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Mobile range extender as an enabler for electrified forestry transports?

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Executive Summary

The TREE project aims to accelerate the electrification of forestry transport, a sector critical for reducing emissions but challenging due to high energy demands and insufficient infrastructure. In Sweden, forestry transport makes up a significant share of heavy-duty transport, transporting high tonnages and having high daily driving distances. TREE brings together over 20 organizations to explore the use of battery-electric trucks and innovative technologies like mobile energy storage systems (MESS) for charging at remote locations. The project will deploy 12 electric trucks across seven Swedish test sites, focusing on roundwood and woodchip transport. The feasibility of MESS as a type of range extender will be assessed to support battery-electric trucks on difficult routes. The project aims are to gather insights from operating MESS in test sites and showcase solutions to overcome challenges in this demanding industry.

Keywords: Heavy Duty electric Vehicles & Buses, AC & DC Charging technology, Fast and Megawatt charging infrastructure, Optimal Charging locations, Energy storage systems

1 Introduction

Electrification of heavy-duty transport will play a key role in achieving the EU climate goals and help to steer away from fossil fuels and thus cut emissions of greenhouse gases. The EU goal is to cut CO2 emissions by 55% by 2030 as part of their Green Deal initiative of which the road freight sector have an important share [1]. However, heavy-duty transport is often viewed as a challenging sector, with forestry transport being one of the most difficult areas to electrify. It is characterized by varied routes with heavy loads in remote geographies with long transport distances. These forestry transport specific challenges must be coped with to efficiently electrify this unique transport sector [2]. Fully piggyback on electrification and charging infrastructure rollout in other heavy-duty areas might be challenging due to the differences in transport missions.

Despite these challenges, there is great potential for CO2-reduction in this area. Forestry transports in Sweden constitutes nearly 20% of the heavy-duty transport work and is therefore important for decarbonization of the freight sector [3]. Despite the challenges, every electrified truck implies a great potential for CO2 reduction highlighting the importance of transition and the rational for prioritizing this sector. Other countries with a strong forestry sector will both have similar challenges and similar motives for decarbonization.

To enable large-scale electric long haul an extensive charging infrastructure will be needed, with charging stations at relevant geographical locations providing enough power when demanded. Previous studies have explored how the vehicles routing, driving patterns, and traffic density influence where stations should be optimally placed [4, 5, 6, 7, 8, 9].

Charge Point Operators tend to prioritize locations with high traffic intensity to maximize potential revenue. Due to costly tariffs for high power-charging, public fast charging requires high utilization to be cost-efficient. At a strategic level, traffic flow intensity can guide smart location of charging infrastructure. But it is not enough, in reality the state of charge also greatly influences the need for charging. A planning tradeoff between enough chargers to avoid long waiting times and still acceptable utilization will be key. Smart planning and/or utilization of the charging infrastructure can reduce the impact [6, 10,11, 12].

There is a potential mismatch between the forest transports flows and the market driven charging infrastructure roll out which tends to prioritize high traffic flow areas. Establishing a dense charging infrastructure in remote areas with varied and temporary flows might be challenging. This implies that the forest transport sector risks missing an opportunity for decarbonization via electrification.

This work introduces and discusses the functionality of a flexible and mobile charging solution for range extension in the challenging forest transport sector. The potential role of mobile energy storage systems with integrated chargers (MESS) for efficient transition will be investigated further in the project. Can the new system component MESS enable more battery-electric trucks to operate over long distances?

2 Experimental platform

The experimental platform for the MESS study is the ongoing TREE project (TRansition to Efficient Electrified forestry transports) which is a joint cross-company forest sector initiative to accelerate electrification in the area [13]. It is a large-scale system demonstrator which aims to explore the potential of electrifying the transport in the forest industry in Sweden. The project gathers more than 20 organizations covering the entire ecosystem required to electrify forestry transport, including forestry companies, hauliers, OEM, charge point operators among others. Within the project, 12 electric trucks will be running across seven regional test sites across the whole of Sweden, from North to South.

Complementary innovative technologies will be showcased, such as e-trailer, high capacity e-trucks carrying exceptionally heavy loads, MESS-solutions and integrated route and charge planning . The focus is on transport of roundwood directly from the forest to the industry and transport of forest industry byproducts (woodchips) between different industry sites, both known for their challenging conditions with high energy demands.

This platform gives a great opportunity for researchers to study the transition to battery electric trucks. Research questions in different disciplines and using various methodologies can be explored via the system demonstration.

All of the BEV trucks included in the project are manufactured by Scania, with technical specifications similar to available commercial alternatives. The project fleet includes different type of BEV trucks, for example transport of wood chips is relatively similar to applications where BEV trucks have been in use for a while. On the other hand, timber carrying truck with electrical crane and 94 ton gross vehicle weight (GVW) high-capacity transport BEV truck for wood chips are more novel applications for BEV trucks demonstrated in the project.

Currently a commercially available vehicle with a gross weight of 74 ton can have a driving range of up to 250 km, but it depends heavily on the operational conditions such the exact truck configuration, road and weather conditions as well as freight weight. The range can also vary depending on the drivers eco-driving skills.

3 Methodology

The future methodology involves large-scale practical evaluation of a MESS in real operation. The MESS is planned to start operating in one of the regional test sites later this year.

The initial results presented here come from detailed GIS-analyses based on real world data, and experiences from workshops with the companies in the TREE project. Both cover initial research to map and evaluate the potential role of a MESS in the system. GIS-analyses have been carried out to evaluate present forest transport flows and intensities in detail. A large historical data set covering almost all transport from the forest during year 2021, 2022 and 2023 has been analyzed. The data set includes origin, destination and what has been transported. In addition, an analysis of existing and coming public chargers was carried out using open data from the Swedish Energy Agency.

A large workshop was also held in August 2024 where more than 50 people from the TREE-project attended physically. Different actors were represented, and the discussions were held in diverse groups of approximately 7-8 people at the time. The overall question for the workshop was:

In whish application can a MESS provide value?

The question was discussed based on both the roundwood case and the wood chip case.

4 The Forestry transport case

In Sweden, which is a forest dense country with a well-developed forestry sector, the transport of roundwood from the forest and by-products between industrial sites accounts for a large share of the heavy-duty transport work. Roundwood trucks travel the longest distance per year, typically twice the distance compared to an average heavy-duty truck. Similar patterns can be seen for woodchip trucks. Both of them carry heavy loads, typically reaching a GVW between 64 and 74 tons as well as often operating the truck in two shifts. This combination gives the high tonne-kilometers in comparison to other sectors. This also implies that fast charging will be important since these trucks lack extended off-shift times or long idle time at industries [3].

The roundwood transport has small volumes at individual locations in the forest which never will be repeated in stark contrast to many other niches with geographically recurring tasks. Routes are being built with a mix of long and short tasks, and different pickup and delivery locations to maximize the share of driving with load given the drivers working time. Both the individual transports and the larger flow patterns vary with time which pose challenges for efficient charging infrastructure roll-out. There is a wide mix of transport tasks in terms of distance and geography and those include both easy and more challenging ones.

Woodchip trucks benefit from operating between established sites, allowing for a more efficient roll-out of permanent charging stations. However, considering high energy demand, the remote locations of the forestry industry and routes along sparsely used roads provide, both now and probably over time, few options of charging along the routes. Increased energy consumption in wintertime comes with additional challenges, even for more frequently used routes. The main transport flows for roundwood and wood chips are visualized in Figure 1.

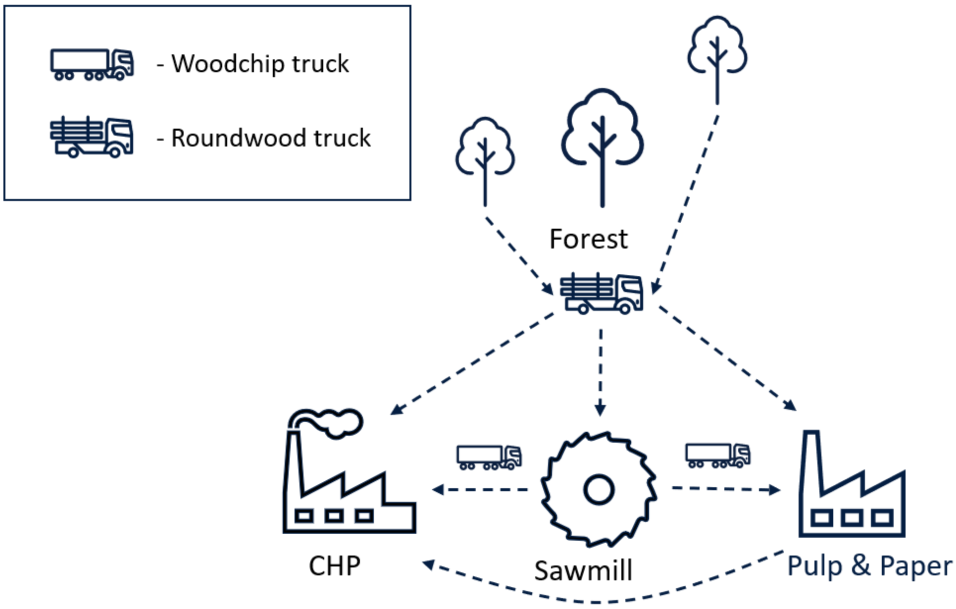

Figure 1. Schematic main transport flows in the forestry industry (CHP = Combined heat and power plant).

Figure 2 highlights that National and European motorways are used less, but trunk roads and A-class roads are important links for forest transports. Even the public road network with less traffic density and the private road network are widely used for forestry transport. Most of the transport starts on private roads, often forest roads. Roundwood trucks often operate in dynamic, off-grid forest locations with limited electric grid infrastructure and high site variability. This also implies that an optimal BET design with regards to e.g. battery size will vary over time.

In contrast to several other logistical systems and supply chains, forestry roundwood transport consists of concentrated flows. The annual supply points cover more than 200 000 pick-up locations which are concentrated to a few hundred main delivery points. Transport is done in the whole country starting with low-intensity flows in remote areas which are being more concentrated closer to different forest industries (Figure 2). Although the average one-way transport distance is slightly above 90 km for roundwood, there are many both shorter and longer ones [3].

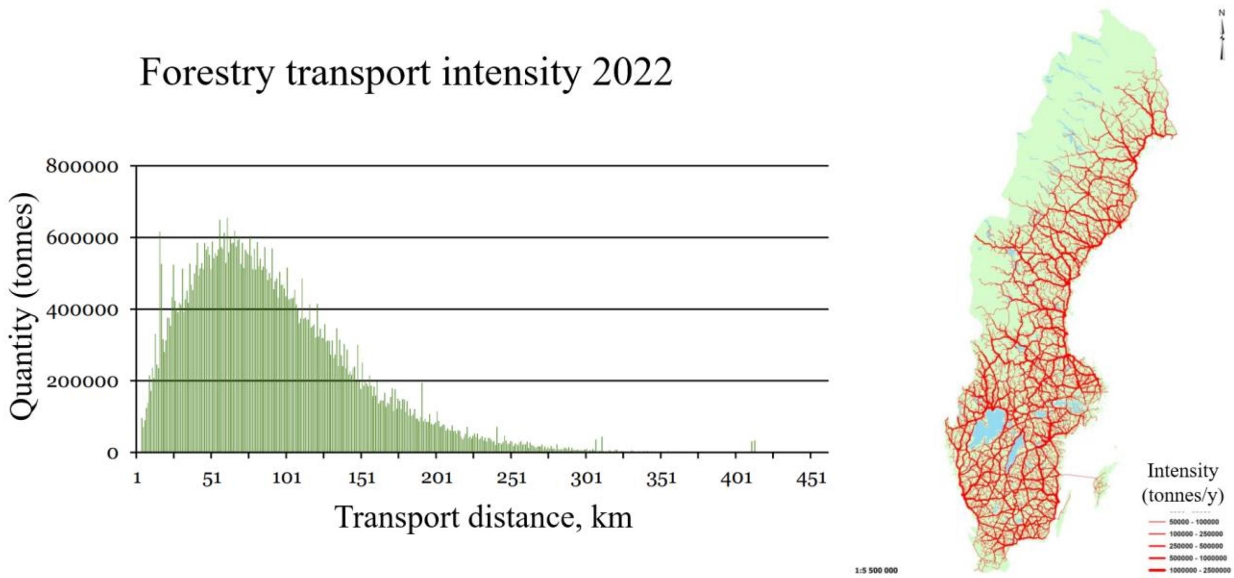

Figure 2. Forest transport intensity in Sweden (tonnes/annum) based on data for every forest transport reported in 2022. Adopted from [3].

Figure 3 presents the average value for all transport distances seen in 2021-2023 from every 10*10 km pixel in Sweden. Given the present range of up to 250 km, a one way distance below 75 km (Green in Figure 3) works fine assuming charging at the industry. The Blue areas 75 to 125 km is more challenging but can also work depending on exact setup. The red areas must be seen as beyond what is possible with today's state-of-the-art products. It is clear that a part of the total transport missions (Figure 2) and transports from certain geographies will be challenging to electrify given that charging only at industries are available, which motivates other charging solutions to reach high share of BEV trucks in the sector. For these, most challenging trips can complementing solutions such as e.g. HVO, biogas or hydrogen. Or one must focus on a more intensive charging infrastructure role-out. At present the charging infrastructure development (Figure 4) has not been aligned with the needs expressed in Figure 3. It is almost the opposite, where public charging is available in areas with already short distance.

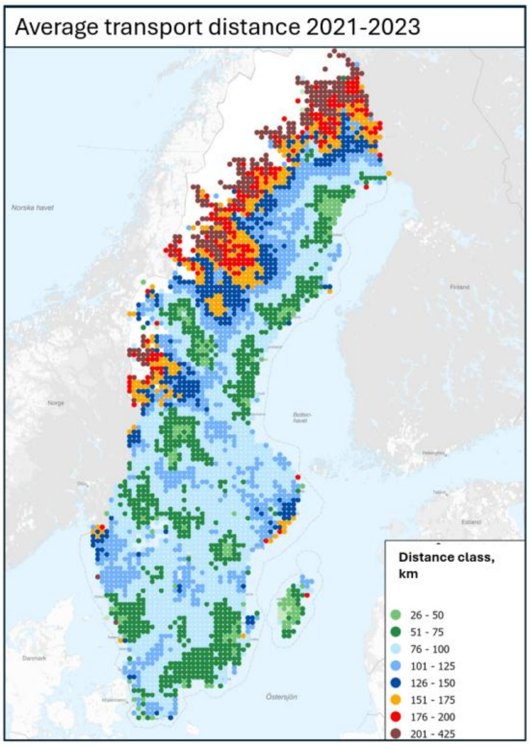

Figure 3. Average transport distance to industry from every 10*10 km pixel. Based on data for year 20121, 2022 and 2023.

Comparing the areas from where the forest material has long distance to an end-user and the existing and planned charging infrastructure, it is clear that present BEV trucks will have challenges with respect to range. New charging infrastructure in the blank areas with long distances would help electrification to move further. However, charging infrastructure will be prioritized to areas with high transport intensities to be cost-efficient. Fast charging with high power requires high utilization rate to cover the cost for power tariffs as well as return on the initial investment. These areas have limited goods flows from other sectors. Figure 5 showcase the number of forest truck passing different road links per day which gives an idea of the possibility to establish charging infrastructure focused on the forestry industry. Focusing on areas with more than 1 truck passing per hour will result in large areas lacking charging infrastructure.

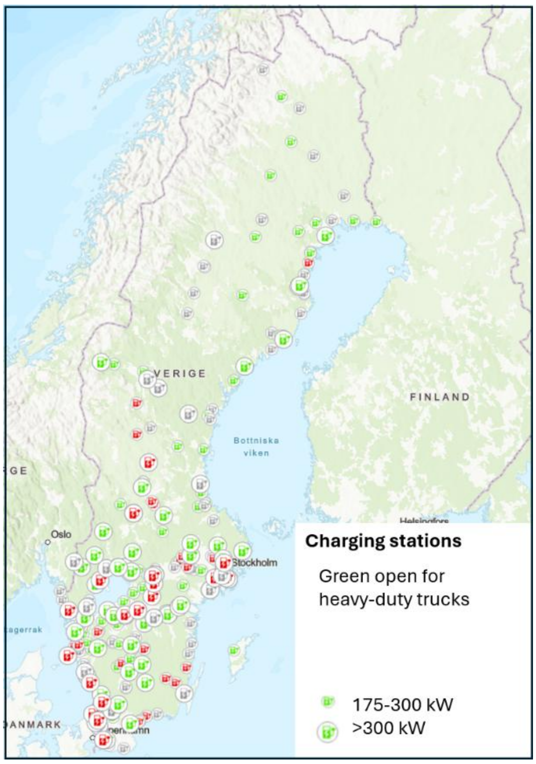

Figure 4. Snapshot over charging stations in Sweden. Green is suitable for heavy-duty trucks and open. Red and grey are unclear of accessibility for trucks and not open as for today.

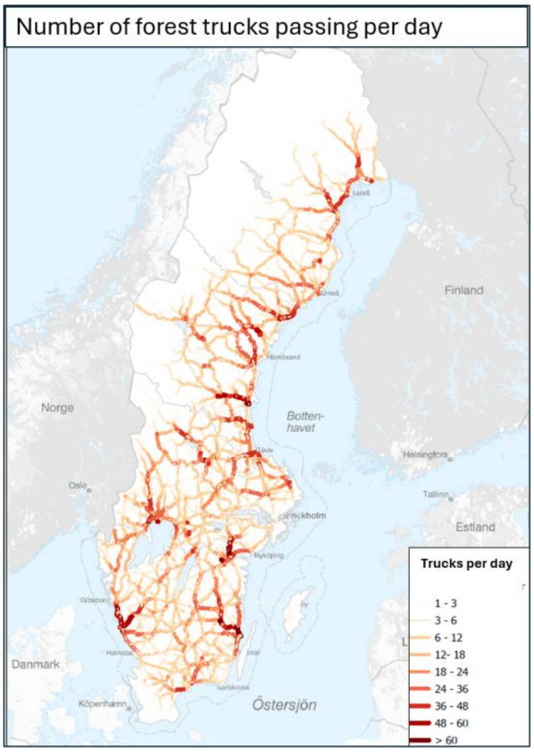

Figure 5. Transport intensity translated to number of forest trucks passing per day for different road sections.

5 Decentraliced mobile energy storage systems as an enabler for electrification

Access to charging is crucial for a successful system transition towards more BEV trucks in the heavy-duty freight sector. Charging can be divided into different categories (Figure 6) Each of the four concepts can be complemented with battery and integrated electricity production, e.g PV systems. Conventional *stationary* and *grid-connected* charging are the most common practice for BEV charging. However, that option can still be very different, e.g. public, semi-public or private, and offered at various power levels. All of the four concepts are also very different in terms of cost structure but can still have their own competitive niche depending on the context in which the solution is placed. The workshop concluded that a *mobile* and *off-grid system* can add different benefits and values, and that the MESS-concept and specifications must be designed with regards to its intended use-case.

	Off-grid	**Grid connected**
Mobile	Mobile energy storage system with charging	Temporary EV charging
Stationary	Off-grid EV charging	Conventional charging

Figure 6. Main charging concepts.

Three initial technical solutions for MESS were considered: Battery Energy Storage Systems (BESS), Hydrogen Energy Storage Systems (HESS), and generators running on sustainable fuels like Hydrotreated Vegetable Oil (HVO). All technologies have pros and cons and different technology readiness levels (TRL), which largely determined the technology's choice for this project's initial stage. BESS is heavy and requires reliable grid access, HESS faces supply and cost barriers for green hydrogen as well as the lowest TRL for the given application. A generator running on HVO is a reliable and robust technology with a secure and financially sustainable fuel supply.

To understand the interplay between different technical solutions and how they impact the system, it is vital to get consistent and reliable data on the performance of both battery-electric trucks and a mobile charging solution, where disruptions from the mobile charger should not impact the data flow received from the truck. Reliability and high TRL were key factors in selecting suitable MESS technology. As a result, a generator powered by HVO was chosen at the project's initial stage due to its robustness, high TRL, and economic viability. The functionality that a MESS solution provides is of focus at this project in form of what benefits can be achieved with such a component in an electrified forestry transport system. However what is a future-proof technology choice remains an open question.

To address the forest transport challenges and to provide a range extension, the TREE project investigates the feasibility of using a MESS to support battery-electric trucks operating over long distances in remote areas. The solution will be more expensive than conventional charging in terms of Euro/kWh. This unit should therefore only be considered as an complement to other solutions and an enabler for temporary challenging transport routes by providing a flexible charging option and thus becoming a type of range extender.

The workshop clearly suggested that a MESS can bring values to the system. However, the dilemma is that due to cost reasons it should only be used in situations where conventional fixed charging point is an unreasonable option. On the other hand, to keep charging costs at sensible levels the MESS as such must be used frequently. However, a steady and consistently high transport intensity open up permanent grided solutions. A compromise can be that the value of a MESS can be distributed among many trucks and thus also the cost. Finding these niches is a key determining factor for a MESS success.

Other value for a MESS is to offer charging while waiting for a permanent solution. Many charging establishments take a long time from planning to operation, sometimes even several years.

A future possible application for MESS can also be to provide charging during loading and unloading. However, practical things must be solved and the design adapted for that application.

The workshop also suggested that a MESS can add value when large disturbances occur. We have in recent decades seen large forest fires, large bark beetle invasions and storms causing great challenges. Theses events caused large temporary unplanned volumes to be handled. A MESS could be operated in such a situation to rapidly help to cope with the new conditions. Conventional forestry operation can also imply significant temporary volumes from an area. By the nature of rotation forestry, the volumes from that exact area will not be available for many decades.

Even regular flows and patterns will differ over time due to many factors. Sizing batteries for extreme situation and the maximum needs during a year will result in expensive overcapacity during many operating hours. A large battery also steals weight which is important for forest transport. A MESS can be motivated as a flexible solutions in such situations to scale up and down range and open new transport areas.

The TREE-project methodology is to continuously gather knowledge and experiences from the electrified transports and gradually challenge both the technical limits of the trucks and the transport efficiency of the electrified transport system. Within the project, MESS will be used to ensure back-up/safety for untroublesome routes, as well as to become a key asset in the form of a range extender for challenging routes and/or to increase the planning flexibility and utilization rate of battery-electric trucks.

6 Future work

The plan is to start operating the MESS later this year. It will initially be tested on a site with extra challenging transport conditions, with long distances and limited charging infrastructure. Learnings from practical operations will provide real world data and experiences which could be used in modelling purposes to systematically explore the value of MESS in the forest transport case.

The vision is that this project will investigate if and how a range extender in the form of MESS can efficiently help electrification of forest transports. By studying not only the MESS as such, but also the MESS in relation to transport planning, learnings can be drawn on the functionalities that a flexible charging solution offers. The initial learnings and conclusions should be used to support the design of future solutions which can incorporate alternative energy storage technologies as they mature, with the goal of enabling battery-electric trucks to operate efficiently in challenging and high-demand forestry applications. Research regarding how MESS affects route and transport planning can be done via the route planning and analysis tool described in [9]. Future research is needed to determine if MESS is a sound solution to accelerate and expand decarbonization of forestry transports.

7 Conclusions

The hypothesis is that adapted solutions, and new innovative technologies can facilitate the electrification in the forestry sector which often is considered extra challenging. The work addressed the feasibility of MESS as a type of range extender to support battery-electric trucks on difficult routes.

A part of today’s forestry transports will be difficult to decarbonize via BET given the state of the art in e-trucks and existing and planned charging infrastructure. Present long forest transports in areas with limited other goods flows may result in a charging infrastructure that does not fit the forest sector needs.

The conclusion from this work is that the functionality that the suggested mobile and off-grid solution provides can help in temporary challenging situations. An identified use case is as a flexible range extension that can change the operating conditions when needed. The flexibility can increase resource efficiency by not dimensioning trucks and infrastructure for the extreme.

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References

[1] European Comission (2019). The European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[2] Väätäinen, K., Anttila, P., Eliasson, L., Enström, J., Laitila, J., Prinz, R., & Routa, J. (2021). Roundwood and biomass logistics in Finland and Sweden. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering, 42(1), 39-61.

[3] Parklund, T., Davidsson, A., and Gustavsson, O. (2024) Skogsbrukets vägtransporter 2024: En nulägesbeskrivning av flöden av biomassa från skog till industri. Arbetsrapport Skogforsk 1197-2024

[4] Al-Hanahi, B., Ahmad, I., Habibi, D., & Masoum, M. A. S. (2022). Smart charging strategies for heavy electric vehicles. Etransportation, 13. https://doi.org/ARTN 100182 10.1016/j.etran.2022.100182

[5] Eagon, M., Fakhimi, S., Lyu, G., Yang, A., Lin, B., & Northrop, W. F. (2022). Model-Based Framework to Optimize Charger Station Deployment for Battery Electric Vehicles. 2022 Ieee Intelligent Vehicles Symposium (Iv), 1639-1648. https://doi.org/10.1109/Iv51971.2022.9827442

[6] Karlsson, J., & Grauers, A. (2023). Agent-Based Investigation of Charger Queues and Utilization of Public Chargers for Electric Long-Haul Trucks. Energies

[7] Krallmann, T., Doering, M., Stess, M., Graen, T., & Nolting, M. (2018, 25-27 May 2018). Multi-objective optimization of charging infrastructure to improve suitability of commercial drivers for electric vehicles using real travel data. 2018 IEEE Conference on Evolving and Adaptive Intelligent Systems (EAIS)

[8] Speth, D., Plötz, P., Funke, S., & Vallarella, E. (2022). Public fast charging infrastructure for battery electric trucks—a model-based network for Germany. Environmental Research: Infrastructure and Sustainability, 2(2), 025004. https://doi.org/10.1088/2634-4505/ac6442

[9] Rönnqvist, M., Flisberg, P., Pernestål, A., Sundström, L. E., & Gustavsson, O. (2025). Integration of electrical and diesel truck in forest operations HVTT18 Heavy Vehicle Transport & Technology, Québec, Canada.

[10] Menter, J., Fay, T.-A., Grahle, A., & Göhlich, D. (2023). Long-Distance Electric Truck Traffic: Analysis, Modeling and Designing a Demand-Oriented Charging Network for Germany. World Electric Vehicle Journal, 14(8), 205. https://www.mdpi.com/2032-6653/14/8/205

[11] Zhu, X., Mishra, P., Mather, B., Zhang, M., & Meintz, A. (2023). Grid Impact Analysis and Mitigation of En-Route Charging Stations for Heavy-Duty Electric Vehicles. IEEE Open Access Journal of Power and Energy, 10, 141-150. https://doi.org/10.1109/OAJPE.2022.3233804

[12] Saqib, E., & Gidófalvi, G. (2024). Dynamic Adaptive Charging Network Planning Under Deep Uncertainties. Energies, 17(21), 5378.

[13] TREE: Transition to efficient electrified forestry, https://www.skogforsk.se/english/projects/tree/, accessed on 2024-10-10