Reduction or elimination of road taxes (isl: pungaskattur) on zero-emission trucks
- Rebate on income tax (e.g., based on CO<sub>2</sub>-reduction)
- 100% depreciation in one year
- Cost reduction of "new zero-emission" fuel, in this case H<sub>2</sub>

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<sup>39</sup> Not zero-emission (diesel heaters).

<sup>40</sup> Related to the map, Isafjordur is the capital of the Westfjords.

It is likely that first movers will step in at a relatively late stage if no incentives are provided as the TCO is expected to be considerably higher in the beginning. The government will also have to support construction of infrastructure which is lacking for H<sub>2</sub> trucks (actually, infrastructure is lacking for all types of potential “new zero-emission” fuel for trucks).

### 3.5.3 Relevant initiatives

The key driver for Iceland is the Governmental policy towards fulfilling the Paris Agreement, but more recently, also its own national goal of 55% reduction of emissions. The main focus and support have been towards battery driven vehicles and many efforts supported mainly towards infrastructure.

The largest hydrogen initiative is the EU H2ME project. Within the project, more than 20 FCEVs have been put into service, an electrolyser was erected next to a geothermal power plant, and two hydrogen refuelling stations were put into service. This initiative has created a lot of learning such as maintenance, operation, storage, etc. for equipment and vehicles. New initiatives and planned increased funding from the government during the next couple of years are targeted towards segments traditionally using high volumes of fossil fuels, such as trucks, buses, and coaches.

### 3.5.4 Other segments that can be relevant

Hydrogen will be the bases for any electrofuels in Iceland, being it ammonia, methanol, e-crude, methane, e-kerosene, etc. Electrofuels will play a key role in other segments where batteries or hydrogen cannot be deployed directly. In that sense, the main focus would be towards the maritime sector, heavy-duty equipment, and then later in aviation.

There are also some industries that could use hydrogen as an alternative to propane and/or methane, such as the asphalt industry and the like. However, such industries are not very big in Iceland so the main focus would be transport connected; land/sea/air.

Photo: Jesper Marker, Pixabay



## 4. Cross-border transport in the Nordics

There are several border crossings between the Nordic countries, some of them with a large volume of heavy-duty trucks. It is not the mandate of the Next Wave project to analyse the volume of cross-border transport between the countries, but the axis Oslo-Hamburg can serve as an example. The number of trucks crossing the borders at Svinesund, the Helsingør bridge, Flensburg, and the Rødby-Puttgarten ferry has been mapped in a report from Umlaut<sup>41</sup>. Figure 17 shows the number of trucks crossing the borders each day along this corridor. The approximate numbers are:

- Svinesund (Norway-Sweden): 3,000
- Øresund bridge (Sweden-Denmark): 2,900
- Øresund ferry (Sweden-Denmark): 1,500<sup>42</sup>
- Flensburg (Denmark-Germany): 6,700
- Rødby-Puttgarten (Denmark-Germany): 2,000

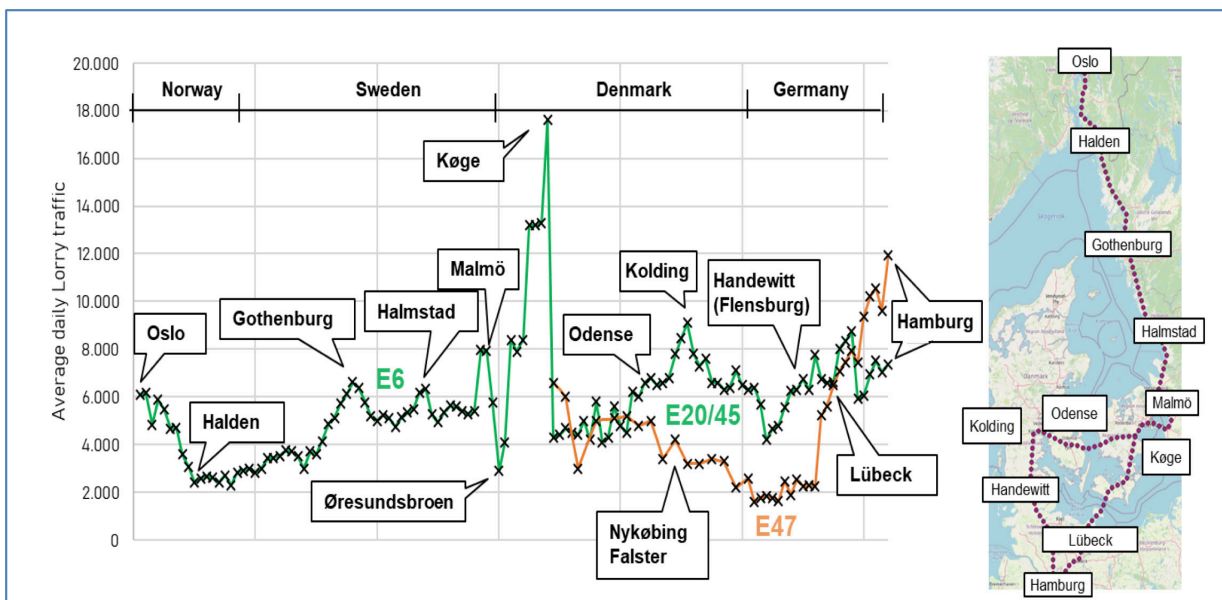


Figure 17. Average daily heavy-duty transport in regions and across borders on the axis Oslo-Hamburg. Numbers by 2019. Source: Umlaut, 2020.

This example shows a substantial number of trucks crossing the borders. It is important that national and regional authorities consider how they should stimulate development of infrastructure to eliminate emissions also from this part of the transport.

<sup>41</sup> Initial hydrogen refuelling station corridor in the STRING Region. Umlaut, 2020.

<sup>42</sup> There are no numbers for the Øresund ferry crossing in the Umlaut report. However, according to the ferry company ForSea, 414,846 trucks travelled with their Øresund ferries in 2020. It equals an average of approximately 1,500 trucks per day.

## 5. A vision for the Nordic rollout of hydrogen trucks

The Next Wave partners have set a target for the numbers of hydrogen trucks that should be deployed in the Nordics by 2025 and 2030. This gives the basis for the number of hydrogen refuelling stations and their location within the same time frame.

The expected number of trucks is depending on several factors. The Nordic countries and regions may influence some of these, but not all. Each country should take an active role in stimulating the deployment of hydrogen trucks individually, as well as recognising the need that only by working together the full potential can be reached in seamless cross-border services and speeding up the deployment. This gives market opportunities for the Nordic hydrogen industry while at the same time fulfilling national obligations with respect to reductions in greenhouse gas emissions.

Roland Berger estimates that an accumulated 110,000 heavy-duty fuel cell trucks are deployed on European roads by 2030<sup>43</sup>. After a moderate uptake until 2027, the market potential analysis according to Roland Berger indicates a significant hydrogen truck market penetration to an overall sales share of ~17% in 2030. Based on the heavy-duty truck market, this refers to approximately 59,500 new registered trucks in 2030. By 2025, Roland Berger estimates the accumulated sales of hydrogen trucks to be 3,800.

The Nordic countries have been leading the way for deployment of electric passenger vehicles in Europe. The Next Wave partnership urge the countries to take the same position for deployment of heavy-duty vehicles. The number of trucks in the Nordics by 2020 is approximately 287,000<sup>44</sup>. We assume that there are approximately 100,000 hydrogen trucks on European roads by 2030. This is based on the Roland Berger estimate together with the assumption that 10% of the trucks are taken out of operation by 2030. Thus, we suggest the following ambitions for vehicles to be deployed in the Nordics, with the distribution between the Nordic countries shown in *Figure 18*:

- By 2025: 740 hydrogen trucks. This equals approximately 0.3% of the total Nordic stock and 19% of all hydrogen trucks in Europe.
- By 2030: 12,550 hydrogen trucks, equalling approximately 4.4% of total Nordic stock, and 13% of all hydrogen trucks in Europe.

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<sup>43</sup> <https://www.fch.europa.eu/publications/study-fuel-cells-hydrogen-trucks>

<sup>44</sup> Evig Grønn: Deployment of alternative fuel vehicles and infrastructure in Norway, Sweden, Denmark, Finland, and Germany, <https://www.evigrønn.no/statistikk-scandia/>. Numbers for Iceland from New Icelandic Energy.

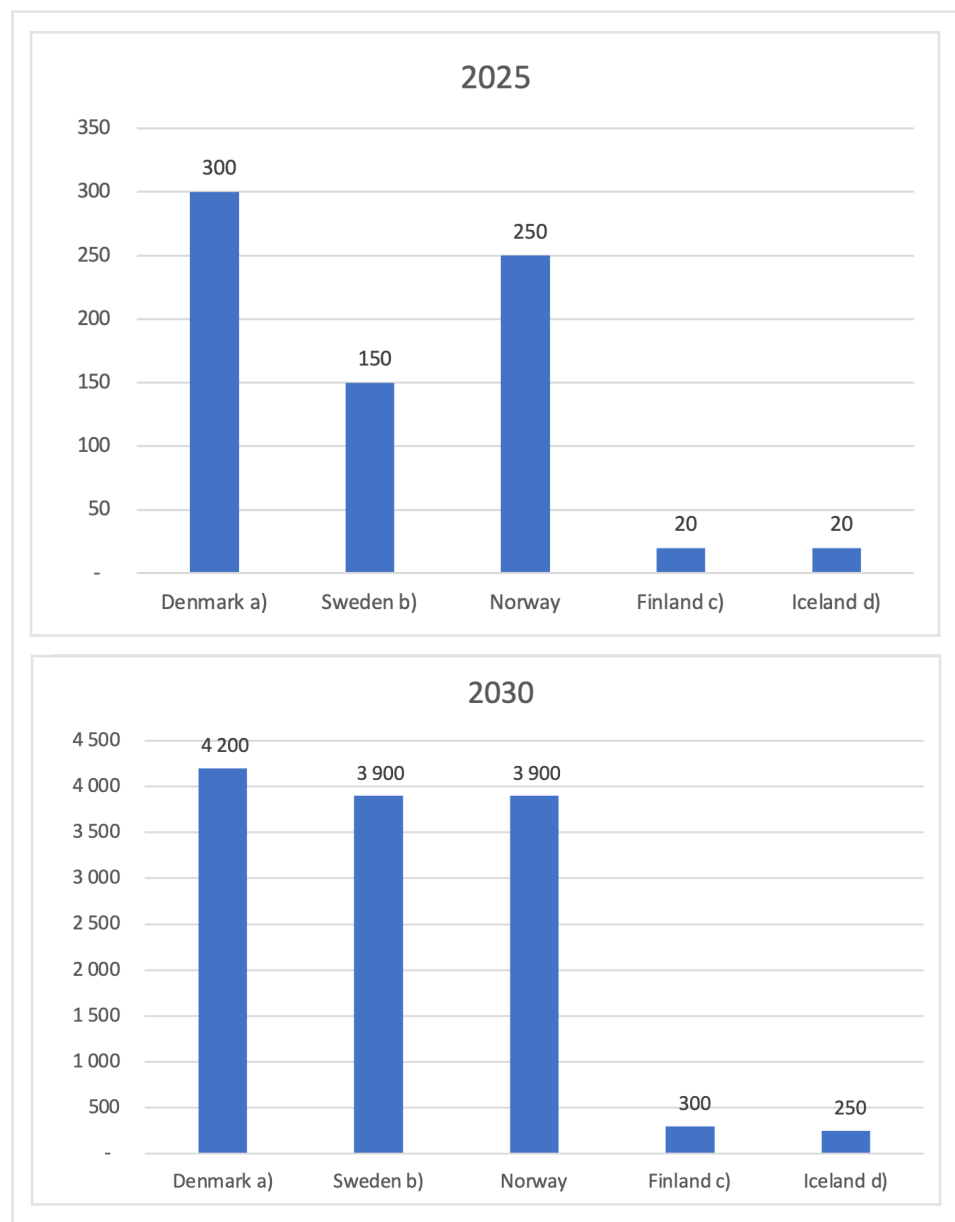


Figure 18. Estimated number of hydrogen trucks in the Nordic countries by 2025 and 2030. Please see text for comments.

Please note the following remarks to the national numbers shown in *Figure 18*:

- a) The Danish transport industry has very ambitious targets (3,000 and 10,000 hydrogen trucks in 2025 and 2030, respectively). In this report, however, we have harmonised the Danish figures with the other Nordic countries due to factors such as more or less similar national/political ambitions and deployment incentives between the countries and the fact there will be limited production of hydrogen trucks in the coming years, still keeping Denmark in lead of the deployment of hydrogen trucks in the Nordics.
- b) The number for 2025 is relatively low because Swedish transport companies in general are waiting for the hydrogen trucks from Scania and Volvo, which are expected to be available in largest numbers by 2025.

- c) Finland has a high share of 60+ tonnes trucks, which are only operated in Finland (and to some degree in Sweden). These heavy-duty trucks are not expected to be available with hydrogen in larger numbers before 2030.
- d) For Iceland, the numbers are based on the current regime of investment incentives. The numbers are expected to be much higher if better incentives are made available.

The Roland Berger study also perform a TCO analysis, comparing the various drivetrain alternatives diesel, diesel e-fuels, fuel cell electric at 350 bar, 700 bar, and liquid hydrogen, as well as battery electric and catenary. The TCO analysis shows that fuel cell electric trucks are expected to be cost competitive to diesel trucks in 2027.

## 5.1 Stimulating the hydrogen truck demand

Deployment of the first hydrogen trucks is a complex task. The complete value chain needs to be engaged to coordinate and solve challenges regarding location and establishment of infrastructure, availability of vehicles, maintenance and service of vehicles, and motivating vehicle operators willing to take the risk of being the first movers. It's a fact that a fleet of vehicles makes it more attractive both for the infrastructure and vehicle providers (as well as vehicle maintenance and service providers) than a single or a few vehicles spread around. This is challenging in the early phase when costs are high.

There are some ongoing projects in the Nordics aiming to deploy trucks and establish infrastructure. The most relevant are the Nordic Hydrogen Corridor project in Sweden<sup>45</sup>, the H2 Truck project in Norway<sup>46</sup>, and the GREATER4H project in the STRING region focusing on the Oslo-Hamburg corridor<sup>47</sup>. Next Wave as a Nordic cross-border initiative keeps the broader view on the heavy-duty hydrogen infrastructure and transport development. Together, these initiatives could help speeding up the deployment of trucks and secure the Nordics a position as an early adapter of hydrogen trucks.

Some activities are crucial to stimulate the demand for hydrogen trucks. Of the most important are:

- 1 A close dialogue with OEMs to position regions and countries as attractive for early deployment of trucks.
- 2 Communication throughout the value chain to build competence and knowledge.
- 3 Communication with policy makers and authorities at regional, national, and Nordic level to ensure good incentives.

The extended Next Wave project (2022-2023) will work with all these activities.

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<sup>45</sup> [www.nordichydrogenpartnership.com/nhc/](http://www.nordichydrogenpartnership.com/nhc/)

<sup>46</sup> [www.h2truck.no](http://www.h2truck.no)

<sup>47</sup> [www.stringnetwork.org/initiatives/#hydrogen-corridor](http://www.stringnetwork.org/initiatives/#hydrogen-corridor)



Photo: Kento Hirasue, unsplash

## 6. Strategic locations for cross-border infrastructure

Each of the Nordic countries have an important role in developing the infrastructure for hydrogen in their own country. Importantly, however, in doing so they also have to cooperate with neighbouring countries to ensure that the stations support cross-border transport services. The proposed regulation of alternative fuel infrastructure (AFIR) states that:

- Neighbouring Member States shall ensure that the maximum distance between refuelling stations is not exceeded for cross-border sections of the TEN-T core and the TEN-T comprehensive network.
- The Member States should do an assessment of the current state and future development of the market as regards alternative fuels in the transport sector, and of the development of alternative fuels infrastructure, considering intermodal access of alternative fuels infrastructure and, where relevant, cross-border continuity.

The Next Wave partners have considered the demand for hydrogen stations at or nearby the most important border-crossings, including the main ports. Ports will serve as energy hubs and play an important role in decarbonization of the European energy system. AFIR includes requirement for infrastructure in ports, and as part of the national policies, the Member States should include *"a deployment plan for alternative fuels infrastructure in maritime ports, in particular for electricity and hydrogen, for port services as defined in Regulation (EU) 2017/352 of the European Parliament and of the Council"*.

The suggested locations of hydrogen stations for cross-border transport are shown in *Figure 19*. The extended Next Wave project will continue the work of stimulating demand and in other ways facilitate the development of stations and deployment of heavy-duty vehicles.

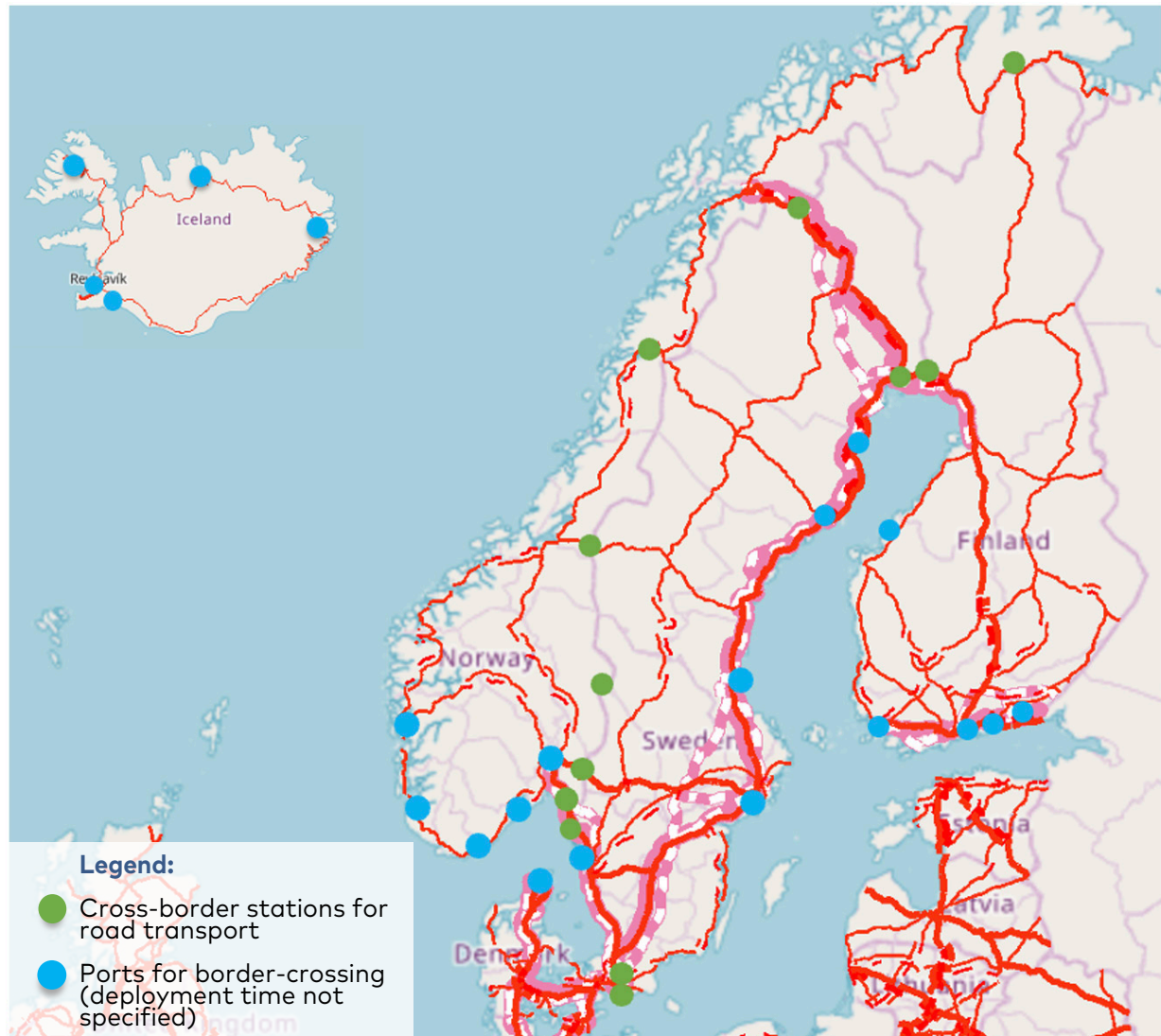


*Figure 19. Suggested locations of initial hydrogen infrastructure with regard to seamless cross-border transport services in the Nordics, including the main ports.*

# **Next Nordic Green Transport Wave - Large Vehicles**

Deliverable 5.1 & 5.2

## **Deployment of hydrogen trucks and infrastructure in the Nordics**

**Status, ambitions, and recommended actions  
to stimulate the demand**

Version 1.0

2021

