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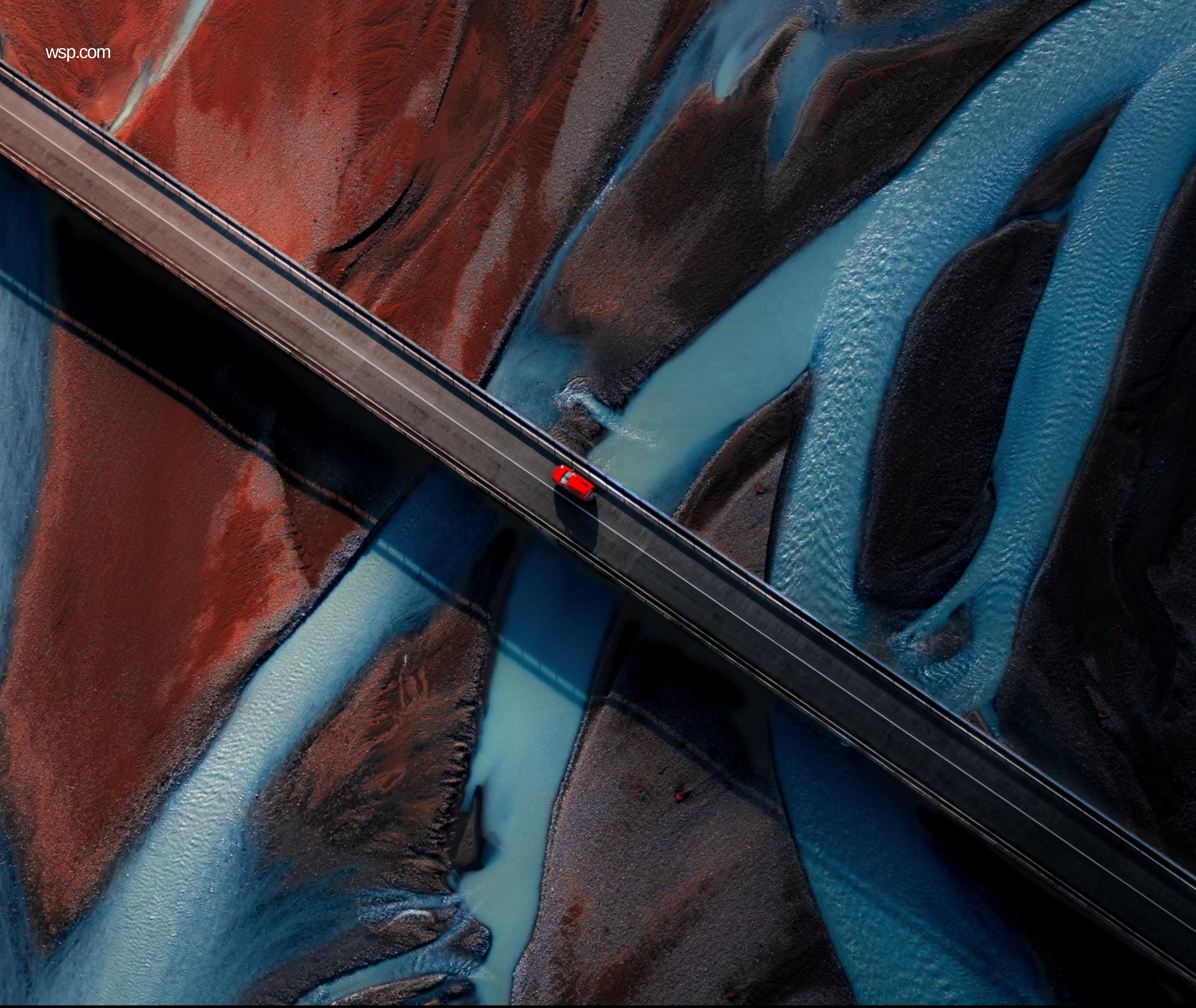

The State of Electric Road Systems

An Overview of Central Aspects

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CONTENTS

Summary ... 4

1. Introduction ... 5

2. Testing and demonstration projects ... 6

2.1 Pilot projects and test results ... 6

2.2 Further research needs and open issues regarding technical aspects of ERS ... 9

3. Comparison with other drivetrains ... 11

3.1 Overview of assessment criteria and drivetrains ... 11

3.2 Challenges for stationary and dynamic charging ... 11

4. Cost Analyses and Demand Forecasts ... 13

4.1 Technoeconomic analyses ... 13

4.2 Cost-benefit analyses ... 14

4.3 Summary of the results ... 15

5. Acceptance ... 16

5.1 Market acceptance ... 16

5.2 Community acceptance ... 17

5.3 Socio-political acceptance ... 17

6. Decision making ... 18

6.1 National decision making ... 18

6.2 European decision making and the AFIR ... 19

6.3 Decision about the technical solution ... 19

6.4 Future possibilities and the way forward ... 19

7. Conclusions and further Research ... 21

7.1 Conclusions from this report ... 21

7.2 Discussions about the future of ERS ... 22

7.3 Further Research ... 23

References ... 25

Appendices ... 27

Appendix A. Presentations from seminar 1: Tests and Demonstration Projects ... 27

Appendix B. Presentations from seminar 2: Decision Making ... 27

Appendix C. Presentations from seminar 3: Cost-Benefit Analyses and Demand Forecasts ... 27

Appendix D. Presentations from seminar 4: The OEMs' Views on ERS ... 28

Appendix E. Presentations from seminar 5: Latest Developments in ERS ... 28

SUMMARY

Electrification of road transport is crucial to limit global warming. Since 2020, dynamic charging via electric road systems (ERS) has received much less attention in scientific literature and in public debate than battery electric vehicles with stationary charging. The future role of ERS in low-carbon road transport is also much more uncertain. The purpose of this paper is to give an overview of the collected knowledge and research gaps on ERS. The paper is based on five digital seminars that were arranged in 2024 and 2025 with presentations from leading researchers, policy makers, and companies in the field.

There are strands for further research on ERS, both related to policymaking, system perspectives and technical issues, although one should not require all issues to be solved before making decisions (in that case no technology would be accepted). Overall, we have sufficient knowledge about ERS: the technology has been proven viable in real-world driving and the corridors for further roll-out are known. Yet, the technological uncertainty about which ERS technology to use, the high upfront investments required, and the neutrality or partial opposition of OEMs remain major challenges. Still, current knowledge is sufficient to take the next step and decide about an ERS roll-out (Plötz, et al., 2024).

The revision of AFIR will be an important event for the future of ERS in Europe. Our recommendation is that ERS should not be mandatory since there is no support for that in the member countries. However, we do recommend that ERS is included as an option that can be used to lower the requirements for stationary charging and hydrogen.

1. INTRODUCTION

Electrification of road transport is crucial to limit global warming. Dynamic charging via electric road systems (ERS) has received much less attention in scientific literature and in public debate than battery electric vehicles with stationary charging. The future role of ERS in low-carbon road transport is also much more uncertain. Plötz et al. (2024) argue that existing field trials, tests, and research projects have collected sufficient knowledge to take the next step: decide and act. The purpose of this paper is to give an overview of this collected knowledge.

The paper is based on 5 digital seminars that were arranged in 2024 and 2025 with presentations from leading researchers, policy makers, and companies in the field. The presentations and, were relevant, a short analysis of the topics can be found on the CollERS 2 project's homepage CollERS 2 | CollERS 2 Home (CollERS – "Collaboration on Electric Road Systems" – is an innovation partnership concerning ERS). The topics discussed at the seminars were:

Table 1. Connection between report chapters and CollERS Seminars

Chapters	Seminar 1	Seminar 2	Seminar 3	Seminar 4	Seminar 5
2. Testing	x				x
3. Cost benefit and forecasts		x			
4. Acceptance				x	
5. Decision making			x		x

The purpose of this paper is not to develop new knowledge, but to give an overview of existing knowledge. The information from the seminars is complemented with knowledge from literature. The purpose of this is merely to put the information from the seminars in context, not to give a full literature review.

As usual in review publications summarizing the current literature in a field of research, we base the conclusions in the present text on the seminars and existing literature. However, we do not merely repeat or state the conclusions from the seminar presentation but draw our own conclusions. As such, all conclusions and potential mistakes are our own and only our own.

Since the presentations at the seminars were often quite detailed, the present report also tends to be detailed in some parts. Hence, it is important to keep some aspects already established in the literature (Plötz, et al., 2024)in mind: the technology has been proven in real-world driving and the corridors for roll-out are known. Yet, the technological uncertainty about which ERS technology to use, the high upfront investments required, and the neutrality or partial opposition of OEMs remain major challenges. Still, current knowledge is sufficient to take the next step and decide about ERS roll-out. If we wait for all challenges to be solved, we will have no solution for sufficient reduction of the climate gas emissions from road transport (neither ERS stationary charging nor hydrogen).

The disposition of this paper is close to the seminars, but not identical (that would have made the paper tough to read). We have tried to have a progression from technical to political analysis. The chapters treat:

- Testing and demonstration projects
- Comparison with other drivetrains
- Cost-benefit analysis and demand forecasts
- Acceptance
- Decision making

In the conclusion chapter, we try to point out suitable next steps for research and decision making.

2. TESTING AND DEMONSTRATION PROJECTS

The technology for electric road systems (ERS) has been developed and tested in many projects in recent years. More than 25 demonstration and pilot projects have been carried out in several countries (including Sweden, Italy, Germany, the Netherlands and more) leading to significant progress in ERS technology. During seminars 1 and 5, several of these initiatives were presented showing that tests have for example:

- Proven the overall functionality of ERS technology (both conductive and inductive) including road maintenance compatibility and functionality in harsh conditions, including winter climate.
- Show that electric vehicles can finish their drive on an electric roadway with more charge than they began with, even in winter climate.
- Successful tests have been conducted with electric road systems that charge electric buses and passenger EVs simultaneously.
- Proven significant fuel consumption reduction and GHG-emission savings for ERSV compared to diesel trucks.
- Indicated that ERS technologies meet electromagnetic compatibility regulations (EMC).

2.1 Pilot projects and test results

There are ongoing test projects with both inductive electric road technology and conductive ground-based and overhead catenary line electric road technology in several countries around the world, including France, Italy, Israel, Germany, the USA, China and Japan. In the USA the focus has mainly been on inductive technology. Other countries like Germany and Netherlands have focused on conductive technology.

In the USA, pilot projects for electric roads have also been carried out in several locations, including Florida, Utah, Indiana, and Michigan. One of the larger projects currently under construction is an electrified highway in Indiana, which will include a testbed with inductive technology. In the fall of 2024, China took an important step in implementing electric road systems by signing a contract for a first major demonstration project with 14 km catenary lines. Since 2023, inductive technology has also been tested in combination with autonomous vehicles in a closed road system at the China FAW Technology Innovation Base. China also has further plans to test inductive technology for buses and trucks, with the first step being to test the technology in an industrial park for buses in Shandong.

In Europe, Germany and France are countries with larger test stretches on public roads either already in place or planned soon. Germany was among the first countries to start testing ERS on public roads and has been operating three ongoing large-scale demonstration projects since 2019 and 2021. France has previously mainly conducted tests on test tracks, but several tests are planned to start 2025 and 2026 on high-traffic highway sections. The French tests include both inductive technology and conductive ground-based technology. The test results should form the basis for a future decision on ERS in France. A smaller test with inductive technology is planned in Norway for powering bus traffic in Trondheim. The concept is a combination of static and dynamic charging to primarily power local bus traffic.

During the seminars, several representatives presented pilot projects and test results from their countries or companies. The projects and their test results are briefly introduced below.

2.1.1 Italy

One of the more ambitious pilot projects for dynamic wireless power transfer (DWPT) was built in Chiari in Italy between 2021-2024. The project was coordinated by the company A35 Brebemi in collaboration with Stellantis and other partners. The ERS-system was made by Electreon. The roadway length was 1.05 km. Further studies are planned to improve the efficiency of the system.

The first part of testing was concluded and demonstrated the DWPT system, in both static and dynamic configurations, transfers power with efficiencies of about 87% for dynamic charging and 92% for static charging. The tests also showed that the electromagnetic field values measured on board the vehicles under test conditions are found to be lower than what is prescribed in the regulations regarding EMF exposure limits. It also showed that the system doesn't have interference to the functionality of electromedical devices such as pacemakers and electro stimulators.

The project was the first electric road system that charged an electric bus and passenger EV simultaneously, underlining the versatility of the system to function as a shared charging platform for both large and small EVs. In the test, the passenger EV and electric bus finished their drive with more charge than they began with and charged from the same roadway. This showed that in specific case scenarios, on-route charging can end up charging a vehicle's battery to the point where end of day or overnight charging might not be needed at all. The electric bus was able to drive three straight days without losing any power and a passenger EV was 22% charged at the beginning and reached 48% charge at the end of the event meaning that it increased in battery state of charge(SOC) while driving on the dynamic charging track (Electreon, 2025).

2.1.2 Germany

Germany has implemented several pilot and test projects of ERS including three larger projects on public roads ELISA, FESH, and eWayBW. All tests on larger public roads in Germany use the Siemens catenary eHighway technology.

The **ELISA** project started in 2018 but has had two different phases. The first phase lasted between **2019 to 2022.** The eHighway Hesse was built on 10 kilometres (5 kilometres in each direction) of the A5 motorway between Langen/Mörfelden and Weiterstadt south of Frankfurt with 5 overhead contact line hybrid trucks. The second phase started in **2023** and ended in December **2024** (analyses ongoing until mid-2025), with a total length of 17 km overhead contact line with 11 ERS-trucks and ERSV. The infrastructure was set up for operation in 24/7 mode. In this second phase traffic, energy, technological, ecological and economic aspects that are relevant for an expansion of the system are researched. A separate project (AMELIE II) has been investigating billing systems and methods for electrically powered trucks and interoperability within the European context. Other projects of the accompanying research are working on items like TCO and business models, electrification of the motorways, traffic management, effects on the electricity grid, and solutions for rescue teams.

The most recent tests on ELISA were conducted with three different trucks (hybrid, hybrid + plug-in, and electric). Findings from the project showed an increase in average availability from GEN 1 (hybrid) to GEN 2 (hybrid + plug-in) by approximately +14%. The GEN 2 fuel consumption reduction compared to GEN 1 was -19% and -38% compared to a reference diesel truck. The GHG emissions savings for GEN 2 were up to 46% compared to a diesel truck.

Future research and development suggested by the Elisa project includes acquiring more knowledge about the trucks regarding how to improve lane detection and about automatic detection of overhead lines and pantograph operation. It also includes further research on how to fully electric 40-ton ERS trucks and about pan modular systems. For the infrastructure, more research into information systems on the status of the overhead line system for drivers and transport companies and the roll out of the billing system would be desirable. Further recommendations are also that general knowledge about scalability should be developed about resilience of the system, network expansion and how to enable cross-border transportation and more general knowledge about the connection of electric roads and autonomous driving (CollERS Seminar 1, 2024).

Further technical and organizational results from the test track eWayBW find that the overhead lines don't distract other vehicle users while driving and that no additional emergency requirements, e.g. in tunnels, are needed in real-world operation. However, the overhead line must be drawn off the road in case of damage. Further, the accompanying research found that CO_2 and NO_x emissions could be significantly reduced with an extensive rollout. The noise reduction from hybrid overhead catenary trucks is rather low, however (Wietschel, et al., 2025). A technology comparison with battery electric trucks (BETs) indicates that a high number of BETs is possible with stationary charging at depots alone while overhead line trucks need more significantly more public charging infrastructure for a market diffusion (Speth, et al., 2025).

In Germany, a pilot project called "Bev goes E-Highway" has recently been conducted (CollERS Seminar 5, 2025). The initiative has aimed to retrofit existing battery-electric trucks with pantograph systems for dynamic charging. The project has encompassed the development of a standardized retrofit interface, on-road testing, and an evaluation of the technology's feasibility. The project has utilized all four of Germany's existing ERS test tracks.

The project has successfully developed a standardized system interface for the integration of overhead line technology, in collaboration with vehicle and component manufacturers. One of the most difficult parts of the project that is recommended to be further tested is vehicle communication. The project has also conducted extended road testing with vehicles featuring various powertrain technologies, enabling direct comparisons between them. Road testing has also been successful showing retrofitting BEVs for dynamic charging works. The project has found that the retrofit concept is economically viable for the vehicle owner as it has the possibility to reduce battery capacity and cost.

The project will continue working on technology assessment through user studies involving drivers from the logistics sector, stakeholder feedback, and validation based on data collected from prototype vehicles. What remains for further research regarding retrofit is standardization and making the technology even more accessible and adaptable to other trucks. TCO and CO_2 savings compared to other alternatives could also be studied further.

The Elonso project (2022 –2025) focused on advancing pantograph technology for electric road systems (ERS) in Europe, aiming to improve interoperability and support cross-border freight. It developed technical specifications, and test stands for evaluating pantograph performance, including lateral movement, high-current handling, and digital modelling (CollERS Seminar 5, 2025).

The pantograph testing resulted in technical specifications for ERS pantographs that was published in December 2024 (Prinz, et al., 2025). The article describes requirements for overhead ERSs and ERS pantograph testing. Among the most important requirements are the rising and lowering times, response to lateral manoeuvres, such as lane changes, and high electrical current during standstill. They present the developed test stands that can test various aspects of an ERS pantograph. The lateral test stand was developed to test basic functions and simulate lateral movements. A second test stand was implemented to test high currents and the subsequent temperature development. In addition, a digital test stand is introduced that is used for planning, design, and modelling.

While significant progress was made, some areas, like simulating real-world conditions (e.g., road vibrations, weather) and conducting risk analyses, require further research. The project also supports EU standardization and calls for broader European collaboration.

A related study (Göhlich, 2025) found that battery-electric trucks using ERS offer the lowest emissions and costs, outperforming both diesel and hydrogen fuel-cell alternatives, making them a promising solution for sustainable long-haul transport.

2.1.3 China

In China, five large ERS pilot projects are currently planned or under construction with more than 500 km in total. The projects are cooperations between companies and universities located in different parts of China (Ürümqi, Hami City, Ordos, Bayan Nur and Yulin). China has a goal of CO_2 neutrality by 2060. The highlighted advantages of ERS are the lack of length limitation and that it can be used for a variety of road types and that it is suitable for intelligent driver assistance systems (CollERS Seminar 5, 2025).

2.1.4 India

In India an ERS project was announced and planned by the government in **2023** with a plan to install ERS on the full Delhi-Mumbai highway and potentially along the full the Golden Quadrilateral, 6,000 km. The project started by acquiring land for the Jaipur-Delhi section (160 km) for electric cable highways for e-buses (CollERS Seminar 5, 2025).

2.1.5 Netherlands

In Netherlands, the ambitions about electric roads are high, and not only at testing level. The goal is that dynamic charging should be a supplement to stationary charging to reach the CO_2 goals. Electric Road Systems in Netherlands are projected to reduce CO_2 emissions by 33 % by 2040. The plan is to integrate ERS into existing infrastructure. Two ERS-trajectories are planned by 2032. The first one, between Rotterdam and Antwerpen, should be ready by 2030 at 100-120 km. The second distance, which is 180-200 km, is planned between Rotterdam and Venlo. This is done using an overhead line and a pantograph. The decision and the choice of routes has been prompted by thorough research and testing in the Netherlands. Research has been done on policy options and CBA, network vision, technology assessment, and concrete projects at the University of Antwerp. The Dutch government earmarked €100 million for its development in 2024.

The Ministerie van Infrastructuur en Waterstaat is working on embedding national and regional policies and on aligning demand and supply for an optimal trajectory and on ensuring the availability of a comprehensive ERS ecosystem (road infrastructure, vehicles, grid integration). Funding is expected to come from Truck Tolling and Climate Fund. And potentially also from EiB and from private initiatives. The Netherlands earmarked €100 million for its development in 2024, but no formal decision has been made due to political instability in the country, with a new election in October 2025 (van Vliet, 2025).

2.1.6 Sweden

In Sweden, the Swedish Transport Administration has conducted activities over the past ten years to contribute to increased knowledge about various electric road technologies and other electrification alternatives that can contribute to the electrification of the road transport system in Sweden. The Swedish Transport Administration has co-financed four electric road demonstrators that have been carried out on public roads in Sweden between **2016 - 2024**. The main purpose of the demonstrators was to investigate the ability of the different technologies to transfer electric energy to vehicles efficiently under the conditions prevailing in the Swedish road transport system. The experiences show that all the technologies tested in Sweden work and can supply the vehicles with electric power while driving. Focus on tests in Sweden has also been on whether it works in winter climates. The test has shown that dynamic charging works, and that the technology is generally maintainable, and tests have shown that installation is possible, but that maintenance needs further testing to experience harsher traffic environments and long-term operation issues. It has also been shown that the technology meets requirements regarding EMF/EMC but that it needs further testing.

The Swedish Transport Administration’s tests of electric roads include both inductive and conductive charging technologies, with conductive charging via overhead lines currently being the most proven system. There are also trials involving conductive charging via road rails.

2.2 Further research needs and open issues regarding technical aspects of ERS

A lot of testing has been done but there are areas that require further development and testing. The remaining challenges may necessitate more pilot projects. This is a consolidated overview of topics that are of interest for further studies based on what was said in the presentations during seminars 1 and 5. Areas that benefit from further research are, for instance:

- **Management systems and other auxiliary systems** such as:
    - Effective information systems for billing, traffic management and information exchange.
    - Ancillary systems and equipment used for road monitoring and traffic control.
    - Vehicle intelligence and vehicle communication includes better lane detection and about automatic detection of overhead lines and pantograph operation, improved ERS detection, seamless compatibility across different vehicle manufacturers, and tighter integration with autonomous driving technologies.
- **Technology-specific R&D**
    - Increase of power transfer for some technological options to accommodate additional charging, improving inductive charging efficiency, and reducing the risk of arcing.

- Safety improvements ensuring electrical and traffic safety as well as enabling a safe roadside- and operational environment.
- **Durability of ERS**
  - Long-term real life performance data is still lacking and should hence be researched more. Long-term endurance testing can provide real-world proof of the concept.
- **Retrofitting**
  - Standardization for retrofitting and making the technology even more accessible and adaptable to other trucks. TCO and CO_2 savings compared to other alternatives could also be studied further.
- **Autonomous driving**
- **Scalability**
  - Resilience of the system, network expansion and how to enable cross-border transportation
- **System perspective**
  - If ERS is intended to serve as a complement to stationary charging, it is essential to develop a shared vision and a coherent strategy for how the overall charging system should be dimensioned and operated in conjunction with vehicle design.
  - Establish a common view of parameters like the power transfer capacity of the ERS (in kW), the appropriate battery size in the vehicles, the required level of electrification, and other interrelated factors.
- **Road management perspective**
  - *How will a fully developed electric road affect the road operator from an accessibility, traffic safety, and management perspective*? Those are issues that are scarcely discussed in the ERS community (as far as we know they have only been discussed during The Swedish Road Administrations presentation at the Berlin conference, see CollERS 2 | Berlin Symposium), but they will need further dissemination before a large ERS implementation.

3. COMPARISON WITH OTHER DRIVETRAINS

How the social acceptance of ERS will develop also depends on how competition from other drivetrains and their characteristics and costs evolve. For a realistic assessment of the future role of ERS in zero emission trucking, a comparison to other technologies is required.

During the seminars, several lively discussions around the technological maturity of different zero emission truck technologies and their challenges took place. The present section summarizes both presentations as well as discussions to highlight the state of knowledge and identify gaps in literature.

3.1 Overview of assessment criteria and drivetrains

ERS is not the only technological option for zero emission truck transport. At the same time, the urgency of emission reduction in road freight requires governments to decide among technologies in the face of technological uncertainty (CollERS Seminar 3, 2024). Supporting all emerging technologies equally would be both expensive and introduce time delays due to uncertainty (CollERS Seminar 3, 2024). In this context, (ITF, 2023) proposes to support technologies based on their likelihood to successfully meet policy goals based on four criteria

- **Technology Maturity** assessed via Technology Readiness Levels (TRLs),
- **Cost-Competitiveness** measured as time to achieve similar or lower total costs of ownership than diesel trucks.
- **Sustainability** based on life-cycle emissions
- **Speed of deployment** based on availability and mass market readiness of the fuel and infrastructure.

The technologies in competition with ERS to future zero emission trucking are battery electric trucks (BETs), hydrogen fuel cell trucks (FCETs), hydrogen combustion engine trucks, biofuels and e-fuels in conventional combustion engine trucks.

ITF (2023) concludes that BETs with stationary charging are among the most mature options, which are expected to achieve total cost of ownership (TCO) parity with diesel by the mid-2020s for smaller vehicles, and around 2035 for larger ones. Further, BEV delivers together with ERS the lowest life-cycle emissions, can leverage existing infrastructure technologies and benefit from synergies with passenger BEV charging. Hydrogen and ERS technologies, on the hand, require significant new infrastructure and longer lead times while TCO is likely to be high for hydrogen options and large-scale availability of biofuels and e-fuels challenging or unlikely in the time frame and speed required. Thus, BET with stationary charging and with ERS offer low costs and low emissions and benefit from the advantages of direct electrification, but ERS poses additional infrastructure roll-out challenges. ERS would, however, have the advantage of smaller batteries in the trucks required when compared to BET with stationary charging. ITF (2023) concludes that BETs with stationary charging currently have the highest likelihood of successfully decarbonising road transport.

3.2 Challenges for stationary and dynamic charging

There have been some debates about infrastructure challenges for BETs with stationary charging as well as dynamic charging during the seminars. The main options for stationary charging are charging in depots, mostly overnight or between vehicles shift, and high-power fast charging, e.g. with the new megawatt charging system (MCS) standard, during regulatory break times for BET in long-haul operation. A potential challenge for both depot and MCS charging is the availability of or lead time to build the required grid connection for sufficient power for charging.

In the case of depot charging, first studies indicate that less than 50 kW for overnight charging would be sufficient for large shares of truck operation (Speth & Plötz, 2024; Hacker, et al., 2025), but that the time to get larger grid connections, e.g. of a few MW for large depots with over 50 trucks, can take a few years in several European countries (Hacker, et al., 2025). However, many studies assume that ERS trucks would also usually charge at depots such that in this case the depot grid connection challenges apply to both technologies.

Concerning MCS charging along the highway, significant grid connections will be required too. However, as vehicles do not charge at full power perfectly simultaneously, charge point operators usually apply for a significantly smaller grid connection than the sum of charging powers, e.g., only 5 MW for 8 MCS chargers. Still, 5 MW of grid connection from medium voltage is currently usually only available at some truck parking lots close to the highways. In this context, some authors argue that ERS would require lower grid connection power locally, as the power demand is more spread along the highway. To be more specific, for a full electrification of a major highway segment, MCS would require a few large MCS and ERS would require many small 1 – 2 MW transformers along the highway. However, physically, the overall electricity demand is the same, as the same large number of vehicles with the same per km electricity consumption would be charged, either continuously or at individual locations. Accordingly, the small transformers along the highway in the case of ERS must also be connected to medium-voltage stations for electricity, but more research is required to fully understand the grid connection challenges for both technologies.

Concerning the time required for grid connection, (Kippelt, et al., 2022) state that for Germany, connecting to an existing medium-voltage ring is suitable for power demands up to 8 MVA and can be implemented within 0.5 to 2 years. Connecting to an existing medium-voltage busbar in a substation via a new MV cable supports power between 8 and 20 MVA, with a realisation time of 0.5 to 4 years. Expanding an existing substation and connecting via a new MV cable accommodates power needs from 20 to 30 MVA and requires 2 to 5 years. Building a new dedicated high-voltage to medium-voltage substation enables loads above 30 MVA and takes up to 10 years to complete (Kippelt, et al., 2022). For other countries, Hacker et al. (2025) summarize that “grid connection has long lead times in all four countries [Germany, France, UK, and Spain]. While grid connection usually takes a few years in Germany, Spain and France, a duration of up to a decade was mentioned by one expert for the UK if the current substations cannot provide the power needed." Thus, the time for grid connections varies between power requirements, countries and locations, but several years for several MVA seems the most likely value in most countries and locations.

Overall, both ERS and stationary charging are likely to experience delays or challenges in grid connections, but the extent of these challenges for either technology is currently a matter of debate with limited empirical data on either side.

4. COST ANALYSES AND DEMAND FORECASTS

Estimating the economics of ERS hinges on two distinct analytical frameworks. Technoeconomic assessments (TEA) rank ERS against competing technologies, typically from a private-cost or total cost of ownership (TCO) perspective, whereas socio-economic cost benefit analyses (CBA) derive a net welfare effect against a no-ERS baseline. Because TEA treats infrastructure largely as a cost to the operator while CBA internalizes public spending and externalities, divergent results are inevitable. The choice of method also correlates with the prevailing funding model: Nordic studies with central-government costs tend to opt for CBA, while countries expecting toll or tariff recovery favour TEA.

As a result, during the seminar, studies using both methodologies were presented with mixed results. Studies using a CBA method in Sweden yielded both positive and negative socio-economic results of ERS. In other countries, in which the technoeconomic method was used, ERS proved to be a cost-effective method as a decarbonising method given certain assumptions.

4.1 Technoeconomic analyses

A techno-economic assessment evaluates both the technological and economic aspects of a proposed system, technology, or project. It encompasses the technical feasibility, operational efficiency, and potential performance of the system, alongside the economic viability, cost-effectiveness, and financial implications of its implementation. This type of assessment can be used for decision-makers to understand the trade-offs between different technological options and to determine the most beneficial and sustainable solution from both a technical and economic perspective. It can involve comparing various scenarios, conducting simulations, and sometimes performing cost-benefit analyses to provide a holistic view of the project's impact and potential.

During CollERS Seminar 3 on Cost-Benefit Analyses and Demand Forecasts (see Appendix C), two recent contributions were discussed. Hacker (2024) studied three technological pathways: 1) BEV, 2) BEV + Fuel Cell Mix, and 3) BEV + ERS vehicles (ERSV) from overhead-lines. The author found that BEVs dominate the market ramp-up in all technological paths and scenarios, but that ERSV can be operated at competitive costs if there is infrastructure available. Craglia (2024) studied different scenarios of technology adoption of different HDVs based on TCO. The author found that ERSV can be cost-competitive but that their utilisation and speed of deployment is yet uncertain. As ERS will require a high initial investment cost, the author argues that ERS probably will need government support or concessionary agreements to be cost-competitive. Further uncertainties about ERS are argued to be which ERS technology is most optimal, which in turn increases hesitation among policymakers. ERS does not seem to have momentum among OEMs and will need to prove its viability compared to other options, such as MSC. However, Craglia (2024) suggests that large scale pilot projects with competitive tendering can help clarify relative costs of ERS compared to MSC. In France, Raynal (2024) presented an analysis of ERS implementation on two networks: 1) a 4 836 km and 2) 8 800 km network carrying 16.1 billion HDV-km annually. The results showed that an ERSV with a 350 kWh battery can operate below diesel costs and that the toll needed to repay the €37.6 billion investment is €0.324 per vehicle-km, which was lower than that of diesel of €0.379. The larger network also yielded an 86 percent reduction in greenhouse gas emissions.

Other literature has also studied the techno-economics of ERS. In the United Kingdom, studies have shown that overhead-catenary ERS consistently outperforms both hydrogen fuel-cell and large-battery electric heavy-goods vehicles on energy efficiency and cost (Ainalis, et al., 2023; de Saxe, et al., 2023). Vehicle-simulation work by de Saxe et al. (2023) confirms that ERS could shrink battery sizes by 41 – 75 percent, translating into capital savings between US $25 000 and $112 000 per vehicle and reduced emissions between 29–127 t CO_2e. In the Netherlands, a country-scale study shows that once network length reaches about 1 000 km the ERS alternative delivers a lower TCO than stand-alone battery-electric trucks, whereas a 125 km pilot does not recover its capital cost (Decisio, 2022). Comparable conclusions emerge from Turkey, provided utilisation rises above the moderate-traffic threshold identified in the model (see Coban et al. (2022). Almost all the reports and studies on the techno-economics of ERS show that ERS can be cost-competitive compared to other technologies while simultaneously being a cost-effective measure to reduce carbon emissions from the road freight sector.

4.2 Cost-benefit analyses

During the CollERS seminar 3 (see Appendix C), results from cost-benefit analyses were also presented. For example, The Swedish Transport Administration (2024) conducted a socio-economic cost-benefit analysis of an ERS implementation on the most heavily used roads in Sweden, assuming a parallel ERS roll-out in the EU. The analysis resulted in positive economic effects for transport companies as benefits from reduced charging infrastructure were larger than potential user fees. However, the total socio-economic cost-benefit analysis resulted in a negative cost-benefit ratio of -0,7. The Swedish Transport Administration concluded that it most likely will be too costly for a small country as Sweden to be the first mover in developing larger ERS network. Uncertainties such as technology choice, high investment costs, future developments of operation and maintenance costs as well as potentially low usage rate as the market for ERS vehicles would still be in an introductory stage given that Sweden is the single market and that a relatively large share of the heavy-duty traffic is international. Nevertheless, an important assumption made in this study is that ERS is assumed to be up-and-running in 2040, a year by which 100 percent of all heavy-duty trucks are electrified in Sweden, meaning that ERS will not contribute with a large socio-economic benefit of reduced greenhouse gas emissions as ERS will compete with other electrified vehicle solutions. Moreover, the usage rate of the ERS system is assumed to be between 15-20 percent, on average 20 percent (although TCO was estimated to be lower for ERS than for BET).

Another study conducted on the Swedish road network was conducted by Rogstadius (2024), in which the willingness-to-pay (WTP) was simulated based on ERS utilisation rates and pricing. Rogstadius modelled the relationship using ASEK 8.0 parameters, similarly to the Swedish Transport Administration (2024). The study found that ERS WTP was slightly higher compared to static charging. Furthermore, simulated ERS WTP was found to decrease over time due to the value of battery savings decreasing with lower battery cost and improved battery utilisation as well as the levelized costs of static charging decreasing with improving utilisation. Contrary to the Swedish Transport Administration (2024), an ERS is assumed to be available in 2035, in which the fleet of heavy-duty trucks in Sweden are not yet fully electrified. Rogstadius (2024) estimated that ERS usage rate where 80 %, i.e. significantly higher than Swedish Transport Administration (2024). Andersson et al. (2024) estimated an ERS usage rate in the middle of Swedish Transport Administration (2024) and Rogstadius (2024). The authors estimated that ERS and BET will have similar usage rates in 2040. The input into the choice model developed was an examination showing that TCO for ERS and BEV will be similar, which is in with the literature (see for example (Jöhrens, et al., 2020)).

Since that latest CollERS seminar (see Appendix C), more recent cost-benefit analyses have been published. In Spain, Flores-Gandur et al. (2025) conducted an impact assessment framework based on cost-benefit analysis incorporating climate change and other environmental benefits, which was applied to a section of the Mediterranean Highway Corridor AP-7. More specifically, the authors developed two distinct scenarios with the baseline scenario reflecting a do-nothing scenario in which traditional diesel-full-powered HDVs operated without dynamic charging and an inductive ERS scenario examining the integration of inductive charging infrastructure. In the ERS scenario, the authors assume that the share of ERS vehicles compared to ICE-vehicles is split in the first year of operation. However, the share of ERS vehicles is then assumed to increase by ten percentage points every subsequent year, resulting in 100 percent ERS vehicles seven years into operation. The authors found that the social benefits of inductive ERS are larger than their social costs, in which the greatest benefit arose from the reduction of greenhouse gas emissions and air pollution when comparing to the baseline scenario. On a larger European scale, Börjesson & Proost (2025) studied how user costs of diesel trucks, battery electric trucks, and trucks relying on overhead lines compares. The authors further studied the economics of ERS on the EU TEN-T road network using two representations: 1) average EU truck flow and truck trip characteristics and 2) domestic and international truck transport between two neighbouring countries with diverging average traffic flows and shares of international truck trips on their TEN-T network. The author's overall conclusion is that the installation of ERS appears to be a robust investment decision for large countries with dense truck traffic but not for less dense countries.

4.3 Summary of the results

Both the presentations from CollERS Seminar 3 and other literature using techno-economic assessments and cost-benefit analyses have revealed mixed results. Techno-economic studies generally demonstrated that ERS can be cost-effective and technologically feasible, with potential cost savings and significant reductions in greenhouse gas emissions compared to other drivetrains. However, cost-benefit analyses indicated that the economic viability of ERS is dependent on traffic density and initial investment costs. While ERS projects seem to be beneficial in regions with high traffic volumes, smaller and less densely populated countries may face challenges due to high costs and uncertainties in technology adoption. Overall, the studies highlight the need for government support and pilot projects to better understand the economic implications and optimize the implementation of ERS.

Table 2. Summary of studies and reports on cost-benefit analyses of ERS

Study/report	Year	Country/Region	Methodology	Demand forecast (ERS use)	Results
Decisio	2022	Netherlands	TEA	25% (alt. 1), 65% (alt. 2), and 80% (alt. 3).	Positive
(Coban, et al.)	2022	Turkey	TEA	50% or 100% depending on scenario	Positive
(Ainalis, et al.)	2022	UK	TEA	N/A	Positive
(de Saxe, et al.)	2023	UK	TEA	N/A	Positive
(The Swedish Transport Administration)	2024	Sweden	CBA	20%	Negative
Andersson et al.	2024	Sweden	TEA		Positive
(Rogstadius)	2024	Sweden	CBA	80%	Positive
Raynal	2024	France	TEA	N/A	Positive
Hacker	2024	Germany	TEA	30%	Mixed
Craglia	2024	N/A	TEA	N/A	Uncertain
(Börjesson & Proost, 2025)	2025	Germany & Sweden	CBA	50% (period 1), 100% (period 2)	Mixed
(Flores-Gandur, et al.)	2025	Spain	CBA	50% (year 1), 100% (year 7)	Positive

5. ACCEPTANCE

This chapter is based on the presentations during seminar 4 by Patrick Plötz, Aline Scherrer, and Matts Andersson (CollERS Seminar 4, 2024).

The success of ERS depends not only on engineering performance or cost competitiveness, but also on how it is perceived, supported, and adopted by various stakeholders. The acceptance of a technology can be described as the willingness and readiness of different stakeholders to support, adopt, and integrate a new technology or system. This makes social acceptance a critical dimension of ERS implementation (CollERS Seminar 4, 2024). Drawing on Wüstenhagen (2007), social acceptance can be understood as comprising three interrelated dimensions: socio-political acceptance, community acceptance, and market acceptance. In this context, social acceptance can be defined as the willingness and readiness of stakeholders to support, adopt, and integrate a new technology or system. The different components of social technology acceptance help to analyze and address the complex social dynamics that influence the diffusion of renewable energy technologies, including ERS.

In the context of ERS, market acceptance plays a particularly central role, as the technology requires alignment and commitment from key industrial actors, most notably truck manufacturers (OEMs), freight operators, and infrastructure providers. Without their active participation, even the most ambitious ERS deployment plans risk failure. At the same time, socio-political acceptance – including clear policy support, public investment, and regulatory coherence – is essential to reduce uncertainty and create long-term stability required for industrial investment (CollERS Seminar 4, 2024). This section applies the social acceptance framework to ERS, with a focus on understanding the role of truck OEMs in shaping market acceptance, and how their strategies, perceptions, and actions influence the viability of ERS as a large-scale climate solution. The following figures summarises the three dimensions of technology acceptance according to Wüstenhagen et al. (2007).

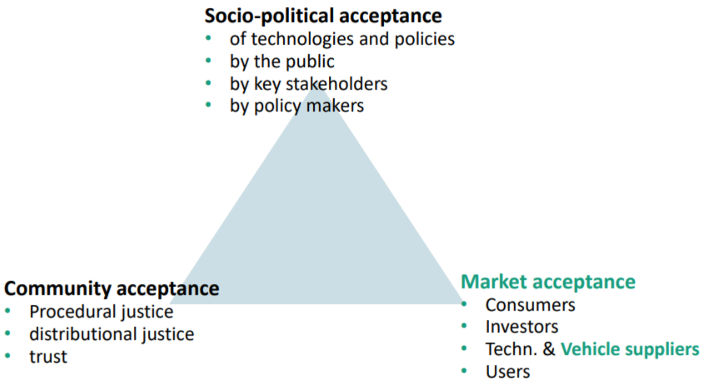

Figure 1. The three dimension of technology acceptance according to Wüstenhagen et al. (2007)

5.1 Market acceptance

OEMs, i.e., vehicles manufacturers, play a key role in the potential future of ERS. Only if they test and offer ERS trucks can logistics companies buy them, and infrastructure operators regain their investments from user fees (CollERS Seminar 4, 2024). The acceptance of OEMs, i.e. one integral part of market acceptance, can be well described by the vehicle offer to the public. Scherrer & Rogge (2025) present an overview based on interviews and vehicle announcements with the seven large truck OEM's that supply most European logistics companies (which was presented by A. Scherrer during seminar 4). They find only Scania to have ERS trucks in their portfolio while Volvo was the only one that considered it an option before 2019. Most of the truck manufacturers focus on battery electric trucks as their main technology option for the future, some having multiple alternative options (Scania, Volvo), one alternative option (Daimler) or wait for the other companies to act first (Iveco, MAN, DAF, Renault). Thus, from a vehicle supplier's perspective, the acceptance for ERS is very low at this point (CollERS Seminar 4, 2024).

Other actors in the market acceptance domain include infrastructure manufacturers and logistics operators as potential users. On the infrastructure side, several companies offer different ERS variants (catenary, induction, in-road electric, etc.). However, typically one company offers only one or very few technology options and there is no overall agreement on the infrastructure producer side which ERS technology is the best option. This is in contrast, e.g. to stationary charging, where almost all infrastructure providers offer CCS and (already have or plan to offer) MCS chargers. On the side of logistics operators, little empirical data about their willingness to adopt ERS is known. Interviews during the field trials in Germany show that the involved haulage companies are overall satisfied with the tests, little is known about acceptance in the overall group of logistics companies (Gnann, et al., 2023).

5.2 Community acceptance

In the German field trials, the project eWayBW (Gnann, et al., 2023) had a very elaborated approach to analyse ERS technology acceptance in general. For the local acceptance, two focus group meetings were conducted with citizens living close to the test track. Before the focus group discussions, they evaluated ERS mostly neutral and only partly negative, while perceptions were even more negative afterwards. However, large numbers of residents reported to be uninterested. The reasons for the rising scepticism were related to cost (difficult to evaluate), technological fit (in relation to BET), comparably short tracks (2.5 km in Baden Wurttemberg) and several failures on the vehicles and transformers or disturbances during the use. Also, an optical disturbance from the overhead lines was mentioned, and the rollout was expected to be difficult, especially in terms of organization.

5.3 Socio-political acceptance

In the eWayBW project (Wietschel, et al., 2025), the participating logistics companies reported positive driving behaviour and reduced noise while driving but also mentioned several technical issues in testing projects and insufficient reliability at that time (due to problems on the vehicles and transformer stations but not uncommon for demonstration projects). The drivers consider noise and ease of use very positive but report less flexibility because of lane dependency. Difficult political acceptance on local, county and national level was also perceived during the field trial, while media reporting turned from neutral to a more negative reporting of ERS over time.

Acceptance by industry is important, and public choice theory suggests that small interest groups with much at stake will be the most effective in influencing government policy (Olson, 1965). Citizens, on the other hand, are typically less organized but have significant political power because they vote. Because citizens rely on information to make political choices, the media is an important element in the process of public opinion formation by affecting people's knowledge, attitudes, and actions (Newbold, 1995; Boyd-Barret & Newbold, 1995; McLeod, et al., 2002). Acceptance literature has some general conclusions on how different factors influence how people vote on an issue. One such factor is that environmental policy measures (which ERS can be seen as) are more popular if the environmental problem is perceived as severe and if the policy measure is seen as an effective solution. Concerning ERS, it might be too early for the public to have formed such opinions (at least in Sweden, Germany is probably further ahead in the discussion). Before the debate heats up, the public usually regards it as a technical question. The financing method affects the popularity of investments. User financing is generally popular but can lead to suboptimal usage. (Andersson, et al., 2022). User financing is more common in continental Europe, while government funding is more common in the Nordics.

6. DECISION MAKING

No EU government has so far committed to large-scale investments in Electric Road Systems. The window of opportunity for common decision-making is currently open, but it will not remain much longer. Coordinated efforts are essential for a common European ERS-network, without collaboration there will probably be no common large-scale expansion of ERS in Europe. The fact that many nations have been waiting for decisions from others or a collective agreement has resulted in stagnation in initiatives. In view of the current market situation with a strong focus on battery electric vehicles with stationary charging, a centrally coordinated ERS expansion plan in Europe is not expected in the near future. But since ERS has the potential to contribute to reduced greenhouse gas emissions in Europe and worldwide, local initiatives are still underway that could enable a gradual expansion of electric roads.

6.1 National decision making

At this point, it is therefore interesting to look at national ERS actions and to examine an expansion strategy that can be derived from national or bi-national activities. It is rather from such initiatives that a larger ERS network could emerge in Europe. In an earlier CollERS report on the application potential of ERS in eight European countries was studied (Hacker, et al., 2023). It showed a high overlap of the prioritized national routes with the European TEN-T core network and a relatively coherent connection of the national routes to cross-border European corridors. In an early market phase without an existing common ERS network, point-to-point connections between important freight handling points could be of importance as they can guarantee high infrastructure utilisation.

A few countries are allocating funds to explore ERS as a viable alternative for reducing the transport sector's climate emissions. At present, the Netherlands and France are leading efforts to implement electric roads in Europe, with the most advanced plans, however at a more local level. The Netherlands earmarked €100 million for ERS development in 2024 (CollERS Seminar 2, 2024) but no formal decision has been made in 2025 due to political instability in the country, with a new election in October 2025. Germany, once a leading proponent of electric roads, now has a government that does not promote or fund further ERS development at a larger scale. As a result, Germany has not launched any new government initiatives in recent years apart from pilot projects, which has influenced decisions in neighbouring countries such as Austria and Denmark, whose own actions are largely dependent on coordinated harmonization at European level. Austria, stated in their *Masterplan mobility 2030* from 2021 that "Overhead lines appear to be a promising technological option alongside other emission-free technologies". A feasibility study has been performed showing a demand potential for dynamic charging on read reactions that are well suited to being equipped with charging infrastructure. However, Austria has no own test tracks and is also stated that a coordinated harmonisation at European level in needed (CollERS Seminar 2, 2024).

In Sweden, the Swedish Transport Administration presented a government assignment regarding electric roads in December 2024 where they concluded that they advised against large-scale construction of electric roads in Sweden. According to the investigation, it would likely be too expensive for Sweden to be the first in Europe with a major expansion and the cost risks are too high compared to the benefits that an early electric road rollout could provide. As the utilisation rate risks being low, it is unlikely that a mature market for electric road vehicles can be created if Sweden is the only market. Additionally, a relatively large portion of heavy traffic in Sweden is international (The Swedish Transport Administration, 2024).

The E-CORE initiative involves partners from Germany, Hungary, the Netherlands, and Austria, aiming to create a unified EU corridor concept for ERS. The project includes political, economic, and technical work packages, focusing on harmonizing operations and building procedures across countries. In addition to the organizational, legal, economic and technical requirements, the project is also investigating the synergies of a combination of electric road systems and fast charging points as well as the potential of bidirectional charging processes to reduce emissions. The next phase of the E-CORE projects is preparing a feasibility study for an electrified corridor from the Netherlands via Germany and Austria to Hungary, specifically for heavy freights vehicles (CollERS Seminar 2, 2024; CollERS Seminar 5, 2025).

6.2 European decision making and the AFIR

At European level, the Alternative Fuels Infrastructure Regulation (AFIR, Regulation (EU) 2023/1804) came into force in April 2024, setting mandatory fleet- and distance-based targets for the roll-out of static charging infrastructure for light- and heavy-duty vehicles. The objective of AFIR is the deployment of basic charging and refuelling infrastructure across the EU. It is also to complete interoperability (physical interface & communication) between vehicles and infrastructure and to ease of use of the infrastructure (information, transparent prices, common payment systems). In the AFIR, ERS-technology is mentioned, but no concrete expansion targets are formulated there. According to a presentation that was held by a European Commission representative on a seminar in May 2025 (CollERS Seminar 5, 2025), it is unlikely that the upcoming revision of AFIR will impose any requirements for large-scale expansion of ERS since there is no support from the member states.

The European Commission is currently undertaking several initiatives related to ERS. In May 2025, a technology and market readiness report dedicated to heavy-duty vehicles was presented. (European Commission , 2025) Within the Sustainable Transport Forum (STF), a task force for ERS is introduced within the zero-emission HDV subgroup. A report will be published this summer where the following topics will be covered: land use, combining static and dynamic charging, ERS in a large-scale electrification scenario, and the impact of autonomous vehicles (CollERS Seminar 5, 2025).

Within AFIR, there is also work on technical standards. A new delegated act adds a standard for ERS- technique (Delegated act 1.14 *Electric Road System (ERS) for dynamic ground level power supply through conductive rails for light- and heavy-duty electric vehicles)*. The regulation aims to address the lack of common technical specifications for alternative fuels infrastructure in the EU (CollERS Seminar 5, 2025). The technical standard is specified in **CLC/TS 50717:2022** 'Technical requirements for current collectors for ground-level feeding system on road vehicles in operation'.

6.3 Decision about the technical solution

For many countries, a common *technical solution* is a prerequisite, making a pan-European decision desirable. There are two paths to choose between: a passive path where one follows a dominant first mover and do not strive for compatibility and an active path where a common decision is made so that the best technology and subsystems are chosen in a way that is compatible all over Europe. (Andersson, et al., 2024). The absence of large-scale agreements has led to informal decisions by actors in smaller regions, often without a comprehensive national strategy. Conflicts arise when national decisions are contradictory yet interdependent. Most agree that overhead contact lines are the most mature ERS technology, and this is the technique that will be used in the Netherlands. (CollERS Seminar 2, 2024). Meanwhile, the UK's National Highways has vetoed ERS with overhead contact lines while simultaneously insisting that ERS expansion must be a collaborative effort. This contradiction risks creating a Catch-22 in a common decision-making process.

6.4 Future possibilities and the way forward

Despite existing challenges, ERS remains a potential solution for the transport sector's climate emissions. It offers a safeguard against the risk of failing to meet CO2 targets due to unforeseen disruptions, such as political reluctance to raise diesel prices or difficulties in deploying static charging infrastructure due to grid constraints. The potential of ERS also lies in that it addresses problems that are not yet fully visible. For instance, once more than 50% of trucks are electric, finding sufficient space for charging stations and ensuring grid capacity will become increasingly challenging. Keeping ERS as a complement to static charging is hence a rational approach in this scenario.

There are circumstances where ERS may offer advantages over stationary charging, particularly in terms of grid capacity limitations and spatial constraints for static charging infrastructure. However, obstacles remain, including concerns over overhead catenary systems and the long-term durability of in-road and in-pavement solutions. Overhead systems are more technologically mature and likely the best option for rapid deployment, yet other technologies may enjoy greater public acceptance and offer better business models and interoperability potential. Road infrastructure gives further challenges, such as low bridges, while national highway agencies have significant influence, often acting as a decisive force, as seen with vetoes in the UK and France. Additionally, ERS currently has a negative net present value and internal interest rate in most calculations which poses economic challenges to broader implementation. However, what is important to bear in mind is that the same applies to many stationary charging facilities as well as to hydrogen refueling stations. Yet, investments are being made in them, for stationary charging most likely as many more actors support the large-scale roll-out of stationary charging BETs making the investment much less risky. The combination of stationery charging and ERS still has the potential to be the 'optimal' solution.

It would still be possible to find a path in AFIR that could facilitate the expansion of electric roads without requiring large-scale national expansion. For example, it could be possible to offset the expansion of stationary charging or hydrogen against building electric roads on certain road sections and enable substitution between static and dynamic charging within a larger system. Such a solution could foster a charging system where static and dynamic charging could be complements. If ERS is integrated into AFIR, ERS could be eligible for funding through CEF (Connecting Europe Facility). CEF finances both work and studies (Johansson, et al., 2023). There is a risk of a deadlock situation if national deployment of ERS is expected before a more ambitious AFIR integration. It can also be kept in mind that hydrogen does not have much support from the member states but is still included in AFIR. This means that it should not be excluded to find a solution where ERS can be included in the upcoming revision, but without coercion.

7. CONCLUSIONS AND FURTHER RESEARCH

7.1 Conclusions from this report

Electric Road Systems (ERS) represent one potential approach to decarbonize road freight transport, but their role in a future zero-emission transport system remains uncertain. The aim of the present report was to summarize the current knowledge and research gaps around ERS based on five online ERS seminars and complemented by existing literature. The report is based on five European ERS seminars complemented by existing literature. It thus has a strong focus on Europe only and could be partially biased, as many participants in the seminars are ERS experts with technology experts often being overly optimistic about the prospect of "their" technology (as is well known for Delphi studies, see, e.g. (Brandes, 2009). Furthermore, the aim of the report was not to give a comprehensive overview of the ERS literature but instead to focus on recent developments and specific topics. Thus, the present report mainly focuses on Europe and has a limited scope.

Across Europe, a growing number of testing and demonstration projects have been completed to assess ERS feasibility. Countries such as Germany, Sweden, and Italy have implemented pilot sections to test catenary, ground rail and inductive charging technologies under real-world conditions. These projects have demonstrated the technical functionality of ERS, gathered operational data, and informed vehicle manufacturers and infrastructure providers about deployment needs and options.

Cost-benefit analyses and demand forecasting are critical for guiding investment decisions. While ERS can principally reduce operational costs by enabling smaller batteries and continuous charging, the high upfront infrastructure investment requires sufficient and predictable utilisation. Demand forecasts must consider corridor-based freight volumes, willingness of fleets to adopt ERS-compatible vehicles, and long-term infrastructure use. Techno-economic studies generally demonstrate that ERS can be cost-effective and technologically feasible, with potential cost savings and significant reductions in greenhouse gas emissions compared to other drive trains. However, cost-benefit analyses indicated that the economic viability of ERS is dependent on traffic density and initial investment costs. While ERS projects seem to be beneficial in regions with high traffic volumes, smaller and less densely populated countries may face challenges due to high costs and uncertainties in technology adoption.

Technology acceptance is another vital factor influencing the likelihood of large scale ERS success. While initial feedback from freight operators involved in demonstration projects is often positive, broader adoption requires large willingness to adopt and support the technology from vehicle manufacturers, hardware providers and fleet operators as well as decisive long-term policy support. The largest challenge in this domain is the lack of clear vehicle producer support. Without broad stakeholder buy-in and vehicles available for early adopters, even technically successful solutions are likely to fail noteworthy market penetration.

When compared to other drivetrain technologies, such as battery-electric trucks (BETs) and hydrogen fuel cell vehicles (FCEVs), ERS is similar in costs and vehicle design to BETs but using dynamic charging while driving instead of stationary charging. As all technologies are in early market stages, their fast large-scale rollout faces several challenges such as high hydrogen production costs, grid connection delays, new material demand for batteries and others. The choice of drivetrain could hence be seen from an risk management perspective (there are advantages of focusing, but risks associated with putting all eggs in one basket). While BETs benefit from fast technological advancement and synergy with passenger car developments, ERS could offer advantages for specific high-utilisation, long-distance applications. However, BETs with stationary charging presently appear to be the most likely dominating future zero emission trucking option due to a technological head start, more decentralized infrastructure rollout, and broad activities from vehicle and infrastructure manufacturers as well as Governments. Thus, ERS is under strong competition in this field and would need to overcome the high initial infrastructure cost hurdle to be competitive.

Political decision making is crucial for ERS deployment. Given limited public funding and competing priorities, governments are increasingly required to prioritize between different zero-emission technologies. The complexity of ERS planning, including cross-border coordination and integration with national charging strategies, means that political commitment must be long-term. Governments also face the challenge of balancing technology neutrality with the need to make choices that guide infrastructure development and market direction. As a harmonized decision of support and implementation by many European Governments appears unlikely in the near future, ERS would need to be rolled out by first mover countries if it is to succeed. There is presently no support for demands from the EU on the member states to make a large scale roll out, so inclusion of demands like the ones for stationary charging and hydrogen in the revised AFIR is not likely at the moment (although one could argue that there was no support for including high demands on hydrogen infrastructure either). However, it is possible to find a path in AFIR that could facilitate the expansion of electric roads without requiring large-scale national expansion. For example, ERS could offset the expansion of stationary charging or hydrogen against building electric roads on certain road sections and enable substitution between static and dynamic charging within a larger system. Such a solution could foster a charging system where static and dynamic charging could be complements. An important aspect is that if ERS is integrated into AFIR, ERS could be eligible for funding through CEF (Connecting Europe Facility). In this way the EU could avoid closing opportunities for ERS, but still not force reluctant countries.

Overall, several aspects about ERS are well established in the literature: the technology has been proven in real-world driving and the corridors for roll-out are known. Yet, there is larger uncertainty about ERS due to (1) uncertainty about which ERS technology to use, (2) the high upfront investments required, and (3) the neutrality or partial opposition of OEMs – allof which remain major challenges. Still, current knowledge is sufficient to take the next step and decide about ERS roll-out (Plötz, et al., 2024).

7.2 Discussions about the future of ERS

Electric Road Systems (ERS) have emerged as a promising, yet still nascent, option in the broader portfolio of zero-emission road freight transport technologies. While pilot projects and studies have demonstrated technical feasibility and low emission potential, several open questions remain regarding the role ERS can play in decarbonising heavy-duty road transport.

ERS face increasing competition from other zero-emission technologies, particularly battery-electric trucks (BETs) with stationary charging and, to a lesser extent, hydrogen fuel cell trucks (FCETs). BETs benefit from rapidly falling battery costs, expanding charging infrastructure driven by the passenger car sector, and higher technology readiness levels. In contrast, ERS technologies require high up-front infrastructure investments and rely on coordinated vehicle and infrastructure deployment, ideally over several countries to enable international long-haul freight. Stationary charging has an advantage here, as the existing CCS is already the European fast charging standard, and the international agreement on MCS standardisation is very advanced already. The lack of immediate cost advantages and deployment speed compared to BETs places ERS at a disadvantage in many short- and medium-haul use cases.

Integrating ERS into current transport and energy policy frameworks remains a second challenge. Existing policies at European and national levels, including vehicle subsidies and infrastructure funding schemes, have primarily focused on stationary charging and hydrogen refueling. ERS, by contrast, lacks tailored policy instruments and is often not explicitly covered in regulations, planning processes, or infrastructure mandates like the EU's Alternative Fuels Infrastructure Regulation (AFIR). This omission creates uncertainty for both public and private stakeholders, limiting investment and alignment across jurisdictions. Ensuring policy frameworks account for ERS-specific characteristics, such as interoperability, corridor-based deployment, and infrastructure co-financing, would be critical to enabling wider implementation.

The main barriers to large-scale deployment of ERS are primarily not tied to technical functionality. Challenges concern, for instance, the speed of construction and gaining public acceptance. There is also a need to define how ERS will complement stationary charging and what power level can be expected by the user, where regional goals differ between 1-3 x power needed for direct propulsion. European standardization and border crossing must develop further, and vehicles need to be able to move between regions and national borders. Otherwise, there is a risk of lock-in effect.

Societal integration is another important aspect for the future of ERS. The widespread rollout of ERS is a complex undertaking, involving administrative, economic, legal, and international cooperation challenges, as well as time-related constraints. The same is true for stationary charging, but there is already the widely accepted CCS standard for fast charging and MCS standardization almost completely as well as broad stakeholder agreement that stationary charging for BET will play a large role in future zero emission trucking. Legitimacy and acceptance of the technology is currently limited and needs to be changed to accommodate ERS technology.

Further research is needed to better understand the system-level implications of ERS and to support evidence-based policymaking. This includes comparative assessments of cost-effectiveness under different use cases, modelling of infrastructure utilisation and demand, and evaluations of business models that can align the interests of vehicle operators, infrastructure providers, and energy suppliers. Moreover, long-term studies on interoperability, lifecycle emissions, and potential synergies with other energy and transport systems (e.g. rail or grid services) or stationary charging of BETs are essential. Continued real-world testing and demonstration, supported by transparent data-sharing, will help reduce uncertainty and inform decisions on whether, where, and how ERS should be scaled. Even if ERS should not be deployed on a large scale with several thousand ERS km across Europe, different more isolated applications or a later ERS roll-out could still be interesting options (Plötz, et al., 2024)

7.3 Further Research

Based on the seminars and our previous knowledge, we recommend the following research concerning policymaking:

- **Policymaking under uncertainty.** ERS is in competition for policy support with other technologies and policy makers are forced to focus spending and policy attention to the most promising technologies. Yet, it remains and open challenge how and when to move from broad and technology neutral R&D funding and demonstration project to large scale mass-market support and roll-out.
- **Choice of Technology**. Much effort has been put into evaluating alternative ERS technologies and discussing which criteria should be used in selecting the best technology. Choosing compatible technologies for all Europe would enable system effects but will most likely be challenging. More effort needs to be put into the process for choosing.
- **Demand forecast and utilisation.** Forecasts for demand/utilisation are important whether ERS is government funded or funded by fees. The scientific literature is dominated by smaller investment calculations, reports written by authorities mainly focus on national systems. We recommend more focus on forecasts for larger (international) systems.
- **Funding strategy.** The role of ERS within a broader infrastructure funding strategy needs to be clarified. We have different funding strategies between countries and for charging strategies there needs to be a place for ERS in a broader infrastructure charging strategy. EU funding (CEF) can be provided based on individual applications but also requires a strategy.

To fill the knowledge gaps from a system perspective, we recommend the following research.

- **Interaction with stationary MCS charging**: If ERS is intended to serve as a complement to stationary charging, it is essential to develop a shared vision and a coherent strategy for how the overall charging system should be dimensioned and operated. Little research has been devoted to the impact of MCS charging on the need for or utilisation of ERS. A single study (Plötz, et al., 2021) has indicated that ERS along major highways would reduce the number of required MCS chargers and that ERS and MCS could have synergies, but the main difficulty is the number of HDVs assumed to be equipped with ERS which directly links to the ERS utilisation. Researching this is important both for the inclusion in AFIR (see our suggestion above) and for an eventual large-scale implementation of ERS.
- **Road management perspective***:* How a fully developed electric road will affect the road operator from an accessibility, traffic safety, and management perspective are scarcely discussed in the ERS community. It does not need to be settled now (the perspective above is more acute), but it will need further dissemination before a large ERS implementation.
- **Grid Impact**: What ERS requires and how much it might lighten the requirements from stationary charging.

From a technical perspective, we recommend the following research:

- **Digital infrastructure.** Effective information systems for billing, traffic management and information exchange. Ancillary systems and equipment used for road monitoring and traffic control. Vehicle intelligence and vehicle communication.
- **Technology-specific R&D.** Increase of power transfer for some technological options to accommodate additional charging, and reducing the risk of arcing , improving inductive charging efficiency, safety improvements.
- **Durability of ERS.**
- **Retrofitting.** Standardization for retrofitting and making the technology even more accessible and adaptable to other trucks.
- **Maintenance**
- **Scalability.** Resilience of the system, network expansion and how to enable cross-border transportation.

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APPENDICES

Presentations held on the digital ERS-seminars can be found here:

CollERS 2 | CollERS 2 Project publications

Appendix A. Presentations from seminar 1: Tests and Demonstration Projects

Table 3. Presentations from the first seminar: Tests and Demonstration Projects.

Name	Year	Title	Organization
Ullröm, Roger	202x	N/A	The Swedish Transport Administration
Lupi, Gianfermo	202x	Electric Road System A35 Brembi Aleatica: Arena Del Futuro Project Wireless Power Transfer Study	Direzione Tecnica e di Esercizo
Linke, Regina	202x	eHighway Field Test in Germany: Findings from the ELISA Project	TU Darmstadt
van Vliet, Arjan	202x	An update on the Dutch ERS Developments	Ministerie van Infrastructuur en Waterstaat
Cebon, David	202x	N/A	The Centre for Sustainable Road Freight
Jakob, Bernard	202x	Oral Presentation	Université Gustav Eiffel
Zethreaus, Dan	202x	N/A	
Åkerman, Patrik	202x	Reaching Goals in Time: The Potential of Dynamic Charging of HDVs	Siemens
Duprat, Patrick	202x	Status of Alstom Electric Road Solution	Alstom
Perez, Sergio	202x	ENRX Next Generation Wireless Roadway	ENRX
Sundelin, Håkan	202x	N/A	Electreon

Appendix B. Presentations from seminar 2: Decision Making

Table 4. Presentations from the second seminar: Decision Making.

Name	Year	Title	Organization
van Vliet, Arjan	202x	Decision Making: Facts, emotions, and patience	Ministerie van Infrastructuur en Waterstaat
Tavasszt, Lóri	2024	Prospects for Electric Road Systems on the Dutch Freight Corridor: Result of 6 projects	TU Delft
Gnann, Till	2024	ERS – The German decision-making situation	Fraunhofer ISI
Bogner, Thomas	2024	N/A	Austrian Energy Agency
Knezevic, Giverny	2024	ERS and AFIR	E-core
Plötz, Patrick	2024	Expansion strategies and possible futures of ERS	Fraunhofer ISI
Andersson, Matts	2024	Choosing ERS technology for Europe	WSP

Appendix C. Presentations from seminar 3: Cost-Benefit Analyses and Demand Forecasts

Table 5. Presentations from the third seminar: Cost-Benefit Analyses and Demand Forecasts

Name	Year	Title	Organization
The Swedish Transport Administration	2024	Planeringsunderlag – Elvägar	The Swedish Transport Administration
Rogstadius, Jakob	2024	The interlinkage between ERS utilisation rates, prices and willingness to pay	RISE
Åkerman, Patrik	2024	Sector coupling opportunities based on time-of-use tariffs	Siemens
Craglia, Matteo	2024	Decarbonising Heavy Duty Road Freight	OECD
Raynal, Marc	2024	Economic analysis of ERS for the French network	Université Gustav Eiffel
Hacker, Florian	2024	ERS in techno-economic comparison to other zero-emission technology paths	Öko-Institut

Appendix D. Presentations from seminar 4: The OEMs' Views on ERS

Table 6. Presentations from the third seminar: The OEMs' Views on ERS

Name	Year	Title	Organization
Plötz, Patrick	202x	Technology Acceptance & The Role of Truck OEMs in Electric Road System	Fraunhofer ISI
Thorén, Christer	202x	ERS from a Scania Perspective	Scania
Scherrer, Aline	202x	The path towards net-zero: European truck manufacturers' heavy-duty AFV innovation strategies 2018 – 2021	Fraunhofer ISI
Andersson, Matts	2024	Timeline of citizens acceptance	WSP
Julius Engasser	2025	MAN's view on ERS (presentation missing, not received from author)	MAN

Appendix E. Presentations from seminar 5: Latest Developments in ERS

Table 7. Presentations from the third seminar: The Latest Developments in ERS

Name	Year	Title	Organization
Witham, Gordon	2025	Results from the BEV Goes eHighway project	RWTH Aachen
Lee, Kil-Young	2025	Results from the ELONSO project	Technische Universität Berlin
Juriado, Rein	2025	The European Commission's views on ERS in the context of AFIR	The European Commission
Lindquist, Giverny	2025	ERS, AFIR, and E-core	IKEM
Cebon, David	2025	Update on India and China	Cambridge