EVS38
Göteborg, Sweden, June 15-18, 2025

Electrified road freight transport in the Nordics: status, challenges and opportunities.

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Executive Summary
Decarbonising freight transport can significantly reduce emissions while affecting a limited number of vehicles. This article examines the state of freight transport electrification in the Nordics, based on the results of a SWOT analysis and a workshop conducted within the Swedish Transport Administration's Research and Innovation Program for Fossil Free Freight (Triple F). High vehicle cost, limited charging infrastructure, unclear policies, and difficult interoperability have been identified as major challenges. On the other hand, the region's innovation capacity, digitalization and environmental awareness, together with a low-carbon electricity mix make it particularly suited for the electrification of freight transport.

Keywords: International Networking, Electric Vehicles, Heavy Duty Electric Vehicles and Buses, Trends & Forecasting of e-mobility, Fast and Megawatt Charging Infrastructure.

1 Introduction

While freight vehicles only account for 2% of the overall road-vehicle fleet (approx. 283 000 heavy-duty vehicles registered in Sweden [1], Norway [2], Denmark [3] and Finland [4] as compared to over 13.5 million passenger cars and 1.8 million vans in 2024), freight is responsible for approximately 25% of the total CO_2 emissions from road transport [5, 6]. This is due to both their much higher utilisation as well as their higher energy consumption.

These figures indicate that decarbonising freight transport can significantly reduce emissions while affecting a limited number of vehicles. While electrification is the main approach for the decarbonisation of light vehicles, with the Nordic countries at the forefront of that transition, electrifying heavy-duty vehicles poses greater challenges. This article examines the state of freight transport electrification in four Nordic countries, namely Sweden, Norway, Denmark and Finland, emphasizing key challenges and opportunities.

The work presented here has been conducted under the Research and Innovation Programme for Fossil Free Freight (Triple F) [7], financed by the Swedish Transport Administration. Triple F is a 12-year programme focusing on the decarbonisation of freight transport in Sweden, resting on three main pillars: i) a more transport-efficient society, aiming to make logistic and transport chains more efficient; ii) a transition towards energy-efficient and fossil-free vehicles, focusing on using the best available transport mode and vehicle alternative for every transport; and iii) a move towards renewable fuels, looking into how to implement these solutions in reality.

In the Autumn 2023 Triple F organized a conference with a Nordic theme in which the differences and similarities in tools and approaches towards a fossil-free freight transport sector were discussed. The main take-home message from that conference was that the Nordic countries have much to gain in sharing knowledge and experiences to accelerate the transition. The work presented in this paper is the second step following the conference. By performing a SWOT analysis followed by a workshop, the Triple F program aims to discuss how the Nordic countries can lead the way and cooperate to accelerate

the transition to a fossil-free freight transport system. The aim of the workshop was to identify the most important topics within research, innovation and implementation where Nordic collaboration would make the most impact.

2 Method

The results presented in this article have been compiled from a wider study that includes all transport modes as well as other fossil-free alternatives such as hydrogen and biofuels. However, due to scope and space limitations, this article concerns only the electrification of road freight transport in the Nordic countries, although figures for biogas and diesel registered trucks are shown in section 3.1 for comparison.

To assess the current state of fossil-free freight transport in the Nordics, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was performed, supported by three different AI tools: Chat GPT, Copilot and Scopus AI. The use of AI at this stage was motivated by the characteristics of the study alongside the authors' eagerness to test these novel research tools. Collecting the information required to perform such a SWOT analysis covering four different countries is challenging. Depending on the country, most of this information is spread across different organisations and agencies. Such information is most often published in the country's language, making it hard to find. Moreover, using only the scientific literature body of work would hardly yield any results, since much of the information is published in the so-called grey literature (i.e. information produced on all levels of government, academia, business and industry, in digital or printed format, which is not controlled by commercial publishing). Additionally, each identified item in the SWOT analysis was complemented with a web and literature search to ensure that no important information was missing.

The SWOT analysis set the grounds for a half-day workshop with actors from the different Nordic countries, to identify prioritised actions within e.g. research, innovation or implementation where the Nordic countries should cooperate to accelerate the transition to a fossil-free freight transport system. All participants had access to a summary of the SWOT results before the workshop. Triple F also highlighted two specific topics as especially relevant for Nordic collaboration:

- *Policy:* How do the Nordic countries approach laws and regulations from the EU for the transition to a fossil-free freight transport system? How to ensure that harmonization of legislation happens when need exists?

- *Sustainable Energy:* What opportunities are there for fossil-free energy production in the Nordic countries and how can we work together to stabilize the energy supply in the area? How can actors in the energy and transport sectors collaborate to develop solutions for fossil-free freight?

First, the workshop participants were asked if they agreed with these two highlighted topics being the most relevant ones for Nordic collaboration towards a fossil-free freight transport, and they were encouraged to list further topics of interest and rank them in order of priority.

Then, the participants were prompted to discuss ways to increase collaboration across borders in joint projects and to identify potential funding sources for such collaboration.

21 people participated in the workshop, as detailed in Table I. This article presents an overview of the most relevant results from the SWOT analysis and the subsequent workshop.

Table 1. Participants in the workshop

Country	**Sector**	**People**
Sweden	Academia / Research institute	9
	Public agency	2
	Regional authority	1
	Industry	2
Norway	Academia / Research institute	1
	Public agency	1
	Regional authority	-
	Industry	1
Denmark	Academia / Research institute	1

	Public agency	1
	Regional authority	-
	Industry	-
Finland	Academia / Research institute	-
	Public agency	1
	Regional authority	1
	Industry	-

3 Current status

3.1 Electric heavy-duty vehicles

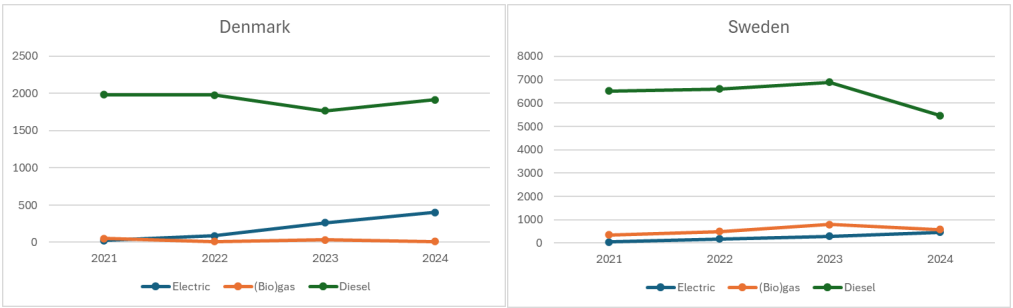
The electrification of the heavy-duty fleet is more challenging and has started later than that of passenger cars in all countries. However, significant increases in the sales of battery electric trucks are observed, especially in the last year, even if these vehicles still account for a small fraction of the fleet. Moreover, due to the commercial nature of these vehicles compared to passenger cars, the transition to electric heavy-duty vehicles is expected to go faster than for private cars once they become economically competitive.

In Denmark, battery electric truck sales grew from 25 units in 2021 to 88 in 2022, 265 in 2023, and 404 in 2024. In contrast, gas (natural or biogas) truck sales remained low, with 50, 11, 32, and 10 units sold in the respective years. Diesel truck sales, though still dominant, showed a slight decline: 1,985 in 2021, 1,980 in 2022, 1,769 in 2023, and 1,918 in 2024 [2].

Sweden shows similar trends, although with higher battery electric truck registrations reflecting its larger population. Registrations rose from 50 in 2021 to 174 in 2022, 294 in 2023, and 466 in 2024. Gas truck registrations, in contrast to Denmark's decline, increased from 347 in 2021 to 500 in 2022, and 793 in 2023, before dropping to 577 in 2024. Diesel truck sales remain dominant, with 6,524 registered in 2021, 6,611 in 2022, 6,892 in 2023, and 5,462 in 2024 [1].

In Norway, the registrations of new battery electric trucks increased from 64 in 2021, to 364 in 2022, 695 in 2023 and 688 in 2024. The number of new gas trucks was 115, 250, 418 and 582 respectively in the same years, while diesel trucks registrations amounted to 4,572, 4,109, 4,622 and 4,249. Compared to Denmark and Sweden in which the total number of diesel trucks in traffic has remained relatively stable, in Norway the total number of diesel trucks in the fleet is clearly decreasing [3].

In Finland, battery electric truck registrations grew modestly, from 2 in 2021 to 15 in 2022, 38 in 2023, and 63 in 2024. Gas truck registrations also increased, reaching 183 in 2024, up from 98 in 2023, 94 in 2022, and 96 in 2021, continuing a growth trend since 2016. Diesel truck sales have fluctuated over the years, peaking at over 5,000 in the early 2000s, dropping below 3,000 in 2010, and recording 3,297 in 2021, 3,124 in 2022, 3,707 in 2023, and 3,116 in 2024 [4].



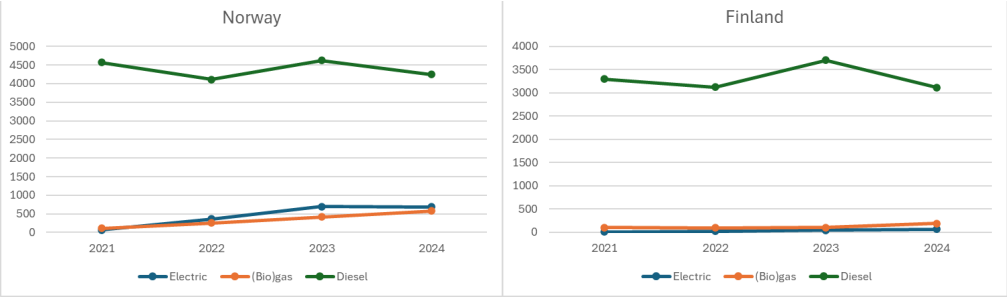


Figure 1. New registrations in the Nordics by fuel type.

3.2 Charging infrastructure for heavy-duty vehicles

The deployment of charging infrastructure is crucial for the successful electrification of road freight transport. While a significant amount of charging will take place at the logistic centres and depots, long-haul transport requires also fast charging infrastructure.

In Denmark, the first dedicated charging stations for electric trucks opened in October 2023. The national charging infrastructure strategy for heavy-duty vehicles includes the commissioning of 5 new stations with 37 spots in 2025, 6 additional stations with 63 spots in 2027, and 14 additional stations with 75 spots in 2030, to a total of 25 stations and 175 spots, with 133 MW of installed power.

In Sweden, in March 2024 there were 51 electric truck charging stations (165 spots). The funding program Regional Electrifying Pilots aims to establish 250 charging stations by the end of 2025.

The development in Norway has been slower, with just 17 charging stations for electric trucks in May 2024. However, a new financial package for 25 additional stations (135 spots) has been approved.

In Finland, there were just 3 publicly accessible charging stations for trucks in October 2024, and a few more had already been subsidised. However, no new funding has been allocated for 2025.

3.3 Relevant policy instruments

Denmark has established a national plan for the expansion of charging infrastructure. So far, approximately DKK 750 million have been allocated for 25 electric truck charging stations with a total of 175 charging spots along the Danish national roads [8]. Additionally, DKK 75 million have been allocated in 2024 for the purchase of electric trucks and the installation of depot loading at hauliers.

In Sweden, public charging infrastructure for heavy-duty vehicles is primarily funded by the Swedish Energy Agency's Regional Electrification Pilots program [9], while non-public (e.g. depot) charging is supported by the Klimatklivet program of the Swedish Environmental Protection Agency [10]. Electric truck purchases are subsidized up to 25%, depending on beneficiary characteristics

Norway also has a national plan for developing charging stations for heavy vehicles, approved in June 2023. So far, the state-owned company Enova has financed 44 fast-charging stations for heavy vehicles [9]. Enova also provides support for buying electric trucks. However, this is offered through competitive bidding, and funding is awarded to the most cost-effective and climate-friendly projects.

In Finland, both the Energy Authority and the Connecting Europe Facility transport programme provide support for installing charging infrastructure for electric trucks.

4 Identified challenges

Economy: Electric heavy vehicles are more expensive than their diesel counterpart. Even in those applications in which their Total Cost of Ownership (TCO) is competitive, the higher initial investment poses challenges, especially for small or medium-sized enterprises (SME) with limited financial resources.

Policy: Despite clear climate goals at EU and national levels, inconsistent and unclear policies hinder market confidence to invest in new technologies, emphasizing the need for long-term, harmonized strategies for fossil-free transport in the Nordics. The workshop participants reflected upon the effect that unstable variable policies had had on electric passenger car sales in their respective countries, discussing e.g. the effect of the sudden removal of subsidies in Sweden and Denmark. However, it was also believed that the Nordics are still ahead of Europe when it comes to transport electrification, and should join forces to reach momentum both in policy making and by sharing knowledge for technical development, to lead the transition and achieve our climate goals.

Infrastructure: Electrification also depends on adequate charging infrastructure, but grid upgrades

required for high-power electric truck charging are often slow and expensive. For instance, Swedish regulations have historically restricted grid expansion based on projected future demand, potentially delaying progress. Furthermore, a shortage of skilled professionals—engineers, electricians, and technicians—threatens the timely electrification of the transport sector.

Transnational fuel availability: A significant part of the goods transport in the Nordics is transnational, attending both to the commercial relationships between the countries and their geographical location. In the strive to achieve a fossil-free transport sector different alternatives to diesel are being tested, such as HVO, biogas, hydrogen and electricity. The different Nordic countries have different conditions for the development of these alternatives and may make different decisions going forward. There is probably not a single solution for all countries, rather it will be a mix of different fuels. However, attending at the transnational character of goods transport in the Nordics, it is important that these fuels are available in all the Nordic countries, so that e.g. HVO trucks from Finland can be used to transport goods into Norway, and biogas trucks from Sweden find a refuelling station in Denmark.

When it comes to electricity, a cross-border integrated platform with information on e.g. charging availability and prices, and solutions facilitating seamless international interoperability of charging infrastructure remain a challenge.

Resilience: Resilience and transition to fossil-free goods transport are sometimes put as counterparts, and resilience is used as an argument to delay or even prevent the transition. However, this does not need to be the case, and there is a possibility to increase resilience in the transition to a fossil-free transport system. In fact, the Nordic countries have the potential to become self-sufficient on fossil-free fuels and develop a set of alternative fuels, which would empower resilience. The recent accession to NATO of Finland and Sweden has lifted the resilience perspective even more, and the workshop participants wondered if security issues could become a springboard for joint infrastructure planning and research across the Nordics.

Supporting services: For a fossil-free goods transport system to be efficient, sustainable and competitive, not only core issues such as the vehicle and the fuel need to be developed, but also a number of supporting functions. Solutions must be communicated to spread knowledge. Ultimately, a system change is necessary to create an efficient and functioning fossil-free transport system. Among these supporting services, during the workshop the following items were discussed: new business models and market structures that facilitate a higher utilization ratio for the more expensive fossil-free vehicles, while also accommodating for the new operational conditions (e.g. recharging times and variable electricity prices in the case of electric trucks); digitalisation as an enabler for smarter transport planning that works across the countries (and thus needs access to relevant data in all countries), e.g. by providing a list of all truck refuelling stations across the Nordics, indicating what types of fuel are available, the power rating of the chargers, their operational status, etc;

Market acceptance: Without market acceptance, it will be difficult to create the tipping point in the transition. Going from a few pioneers to the majority of actors requires a new norm in the development ahead. Given the traditionally low margins in the transport sector, the transition must be economically competitive with the current diesel solution, unless there is a will from the customer (the transport buyer) to pay extra for fossil-free transport. Unfortunately, especially in times with less favourable economic conditions, this will is not present and almost the only important requirement is to transport goods at the cheapest price. It is therefore important that large companies like ASKO in Norway who are driving the transition, pave the way and establish good examples. It is also pivotal to spread the lessons learnt from these first movers taking part in tests and demos. In order to effectively communicate and spread information and knowledge about what solutions are possible and which aspects transport actors need to consider, it is important to share on a larger scale between countries.

5 Opportunities

The Nordic region presents several characteristics that favour the transition to electrified freight transport. The Nordic countries are among the most sustainable and environmentally aware in the World, with Finland, Sweden and Denmark ranking 1st, 2nd and 3rd respectively in the Sustainable Development Index ranking for 2024 [11]. Moreover, they also rank at the top of the Global Innovation Index 2024, with Sweden in 2nd place, and Finland and Denmark in 7th and 10th place respectively [12]. Nordic societies are also highly digitalised already. For these reasons, Nordic citizens are more receptive to innovative solutions, especially if they are targeting important societal issues like climate change.

When looking at transport electrification in particular, all countries in the Nordics have a highly decarbonised electricity mix, hence electrification will result in an immediate reduction of the emissions. Norway presented the least carbon intense electricity generation in 2023, averaging 30 gCO_2eq/kWh, followed by Sweden with 41 gCO_2eq/kWh, Finland with 79 gCO_2eq/kWh and Denmark with 152 gCO_2eq/kWh [13]. This values are to be compared with the EU average of 244 gCO_2eq/kWh or China's 581 gCO_2eq/kWh [14].

Finally, the similarities between the countries in terms of climate, population density, and socioeconomic and cultural factors allow for mutual learning, maximising the effectiveness of policy instruments based on each other's experiences.

6 Conclusions

Although several challenges remain to be solved, the Nordic countries are well-positioned to lead the transition to fossil-free freight, due to their cultural and socioeconomic characteristics. However, achieving this requires coordinated policymaking and knowledge sharing to address the challenges and capitalize on the strengths.

High vehicle cost and limited charging infrastructure have been identified as major challenges for large-scale deployment of electric trucks. These can be mitigated through advancements in battery technology resulting in lower vehicle costs and improved range, as well as developments in power electronics and charging system optimization. Additionally, logistics systems must adapt to electrification, with innovations in digitalisation, vehicle utilization (e.g. night deliveries), financial solutions or business models that result in reduced Total Cost of Ownership (TCO).

Collaboration among countries is essential to accelerate the adoption of electric heavy-duty vehicles in the Nordics. This includes ensuring seamless cross-border transport with accessible charging solutions and stable, predictable costs. To further evaluate the suitability of electric trucks in the region, large-scale demonstrations of cross-border electric freight transport should be prioritized as the next step.

As mentioned in the introduction, the aim of the workshop reported in this article was to identify the most important topics within research, innovation and implementation where Nordic collaboration would make the most impact in the transition to a fossil-free freight transport system, rather than to make a comprehensive analysis of all aspects of transport decarbonisation in the different countries. Despite the thorough planning, attendance to the workshop was limited by both budget and availability of the considered participants. Gathering a homogeneous group in which all countries had the same number of participants with the same backgrounds and roles and expertise proved to be extremely difficult. The predominance of Swedish participants can be explained by both geographical proximity, as well as previous existing relations with Triple F.

Acknowledgments

This research has been funded by the Swedish Transport Administration as a part of the Triple F programme.

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Presenter Biography

Francisco J. Márquez Fernández was born in Spain in 1982. He received his M.Sc. in Industrial Engineering (major in Industrial Electronics) in 2005 from the University of Sevilla, Spain, and his PhD in Industrial Electrical Engineering in 2014 from Lund University, Sweden. Currently he is a Research Leader in Electrification at the Swedish National Road and Transport Research Institute, and an Associate Professor in Industrial electrical engineering at Lund University. He is also responsible of the area Technology, within the Research and Innovation Program Triple F.