FUNDING A EUROPEAN ELECTRIC ROAD SYSTEM

AN OVERVIEW OF EUROPEAN AMBITIONS AND FUNDING OPPORTUNITIES

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CONTENTS

SUMMARY

The purpose of this report is to address the key issues regarding the funding of a European electric road systems (ERS) network. The report aims to provide recommendations on the policy direction Sweden could take for the rollout of ERS. To achieve this, the report includes a literature review, a regulatory review, and interviews with key stakeholders. Additionally, two policy scenarios were developed and compared to offer recommendations on Swedish policy for ERS rollout.

From Theory to Practice: How Can ERS be Funded?

The theoretical background categorises ERS based on its main policy goals, which are decarbonisation and the improvement of passenger and freight transport systems. It was found that both goals require some form of policy intervention. A review of international transport funding strategies outlined different options for roads, ranging from public to private funding. The chapter on funding strategies distinguished between centralised and decentralised funding, various types of funding schemes, and the characteristics of road infrastructure investments. The subsequent chapter of ERS as an emerging technology highlighted the need for public funding if ERS is to become scaled up fast enough to meet climate goals.

A Window of Opportunity Until 2028

The regulatory overview assessed existing EU policies related to ERS, the envisioned future revisions of those policies, and identified levers for facilitating ERS scaling up of ERS. This examination of key legislation and policies in the ERS space identified TEN-T, AFIR, Connecting Europe Facility (CEF), and other relevant legislations. Currently, CEF can finance ERS under the existing legislation, but CINEA claims that ERS is not eligible the moment. According to the EU policy process, CEF will be updated with a new budget and new goals by 2028. Prior to that, a draft of the new CEF regulation will be negotiated. For ERS to be eligible for EU funding, the EU's AFIR review and proposal for revision planned for 2026 must include ERS. Notably, the regulatory overview highlighted that CEF only funds projects that are already under implementation. This report identifies the years up to 2028 as a window of opportunity.

Policy scenarios

The report presents two policy scenarios. Together, the analysis indicates that timing is crucial for the viability of scaling up ERS.

Four Timing Aspects

Without the right timing, ERS may miss the window for scaling up. Timing is related to four aspects: Firstly, policy goals - especially the urgent goal of decarbonising road transport. Secondly, technological and market maturity: ERS is a well demonstrated technology but with high investment cost. Market demand is still limited among vehicle manufacturers, etc. Thirdly, relying solely on national public funding would delay ERS rollout, potentially beyond what is necessary to achieve climate goals. Fourthly, and consequently, enabling the funds and incentives necessary for large-scale ERS deployment requires EU funding through CEF. These four timing aspects need to be jointly addressed because the right policy support for ERS infrastructure is necessary to create market supply and demand, such as the development and availability of vehicles compatible with ERS.

RECOMMENDATIONS

To address the timing aspects and enable ERS rollout, two recommendations are as follows:

1

Enable CEF Funding for ERS

Sweden and other countries should strive to make ERS eligible for CEF funding by 2028. AFIR needs to prioritise ERS at the same level as stationary charging and hydrogen infrastructure.

2

Secure CEF Funding for Swedish ERS Projects

Sweden should have ERS projects already under construction when applying for CEF funding. This means that Sweden needs to decide whether to invest in ERS on a large scale, either in the upcoming transport infrastructure plans (2026 or 2030). By doing so, Sweden will meet the criteria necessary to apply for CEF funding.

INTRODUCTION

BACKGROUND

Road transport is undergoing a significant transformation, moving away from fossil fuel dependence. While passenger cars and urban busses have already made the progress in decarbonisation, the market for heavy-duty vehicles (HDV) is still in the early stages of this process. In 2019, transport accounted for approximately one quarter of EU's greenhouse gas (GHG) emissions, with about 72% coming from road transport at (EEA, 2022). In Sweden, heavy-duty vehicles make up about 20% of the total GHG emissions from transport, despite constituting only about 2% of the overall road vehicle fleet.[1] Decarbonising road freight is, therefore, a crucial objective. The EU Green Deal has set a goal to reduce the GHG emissions by at least 55 % by 2030 (compared to 1990-levels), with a long-term aim of reducing emissions in transport by 90 % by 2050.[2]

Electric road systems (ERS) encompass a range of technologies aimed at electrifying road transport through dynamic charging of vehicles. ERS primarily targets heavy-duty vehicles involved in long-haul or shuttle transport, although other types of vehicles may also utilize the system. The potential market for vehicles such as passenger cars using ERS is not yet fully understood. Additionally, uncertainties exist regarding the future development of other zero-emission technologies, such as stationary charging infrastructure.

The combination of ERS (dynamic charging) and stationary charging depends on technological, regulatory, and economic conditions. The upcoming regulation for alternative fuels infrastructure (AFIR) includes requirements for member states to expand stationary charging infrastructure and the infrastructure for fuel-cell electric vehicles. However, there are no specific requirements for ERS. Furthermore, while infrastructure for stationary charging can be established incrementally by different actors, ERS requires significant upfront investment to establish a route. The funding mechanisms for such investments remain uncertain.

What is the Purpose of This Report?

The purpose of this study is to shed light on the main funding issues related to a European ERS network and to suggest Sweden's position in this regard. Ultimately, the report aims to provide recommendations on how Sweden can influence the EU to utilise its funding tools to incentivise ERS deployment.

Previous Research Within CollERS

This report is part of the international research collaboration on ERS, CollERS. It draws on the second discussion paper from CollERS, which concluded that there are no legal obstacles on the EU level for national for ERS developments.[3] The discussion paper also identifies the Trans-European Network for Transport (TEN-T) regulation and the proposed AFIR as the appropriate instruments for ERS deployment in Europe. However, the realisation of "ideal" scenario, where

[1] (The Swedish Environmental Protection Agency, 2023; Transport Analysis, 2023)
[2] (European Commission, 2023)
[3] The CollERS website: https://electric-road-systems.eu/e-r-systems/. Discussion paper two: (Andersson, et al., 2022)

ERS users can seamlessly travel across multiple countries with a uniform payment system and service provider, remains uncertain.[4]

Regarding funding, the second discussion paper highlighted that the amended Eurovignette directive enables Member States to use distance-based road tolls to finance the construction, operation, or maintenance of ERS, although some legal uncertainties persist. Additionally, a rollout could be supported by TEN-T planning and funding tools for the core network. This paper continues to explore this idea.

The third discussion paper within CollERS briefly discusses principles for levying user fees.[5] maintenance costs or used to allocate infrastructure capacity to its most valuable use (so called economically efficient fees). The term "its most valuable use" is referring to society's valuation of ERS use compared to alternative transport technologies. If one vehicle kilometre of ERS usage causes substantially less damage to society than one vehicle kilometre of another technology, transport companies could be incentivised to use the ERS. This incentive can come in terms of a low user fee. The third discussion paper also present national strategies in European countries for an ERS rollout and a calculation of the total cost of ownership for each country.

Critical Juncture: The Crucial Years for ERS and Decarbonising Road Transport

A launch vision for ERS by The Institute for Climate Protection, Energy and Mobility (IKEM) published in 2022 emphasised that the years leading up to 2026-2027 will be crucial for ERS to contribute to decarbonising road transport (IKEM, 2022). During this period, Germany will make decisive choices (expected between 2024 – 2026), and the AFIR will undergo a review with a revision process initiated. Germany and France, according to IKEM, are influential first movers that can influence second movers like the Netherlands and Austria. Sweden, although a pioneering country, has less influence on other nations due to its geographical position and comparatively smaller transport flows.

Balancing the Funding Equation: National Budget Allocations and User Fees

In 2021, a Swedish government inquiry on ERS recommended that investment costs should be funded through national budget allocations, while user fees should cover operations and maintenance costs.[6] The user fee should, according to the inquiry, also cover the electricity costs, and operating costs for payment systems. During the initial years, the inquiry suggested that the national government should partially cover the user fees in advance to encourage early adopters.

METHOD

This study employs a comprehensive desk research approach, which includes a literature review, a regulatory overview, and interviews with key stakeholders on funding topics. The literature overview encompasses scientific articles and relevant publications to establish a theoretical understanding of ERS and different funding mechanisms. A regulatory overview assesses existing EU-

[4] There could still be several competing service providers. The point is that the user should not have to sign a new contract for every border crossing.

[5] (Andersson, Johansson, Jöhrens, & Mottschall, 2023)

[6] (SOU, 2021:73)

policies, potential future revisions, and identifies areas for improvement in relation to ERS funding. Insights from interviews conducted with experts from the European Climate, Infrastructure, and Environment Executive Agency (CINEA) and the Swedish Connecting Europe Facility (CEF) further enhances the analysis. Finally, two policy scenarios are discussed to explore potential outcomes and implications of different funding schemes for ERS in Sweden and Europe.

DISPOSITION

The rest of the report is structured as follows:

1. **Theoretical Background**: This section delves into the nature of ERS as a public good, distinguishes between centralized and decentralized funding approaches, explores various types of funding schemes, and examines the characteristics of road infrastructure investments. It also presents international examples of road infrastructure funding for comparative analysis.

2. **Regulatory Overview**: This section provides an examination of key legislation and policies that shape the development and funding of road infrastructure projects. It focuses on important regulations such as TEN-T, AFIR, CEF, and other relevant legislations to highlight their role in the ERS context.

3. **Funding Mechanisms**: This section discusses different funding mechanisms, sources, and the roles of various funding actors. It explores how funding for ERS can be sourced and allocated effectively, considering the theoretical background and legal framework.

4. **Findings and Insights**: This section presents a discussion of the report's findings, drawing upon insights from the theoretical background, funding mechanisms, and legal framework. It highlights the challenges and opportunities related to funding ERS and provides recommendations based on the analysis.

THEORY AND FUNDING STRATEGIES

KEY TAKE-AWAYS

- → The characteristics of ERS as a good have important implications for funding and management.
- → ERS can be categorised as an impure public good, meaning it is partly rivalrous, affecting other users' access due to congestion.
- → Government support for ERS is crucial, as relying solely on profit-maximising actors result in fewer social benefits for the system.

WHAT CHARACTERISES AN ELECTRIC ROAD SYSTEM?

The features of ERS as a good or service have implications for the functioning of different funding sources, as the role and incentives of various actors vary based on these characteristics.[7] While there are various ERS technologies, they share key features such as high upfront investment costs, congestion issues beyond a certain traffic volume, and the potential exclusion of certain drivers or vehicle types from accessing the infrastructure.

ERS will be integrated into existing road infrastructure, sharing many characteristics with regular roads. The ERS lane will likely be available to all road users, although not all vehicles will have access the ERS infrastructure. Like regular roads, the addition of ERS infrastructure will increase congestion as each additional user occupies space on the road.

Additionally, ERS introduces an additional congestion factor related to power usage. The power grid connected to the ERS has limited capacity, and above a certain number of vehicles, each additional ERS user will impact the power available to other users. This power capacity becomes particularly crucial on uphill slopes.

Like other types of infrastructure, ERS involves high initial investment costs and relatively low marginal costs (e.g., wear and tear per vehicle-kilometre). This situation typically lead to a profit-maximising road manager charging a high user fee. However, this would result in lower ERS usage and potentially reduced social benefits, such as decreased CO_2 emissions. In such cases, government subsidies, like public transport fares, are often implemented.

Network effects also provide a rationale for government intervention in planning and constructing road infrastructure. The benefits of a road network increase with more users and connections (known as network externality). When infrastructure crosses multiple jurisdictions, certain incentives can emerge. For instance, in a hypothetical scenario involving three countries within a union like the European Union (countries A, B, and C), all benefit from constructing a power line (or another type of infrastructure) that crosses from country A through B to C. Country B, being in the middle, may underinvest if the other two countries contribute relatively more to connect them. In this case, the union could intervene and provide incentives for all countries to contribute to the investment.

Investment In an Innovative Technology

Certain characteristics of technology diffusion have significant implications for funding strategies, particularly in the case of ERS. The concept of urgency plays a central role, driven by the need to address climate change and geopolitical disruptions that could disrupt fossil fuel-dependent transport. The urgency stems from the pressing need to implement zero-emission fuel technologies to mitigate climate change risks. The consequences of inaction can have significant negative effects on societal goals, particularly in the realm of transport. These include economic risks associated with climate change, disruptions in

[7] A more thorough theoretical presentation on different types of goods is summarised in the appendix to this report.

transportation due to uncertain fossil fuel supply, and ecosystem loss resulting from the extraction of rare earth minerals.

Delaying the implementation of ERS entails costs associated with these risks. The urgency to prevent climate damage is amplified by the cumulative nature of climate emissions. The costs incurred may be higher than expected due to threshold or cascading effects of the risks.

One risk factor pertains to the uncertain supply of critical minerals required for traditional electrical vehicle (EV) technology. ERS mitigates this risk by enabling vehicles to utilise smaller batteries, thereby reducing the total quantity of critical minerals needed. Moreover, climate action exhibits public good properties, and non-ERS technologies alone may not suffice to achieve the necessary scale-up within the required timeframe. ERS is currently not cost-competitive, the combination of these factors may justify rapid concerted action to develop a diverse portfolio of transportation energy solutions, which can include ERS.

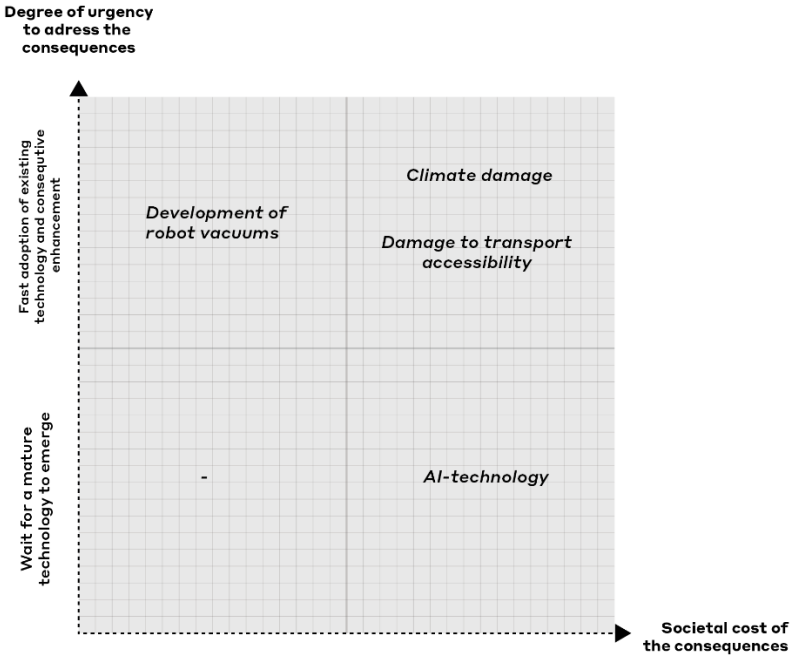

Figure 1. Cost of waiting to phase out fossil fuels in transport. Interpretation: the horizontal axis shows the cost to society of delaying energy transition from fossil fuel; the vertical axis shows the urgency to avert those costs. For example, societal cost of climate change is high, and is urgent to prevent, because climate emissions are cumulative, and cause threshold and network effects.

DIFFERENT TYPES OF FUNDING SCHEMES

KEY TAKE-AWAYS

- → Funding for goods with public good characteristics, like road infrastructure, may need centralised sources such as taxes, national budgets, or loans.
- → Private funding or public-private partnerships can also be utilised, but investment risks and availability of funding can be challenges in funding road infrastructure projects.
- → User fees on new or existing infrastructure is another funding option, but acceptance and support for different funding mechanisms can vary.

Goods with public good characteristics, particularly those related to climate change mitigation, raise important questions regarding usage, allocation, and coordination. Determining who should have access to these goods, in what quantity, at which location, and during which period becomes crucial. Funding for public goods often requires some degree of centralised funding to ensure their provision.[8] This coordination becomes particularly relevant when addressing interdependencies across jurisdictions, such as in the case of transport infrastructure.

In Sweden, funding for road infrastructure has traditionally been provided by the national government through various sources. These include the national budget, state loans (domestic or international), national value-added tax (VAT), national income tax, local income tax, local property tax, property, and value capture as well as taxes on congestion, energy, and CO_2. Different funding schemes may require specific electoral support. A recent study in Sweden found relatively higher support for income tax and user fees, while support for value-added tax was lower.[9]

When traditional funding sources are deemed insufficient, alternative approaches are explored. Private funding through public-private partnerships (PPPs) is one option, enabling private investors to participate in the construction or operation of infrastructure under a concession agreement. In this model, the private sector invests in infrastructure with the expectation of financial returns. Concessions and investments by private insurance firms for their pension funds are other avenues for such funding.[10] However, it is important to note that private funding often falls short of expectations, potentially due to of risk perceptions. Policy interventions are necessary to design instruments that mitigate risk. In fact, a study of seven European OECD countries found that the primary challenge lies in the overall availability of funding rather than risk perception.[11]

Investments in road infrastructure can face various risks, but policy interventions can help mitigate them. The characteristics of road infrastructure, such as its capital-intensive nature, and long-life span, economies of scale, externalities, heterogeneity, complexity, involvement of numerous stakeholders, and the need to assess investments risks amplify the investment risks. These factors introduce political and regulatory risk, macroeconomic and business risk, and technical risk.[12]

Another potential funding source is the utilisation of user fees on newly constructed infrastructure and general user fees. However, political acceptance represents a significant constraint to user funding, as observed in the study of the seven European OECD countries. It is important to consider that these findings were based on data collected around the 2007 financial crisis and may require re-evaluation in the current context.

[8] (Oates, 2005)
[9] (Andersson, Jonsson, Brundell-Freij, & Berdica, 2022)
[10] (Della Groce & Gatti, 2014)
[11] (Makovšek, 2018)
[12] Further details on related issues and risk can be found in publications by organisations such as the (OECD, 2015) and (Makovšek, 2018)

INTERNATIONAL EXAMPLES OF ROAD INFRASTRUCTURE FUNDING

This subsection provides an overview of road infrastructure funding approaches in various countries, highlighting the diversity of funding mechanism. While these countries share similar institutional frameworks, there are variations in their funding strategies, including the reliance on national budgets and private investments. These examples illustrate the range of funding options and their potential influence on the funding of ERS.

KEY TAKE-AWAYS

- → Funding mechanisms for road infrastructure vary across countries, with different reliance on national budgets and private investments.
- → Sweden and Denmark primarily fund road infrastructure through government budget allocations and user fees, while Norway employs public-private partnerships (PPPs) in addition to government funding.
- → Finland relies on government appropriations and fuel- and vehicle-related taxes, while France utilises private concession companies collecting tolls for motorway funding. In the United States, road infrastructure is primarily funded through public sources, supplemented by user fees and PPPs.

Sweden

In Sweden, road infrastructure funding relies primarily on national budget allocations and user fees. The national government, through the Swedish Transport Administration (Trafikverket), is responsible for the development and maintenance of national roads, while local governments manage local roads and streets (Hasselgren, 2013). Government budget allocations, derived from general tax revenues, play a significant role in funding road infrastructure. User fees, such as congestion charges and bridge tolls, contribute to infrastructure investment (The Swedish Transport Administration, 2022).

Denmark

Similarly, Denmark's road infrastructure funding combines government budget allocations and user fees. The Danish government is responsible for the national road network, while municipalities manage smaller roads (Hasselgren, 2013). Fuel and vehicle taxes, along with general tax revenues, provide government funding for road infrastructure. User fees, particularly tolls on bridges, contribute to infrastructure financing.

Norway

Norwegian road infrastructure funding includes user fees and public-private partnerships (PPPs). The government agency Statens vegvesen oversees the road network, and tolls play a significant role in funding (Hasselgren, 2013; Welde, Bråthen, Rekdal, & Zhang, 2020). The AutoPASS toll collection system generates revenue for investment projects, and tolls are also used to manage congestion and enforce low emission zones. PPPs involve private investors in infrastructure design, construction, funding, maintenance, and operation (Hasselgren, 2013).

Finland

Finland's road infrastructure funding relies on government appropriations, fuel and vehicle taxation, and PPPs. The Finnish Transport Administration is responsible for road infrastructure, and funding is primarily derived from government allocations and revenue from taxes (Leviäkangas, et al., 2011; Hasselgren, 2013). PPPs have also been utilized, with the Nordic Investment Bank financing projects such as the E18 motorway (Nordic Investment Bank, 2016).

Germany

Germany's road infrastructure funding combines government budget allocations, user fees, and PPPs. The country's federal state system divides responsibilities between the federal level and 16 states (Hasselgren, 2013). National budget allocations, including fuel and vehicle taxes, contribute to infrastructure funding. User fees, such as tolls for heavy goods vehicles, are used to finance road construction and maintenance. PPPs have also been implemented, with private companies involved in design, construction, and operation of road projects (Vinci, 2021).

France

France's road infrastructure funding is characterized by a more decentralized approach. Motorways are primarily managed by private concession companies that collect tolls in exchange for operating and maintaining specific sections (Smith, 2016). Toll revenues constitute a significant funding source for construction, operation, and maintenance, along with national and regional budget allocations.

United States

In the United States, road infrastructure funding involves federal, state, and local levels of government. State departments of transportation are responsible for infrastructure planning, design, construction, operation, and maintenance (Hasnat & Bardaka, 2023). Public funding, including federal budget allocations, plays a significant role in financing road projects. User fees, such as tolls, are used in some states to fund infrastructure, and public-private partnerships have emerged as a funding mechanism to leverage private capital (Hasselgren, 2013; Guiny, et al., 2016).

Table 1. Summary of road infrastructure funding schemes in different countries

	Country	National budget	User funding	Private funding
	Sweden	Tax revenue	Congestion taxes and infrastructure fees	-
	Denmark	Tax revenue, state-owned companies	Infrastructure fees	-
	Norway	Tax revenue	Tolls	PPPs
	Finland	Tax revenue	-	PPPs
	Germany	Tax revenue	Heavy truck tolls	PPPs
	France	Government budget allocations	Tolls	Private concession companies
	United States	Federal budget allocations	Tolls, fuel tax, vehicle taxes/fees, road tax	PPPs

Summary of international examples

The international examples highlight diverse funding strategies for road infrastructure, highlighted in Table 1 below. Sweden and Denmark rely on national budget allocations and user fees, while Norway incorporates user fees and PPPs. Finland combines government appropriations, taxation, and PPPs, and Germany utilizes budget allocations, user fees, and PPPs. France has a more

decentralized funding scheme, with tolls collected by private concession companies. The United States combines public funding, user fees, and PPPs to finance road infrastructure projects. These examples showcase the range of funding mechanisms and their potential relevance for funding ERS.

REGULATORY FRAMEWORK

KEY TAKE-AWAYS

- → The EU have updated its regulatory framework to meet the targets in the Green Deal, which has implications for the infrastructure for alternative fuels.
- → The EU legislative processes aim to raise sustainability ambitions in transportation and align regulations accordingly.
- → New regulation in AFIR claims ERS is an emerging technology that must be accounted for.
- → Regulation on financial incentives (CEF) indicates that funding ERS along the TEN-T would be possible.

This section provides an overview of the current regulatory framework related to the deployment of ERS in the EU. The focus is to identify potential gaps in existing legislation and highlight key revisions and amendments that are underway.

To align with the EU's binding targets of reducing emissions by at least 55% by 2030 and achieving climate neutrality by 2050, the EU Commission introduced a legislative package called "Fit for 55". This comprehensive package includes various acts, such as the replacement of the current directive with a new alternative fuels infrastructure regulation (AFIR), amendments to the EU emissions trading system (ETS) directive, the effort sharing regulation (ESR), and the renewable energy directive (RED) (The Council of the EU and the European Council, 2023).

Furthermore, the EU currently revising the TEN-T regulation to ensure its alignment and coherence with the new legislations. The TEN-T regulation holds significant importance in facilitating the potential large-scale rollout of ERS, which is further elaborated on in the subsequent sections. Additionally, the CEF regulation, Eurovignette directive, and ITS directive are also relevant acts that needs consideration in the context of ERS. The CEF regulation acts as a crucial incentive for Member States to complete their respective sections of the TEN-T corridors. The Eurovignette directive regulates the grounds for imposing user fees on ERS, and the ITS supports electronic fee collection.

In this section, the primary focus centres around the AFIR, TEN-T, and CEF regulations, with additional insights provided on the other acts. These three play a critical role in enabling the potential large-scale ERS rollout across Europe. The AFIR establishes the necessary definitions and requirements for charging infrastructure, while the TEN-T serves as the fundamental regulation outlining the overall ambitions for transport corridors. The CEF regulation provides financial incentives to support the completion of the TEN-T. Related literature in this topic is discussion paper 2 within CollERS and IKEM's policy paper European launch vision for Electric Road Systems (Andersson, et al., 2022; IKEM, 2022).

ALTERNATIVE FUELS INFRASTRUCTURE DIRECTIVE/REGULATION

Current legislation and its gaps

The **Alternative Fuel Infrastructure Directive** (2014/94/EU), establishes a framework for the deployment of alternative fuels infrastructure in the EU. The directive requires Member States to develop long-term National Policy Frameworks (NPF) for the deployment of the alternative fuels and the planning of relevant infrastructure, particularly along the core network of the TEN-T (European Commission, 2022).

However, this has resulted in disparities in the level of ambitions and policies among Member States. One of the key concerns is the lack of detailed and binding methodology for calculating targets and adopting measures. This has led to variations in the ambitions and policies of Member States, hindering the establishment of a cohesive and coordinated approach to alternative fuels infrastructure deployment.

Another important aspect that the AFID does not adequately address is the interoperability of infrastructure and user services. Challenges exists related to the availability and accessibility of high-quality information about the location, availability, and usage conditions of alternative infrastructure. Customers often face difficulties in obtaining accurate and up-to-date information regarding the availability, pricing transparency, and payment services associated with recharging points.

According to article 2 (1) in the AFID, these alternative fuels include electricity, hydrogen, biofuels, synthetic and paraffinic fuels, natural gas (in gaseous or liquified form) and liquified petroleum gas.

Revision

The EU will repeal AFID and replace it with the alternative fuels infrastructure regulation (AFIR)[13] to address several key objectives aimed at facilitating the widespread adoption of low- and zero-emission vehicles across the EU (European Commission, 2021). Primarily, AFIR seeks to ensure establishment of an extensive network of alternative fuels infrastructure throughout the EU, supporting the necessary uptake of alternative fuel vehicles, such as electric cars, vessels, and aircraft.

The proposal for AFIR sets binding requirements for mature, standardised alternative fuel technologies and require distinct infrastructure. It also sets important dates. By the end of 2025, there should be recharging stations at least every 60 km on main roads for passenger cars and trucks below 3.5 tonnes. By the end of 2030, similar recharging stations should be available for trucks above 3.5 tonnes, and there at least one recharging station in each safe and secure parking area for trucks above 3.5 tonnes. Additionally, there should be hydrogen refuelling stations at least every 200 km on main roads. The EU has projected that by 2050, 50 percent of all cars and vans in the EU will run on alternative fuels.[14]

The proposal places strong emphasis on the full interoperability of the alternative fuel infrastructure within the networks for stationary charging, hydrogen, or ERS. Interoperability should be understood in terms of physical connections and communication standards, such as data exchange (European Commission, 2021).[15] This objective encompasses not only the resolution of physical connection issues but also the standardisation of communication protocols and data exchange within the electromobility ecosystem. By doing so, AFIR aims to create a seamless and functional infrastructure network that allows for efficient cross-border travel and ease of use for consumers.

The Commission's proposal for AFIR acknowledges ERS as an emerging technology that should be accounted for (see recital 53 in the proposal). The final formulations agreed upon have yet to be communicated, but the Parliament made amendments to the proposal in October 2022, see Table 2 below (European Parliament, 2022). The definition of ERS in Article 2 was also amended by the Parliament.

[13] The Council and the European Parliament reached a provisional agreement on AFIR on March 28. (The Council of the EU and the European Council, 2023). The provisional agreement is now subject to formal approval.
[14] A full review of the regulation is scheduled for the end of 2026.
[15] Regarding ERS there is an additional interoperability because of competing technologies.

Table 2. Text proposed by the Commission and amendments by the Parliament.

V	Text proposed by the Commission	Amendment by the Parliament
Recital 53	It is also necessary to define the suitable governance framework and roles of the different actors involved in the vehicle-to grid communication ecosystem. **Moreover,** emerging technological developments, such as electric road systems ('ERS') **have to be accounted for.**	It is also necessary to **swiftly** define the suitable governance framework and roles of the different actors involved in the vehicle-to-grid communication ecosystem **while taking into account and supporting** emerging technological developments **with high GHG emission reduction potential,** such as electric road systems ('ERS'), **notably inductive and overhead catenary line charging solutions.**
Article 2	'electric road system' means a physical installation along a road that allows for the transfer of electricity to an electric vehicle **while the vehicle is in motion**	'electric road system' means a physical installation along a road that allows for the transfer of electricity to an electric vehicle **to provide it the energy necessary for propulsion, or for dynamic charging.** **'dynamic charging' means the charging of an electric vehicle battery while the vehicle is in motion**

Noteworthy is that the Parliament specifies inductive and overhead catenary line charging solutions, without explicitly mentioning the ground-level conductive rail solution. The reason for this omission is unclear to the authors. The word "notably" can be further interpreted to specify two of the technologies without disqualifying other technologies. The Parliament also distinguishes between energy for propulsion and energy for dynamic charging, where the latter is defined as charging the battery while the vehicle is in motion.

The Commission requested European standardisation organisations to draft standards with technical specifications according to Annex II in the AFIR proposal. A standards document for ground-level conductive rails has already been published, and the standards document for power supply via overhead lines is currently under drafting.

TRANS-EUROPEAN NETWORK FOR TRANSPORT (TEN-T)

Current legislation and its gaps

The **trans-European network for transport (TEN-T)** (Regulation (EU) No (1315/2013)) addresses the implementation and development of a European-wide network of highways, railways, inland waterways, and ports in the EU (European Commission, 2023). The objective of the TEN-T is to close gaps, remove bottlenecks, and technical barriers while simultaneously strengthening social, economic, and territorial cohesion in the EU. The TEN-T policy also supports the application of innovation, new technology and digital solutions to all modes of transport with the aim of reducing environmental impacts and enhancing energy efficiency.

The TEN-T consists of two network layers: the core and comprehensive network. The core network is established based on the comprehensive network and includes the most important connections, linking the key nodes. It is expected to be completed by 2030, with extensions completed by 2040. On the other hand, the comprehensive network is projected to be completed by 2050.

Figure 2 below illustrates the core network corridors. In the case of Sweden, the Scan-Med corridor in pink holds the greatest importance. It encompasses the entire E4 (from Helsingborg via Stockholm to Haparanda) and the E6 (from Trelleborg via Gothenburg to Oslo). This corridor connects Sweden and Denmark through the Öresund fixed link and extends through Denmark in two directions: to Rødby and across Fehmarn Belt to Hamburg, continuing west towards Jutland and then south to Hamburg.[16]

KEY TAKE-AWAYS

- → TEN -T aims to develop a European-wide network of highways, railways, inland waterways, and ports to strengthen cohesion in the EU.
- → The core network, to be completed by 2030, includes important connections between major nodes, while the comprehensive network is to be completed by 2050.
- → The revision of the TEN-T regulation aims to address gaps and issues related to infrastructure standards, network connectivity, safety, and governance.
- → The main objectives of the revision are to promote greener transport, ensure seamless and efficient transport, increase resilience to climate change and disasters, and improve governance tools.

[16] For more on corridor analysis, see the first report within CollERS 2 (WSP, 2022).

Figure 2. TEN-T core network corridors for road transport and ports

Revision

The revisions of the TEN-T regulation aim to address several problems identified by the European Commission (European Commission, 2021):

1. Insufficient and/or incomplete TEN-T infrastructure standards and a lack of integration of standards for alternative fuels infrastructure on the TEN-T
2. Capacity bottlenecks and an inadequate network connectivity to all regions within the TEN-T
3. Insufficient safety and reliability of the TEN-T infrastructure
4. The need for updated governance instruments and a review of the TEN-T network design increase coherence with other policies, including aligning national interests and responsibilities with TEN-T objectives.

According to the European Commission's (2021) proposal, the revision of the TEN-T regulation is driven by four main objectives.

1. **Making transport greener:** Promote environmentally friendly transport by providing the necessary infrastructure to reduce congestion and decrease greenhouse gas (GHG) emissions and pollution of air and water. This will be achieved by enhancing the efficiency of each mode of transport and promoting the use of more environmentally sustainable forms of transport such as rail, short sea shipping, and inland waterways. By achieving a more sustainable modal composition of the transport system, the negative externalities of transport will be reduced.
2. **Seamless and efficient transport:** Promote seamless and efficient transport by fostering multimodality and interoperability between the different modes of transport. In addition, it aims to better integrate urban nodes into the network by removing bottlenecks and missing links. These measures will contribute to the completion of the internal market.
3. **Increase the resilience:** It is essential for the TEN-T infrastructure to be resilient to potential adverse impacts of climate change to protect public investments and ensure their continued usability in the new climate.
4. **Improve efficiency of governance tools:** Streamlining the reporting and monitoring instruments and at reviewing the TEN-T network design.

CONNECTING EUROPE FACILITY (CEF)

Current legislation

Article 3 of the **Connecting Europe Facility** (CEF) regulation aims to accelerate investments in the trans-European network (TEN) and to leverage funding from both public and private sectors (European Commission, 2021). CEF for transport serves as the funding instrument to realise European infrastructure policy, primarily finishing the TEN-T. It provides support for investments in new infrastructure construction and the repair of existing infrastructure.

The regulation sets the framework for the period 2021 – 2027, with the goal of developing and modernising the transport, energy, and digital sectors of the TENs. The updated version of this regulation, effective from 2021, aligns CEF with the policy objectives of the European Green Deal, which include climate neutrality, zero-pollution ambition, and a significant reduction in transport-related greenhouse gas emissions.

CEF also promotes innovation in the transport system to improve infrastructure utilisation, reduce environmental impact, enhance energy efficiency, and increase safety. According to article 4 in CEF, it has a budget of €25.8 billion for the objectives related to transport for the period 2021 – 2027 (European Commission, 2021). A portion of this, roughly half, is for Member States with a gross national income below 90 % of the EU average. This primarily includes countries in eastern and central Europe.

Eligible actions in the transport sector are defined in Article 9(2) of the CEF regulation. Of particular interest is point b(iv), which notes that:

> *"actions supporting new technologies and innovation, including automation, enhanced transport services, modal integration and alternative fuels*

KEY TAKE-AWAYS

- → CEF aims to expedite investments in transportation infrastructure and attract funding from both public and private sectors.
- → The updated CEF regulation aligns with the objectives of the European Green Deal, including climate neutrality and reducing greenhouse gas emissions.
- → CEF promotes innovation in the transport system, including new technologies, modal integration, and alternative fuels infrastructure.
- → The CEF budget for transport objectives for the period 2021-2027 is €25.8 billion, with a portion allocated to Member States with lower income.
- → Challenges include funding gaps for infrastructure projects, insufficient measures to address climate change and decarbonisation, and the need for better coordination and synergies among EU funding programs.

infrastructure for all modes of transport in accordance with Article 33 of Regulation (EU) No 1315/2013."

Regulation 1315/2013 is the current TEN-T regulation in which Article 33, on the topic new technologies and innovation, states that *"In order for the comprehensive network to keep up with innovative technological developments and deployments, the aim shall be in particular to:*

a) support and promote the decarbonisation of transport through transition to innovative and sustainable transport technologies.

b) make possible the decarbonisation of all transport modes by stimulating energy efficiency, introduce alternative propulsion systems, including electricity supply systems, and provide corresponding infrastructure. Such infrastructure may include grids and other facilities necessary for the energy supply, may take account of the infrastructure-vehicle interface and may encompass telematic applications".

An interpretation of this is that ERS could be eligible for funding through CEF, or more specifically through the Alternative Fuels Infrastructure Facility (AFIF) calls within CEF. CEF is administrated by the European Climate, Infrastructure and Environmental Executive Agency (CINEA) for deploying large scale innovative solutions. For development and testing of new technologies, CINEA also funds projects through Horizon Europe. There are synergies between these and CINEA raise awareness and showcase project examples with mature technology that can potentially be deployed within the CEF programme (European Climate, Infrastructure and Environment Executive Agency, 2023).

CEF finances both works and studies,[17] where the financial support for works within the transport sector shall not exceed 30 % of the total eligible costs (see Article 15). There are however exceptions where the support can be increased to 50 %, such as the support for new technologies and innovation.

Challenges and gaps

The 2018 impact assessment of CEF identified several challenges with the previous CEF program, including the completion of TEN-T network, energy transition, and the need for ordination and synergies (European Commission, 2018).

The assessment highlighted that the budget was insufficient to address all investment needs, resulting in funding gaps for infrastructure projects. Despite the importance of funding from Member States and the private sector, it remained insufficient. In 2018, the estimated total funding required for the TEN-T Comprehensive Network and urban transport investment between 2021 and 2027 was approximately €1 trillion, while the CEF transport program for the same period aimed to cover about 10 % of that amount.

Based on the assessment, it was concluded that the CEF program for 2021-2027 should clearly distinguish itself from other EU funding programs, maintain and promote its objectives, avoid overlaps, and optimize synergies with other budgetary resources of the EU. CEF focuses on supporting the large-scale roll-out and deployment of innovative technologies, while Horizon Europe supports research and innovation needs (European Commission, 2018).

[17] The definitions of "studies" and "works" are roughly as what they sound like, see Article 2 in the CEF regulation.

FURTHER RELEVANT LEGISLATIONS

EU Emissions Trading System (ETS) Directive and Effort Sharing Regulation (ESR)

The EU Emissions Trading System (EU ETS) Directive and Effort Sharing Regulation (ESR) are connected and form crucial tools for reducing greenhouse gas emissions within the EU. Both are undergoing revisions as part of the "Fit for 55" package. In April 2023, the ESR amendment was adopted, while the provisional political agreement on ETS reform was reached by the Council and the European Parliament in December 2022 (which is yet to be adopted) (The Council of the EU and the European Council, 2022; European Commission, 2023). Historically, the ESR has covered sectors not included in the EU ETS and set binding emissions reduction targets for each Member State. However, the amended ETS directive, will introduce a separate trading system for road transport, while the sector will continue to be covered by the amended ESR regulation. The argument for including road transport in both legislations is that a carbon price (established through the ETS) would not meet the required goals on its own (European Commission, 2021).

The most apparent effect of ETS on ERS is that the money collected from the trading is going to the Innovation Fund. 150 million allowances will be issued under the new system and made available for the Innovation Fund for development of new low-carbon technologies in the sectors of buildings and road transport. To be eligible for funding as a (large-scale) demonstration project via the Innovation Fund, technologies must be sufficiently developed. Pure research and development projects or market launch measures are not the primary focus (IKEM, 2022).

Renewable Energy Directive (RED)

The Renewable energy directive (RED), initially adopted in 2009, is the main EU instrument for promoting energy from renewable sources. It was revised in 2018 (RED II) and has undergone a second revision (RED III) as of spring 2023. The provisional agreement is to increase the renewable energy target for 2030 from 32 % to at least 42.5 % (Eruopean Commission, 2023). RED III indirectly impacts ERS as it acknowledges the need for recharging infrastructure in line with the AFID and advances in biofuels (IKEM, 2022). The rapid and incentivised development of these fuels would potentially reduce the role for ERS in emissions reduction within the road transport sector. In other words, the contribution of ERS to emissions reduction depends on other policies targeting the same objectives.

Eurovignette Directive

The Eurovignette Directive establishes rules for collecting fees for the use of certain infrastructure, such as toll roads and bridges, by vehicles above a certain weight (European Commission, 2022). The Eurovignette Directive is relevant for ERS in terms of fee collection. For example, fees for using ERS infrastructure could be based on factors such as distance travelled, electricity consumption, and the duration of use. The directive can also serve as a framework for information exchange between countries, which is crucial for the proper functioning of ERS

KEY TAKE-AWAYS

- → **EU ETS II:** The EU emissions trading system is undergoing reform as part of the 'Fit for 55' package. This includes a separate trading system for road transport and funding for low-carbon technologies.
- → **Renewable Energy Directive (RED II):** Each EU Member State must set obligations for fuel suppliers to increase the use of renewable energy in the transport sector by 2030.
- → **Eurovignette Directive:** The Eurovignette Directive sets rules for infrastructure fees, which could be used to collect fees for the use of electric road system (ERS) infrastructure.
- → **ITS Directive:** The ITS Directive prioritizes the deployment of intelligent transport systems and interoperability, which may be relevant for the administration and billing of ERS and electricity systems.

infrastructure and to prevent fee evasion. However, specific regulations or amendments would be needed to include ERS within the Eurovignette directive. For instance, the directive does not currently specify the types of infrastructure considered as roads (Andersson, et al., 2022).

On that note, the Eurovignette directive was amend with article 9(1a) which states that "*Member States should not be prevented from applying, on a non-discriminatory basis, fees specifically designed to finance the construction, operation, maintenance, and development of installations, embedded in, or deployed along or over roads, providing energy to low- and zero-emission vehicles in motion and levied on such vehicles.*"

Intelligent Transport System (ITS) Directive

The ITS Directive (2010/40/EU) aims to encourage the deployment of ITS within the EU. While ERS is not explicitly mentioned, the directive prioritises the integration of vehicles with transport infrastructure and emphasises interoperability, which could be relevant for the future administration and electric billing systems of ERS. Article 2 of the directive also prioritises the development and utilisation of specifications for the optimal use of road and traffic data.

POTENTIAL OF EU-FUNDING

Based on the information presented earlier regarding the regulatory framework, the following conclusions can be made. In recent years, EU has been working on legislation to promote sustainability in transportation and align regulations with these goals. The AFIR sets out the requirements for building alternative fuels infrastructure. It acknowledges ERS as an emerging technology and requests European standardisation bodies to develop standards for it. The CEF regulation states that eligible actions for funding include those related to the decarbonisation of all transport modes, promoting energy efficiency, and introducing alternative propulsion systems, such as electricity supply systems, along with necessary corresponding infrastructure."

CINEA, that administers the CEF fund, has been asked if ERS can be funded through AFIF (the alternative fuels infrastructure facility, part of CEF). CINEA has responded that ERS are not currently eligible for funding under the existing program.[18] This position was also confirmed by Anneli Malmberg, a representant at the Swedish CEF secretary, whom WSP has been in contact with. CINEA does provide specific reasons for this response, but a plausible explanation could be that CEF funds actions (projects) that have reached a certain level of maturity. Among the award criteria within CEF are maturity (see article 14 of the CEF regulation).

An AFIF call[19] specifies that the maturity criterion assesses the project's readiness/ability to start and finished within the proposed timeline, the status of contracting procedures and necessary permits, and the financial capacity to complement the CEF investment. Currently, there are no permanent ERS projects that have been initiated. However, there are prospects of ERS development in Sweden and other EU countries within the next few years. In the meantime, research funding through the Horizon Europe programme can be utilised for ERS (Volkery, 2023).

Nevertheless, before large-scale roll out, CEF will be updated with new goals and a new budget as a part of the EU's long-term budget, beginning in 2028. This window of opportunity will be further discussed in the discussions and conclusions chapter. It is also noteworthy that AFIR will undergo a review by December 2026, which may result in proposed amendments. By that time, it is possible that ERS technologies have established standards and will no longer be considered emerging technologies.

KEY TAKE-AWAYS

- → ERS is currently not eligible for funding within CEF, according to CINEA.
- → Poland, Germany, and France have received the largest amounts of funding from the CEF transport program.
- → A hypothetical calculation suggests that the cost of ERS deployment in Sweden could be around €2.23 billion, with the possibility of up to 30% coverage from EU funding.
- → The establishment of a larger ERS network brings higher value for users and can contribute to achieving TEN-T goals.

CEF CONTRIBUTIONS AND REGIONAL DISPARITIES

According to data obtained from an online dashboard that presents data on grant agreements managed by CINEA, a total of 1,270 projects have received EU-contributions totalling €29.1 billion since the inception of the CEF program in 2014 (CINEA, 2023). Analysing the EU-contributions per country, Figure 2 reveals Poland, Germany, and France have received the largest funding amounts, with respective contributions of €5.7 billion, €2.8 billion, and €2.4 billion. Both public and private participants have received EU contributions, with respective amounts of €22.8 billion and €6.2 billion.

[18] See CINEA's answer here: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/support/faq/21443
[19] Call CEF-T-2021-AFIFGEN

Table 3. European countries that have received funding within CEF Transport between 2014 – 2023.

	Country	Number of projects	Number of participations	EU-contribution (billion €)	Average EU-contribution per project (billion €)	Share of the total CEF Transport budget
	Poland	88	101	5.7	0.65	19.5%
	Germany	175	327	2.8	0.16	9.8%
	France	186	371	2.2	0.12	7.6%
	Czechia	83	102	1.5	0.18	5.4%
	Denmark	50	70	1.5	0.29	5.0%
	Finland	73	124	0.3	0.05	1.2%
	Norway	6	7	0.01	0.02	0.1%
	Sweden	92	183	0.5	0.06	1.9%

Note: The distinction between "Number of projects" and "Number of participations" pertains to the country, or an entity within a given country, assuming the role of project coordinator. If a country or its entity has acted as the coordinator, it contributes to the "number of projects" metric, while the "number of participations" denotes the instances in which a country has participated in projects without assuming the coordinator role.

Table 3 indicates that that countries in the eastern part of Europe, such as Poland, tend to receive more funding compared to countries in the western part. However, Denmark is an exception in this regard. This information is relevant when assessing future CEF funding to Sweden, and other countries that would be desirable to include in an international ERS network.

So far, Sweden has received contributions amounting to €0.55 billion for a total 92 projects in total, averaging approximately €6 million per project. This average amount is lower than the EU-average of €22 million per project. Swedish public and private actors have participated in a total of 183 projects, with public actors receiving €426.4 million and private actors receiving €125.8 million. Of the €426 million to public actors, about €26 million (approximately 60 percent) have been allocated to the Swedish Transport Administration. Furthermore, Sweden's share of the total CEF Transport budget is approximately two percent.

HOW MUCH COULD AN ERS DEPLOYMENT COST?

To provide a comprehensive understanding of the funding required for expanding ERS, it essential to consider the availability of EU-level, national, and sub-national funding. This allows us to gauge the level of funding in relation to other transportation technologies and centrally available funding, such as the CEF. Identifying these key aspects helps mitigate errors in decision making, ensuring accurate assessment of funding availability vis-à-vis the costs with ERS.

For this reason, it is beneficial to present a hypothetical cost example as a basis for discussion and further analysis. While it is not possible to provide an exact cost estimate for ERS expansion, assumptions can be made regarding the cost per kilometre of ERS, the length of the system, and share of EU funding available to conduct a hypothetical calculation.

According to the Swedish Transport Administration (Trafikverket), the construction costs for ERS vary depending on the technique used, ranging from approximately €0.6 million to 1.8 million per kilometre, as a rough estimate. Additionally, there are costs associated with ITS and other components,

amounting to approximately €0.9 million to €1.4 million per kilometre respectively. (The Swedish Transport Administration, 2023).[20] Based on these assumptions, the total construction cost of ERS could range from €2.8 million to €4 million per kilometre. If we assume the lower end cost of €2.8 million per kilometre, it produces the solid lined graph in

Figure 3 which illustrates total investment costs in that case.

Considering a Swedish context, it is reasonable to assume that ERS would primarily be built along existing roads connecting Stockholm, Gothenburg, and Malmö. The total distance encompassing these cities amounts to approximately 1,400 kilometres. However, it is unlikely that the entire distance between these cities will be covered by an ERS. Hence, a further assumption is that approximately 60 percent of the distance, equivalent to roughly 800 kilometres, will be covered.

Based on 800 kilometres of ERS and a cost per kilometre of €2.8 million, the total cost of deploying ERS in Sweden would amount to approximately €2.25 billion. If CEF provides financial support for 30 % of the investment cost, it would correspond to approximately €670 million. The total CEF Transport budget for the 2021 – 2027 financial framework period is €25.8 billion, with approximately €13 billion available for Sweden, excluding funds earmarked for the Cohesion Fund. Hence, the demand for CEF funding in the Swedish context would represent five percent of the current CEF Transport budget available through the MFF 2021 – 2027, based on the calculation above. In the higher scenario of approximately €4 million per kilometre, the corresponding figures would amount to a total cost of €3.1 billion, a potential CEF contribution of €945 million, and a demand of approximately seven percent of the current CEF Transport budget.

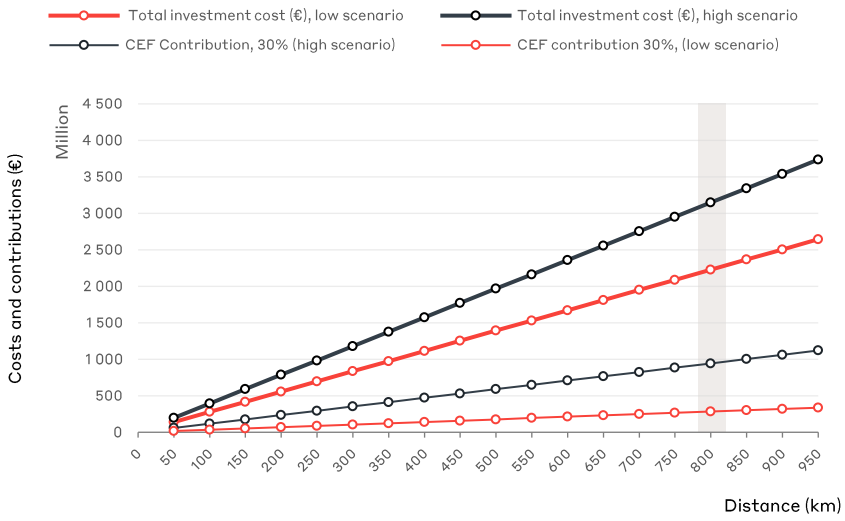

Figure 3. Hypothetical cost of ERS per kilometre with and without CEF funding. The solid blue line illustrates the total investment cost, given assumptions about €3,9 million per kilometre and the dashed blue line represents potential CEF funding of 30 % of the investment cost. Similarly, the solid red line illustrates total investment cost, given assumptions about €2,6 million per kilometre, and the dashed red line illustrates potential CEF funding of 30 %

[20] Correspondence with The Swedish Transport Administration revealed that the cost of ERS per kilometre amounted to between 10 – 30 million SEK, ITS to 10 million SEK, and other costs to 15 million SEK. Figures used in the text has been converted to Euros using the SEK/EUR exchange rate of 0,0884 from May 17th, 2023.

of the investment cost. As for timing, see figure 3 above (CEF funded ERS roads in Sweden could be in use when CINEA decides to fund ERS and when there is a mature ongoing project).

Expanding the ERS network incurs not only costs but also offers increased value for users. An associated concept is the weakest-link property, which suggests that for ERS is be considered part of the TEN-T core network, it needs to cover a certain distance. This enables economies of scale among OEM:s and transport companies. It worth considering a threshold for critical mass, or in this case, a minimum distance of ERS necessary to justify its role as a technology that serves the goals of the TEN-T. ERS can also complement stationary charging technology and provide enhanced range along specific corridors.

STAKEHOLDER INSIGHTS

In WSP's parallel project, "How should the choice of ERS technology for Europe be made?", a semi-structured interview study was conducted to gather insights from various stakeholders, including vehicle manufacturers, ERS providers, logistics and freight businesses, academia, and government representatives (WSP, forthcoming). The interviews revealed a common opinion that the infrastructure for ERS must be established prior to the market's actualisation. As highlighted in the government inquiry on ERS, the initial traffic volumes will be insufficient to support user fees that cover operational and maintenance costs.[21] Therefore, during the early stages, policies should incentivise the use of ERS for early adopters.

Many respondents emphasised the importance of long-term thinking and argued that the state should bear the brunt of significant investments and risks associated with ERS, despite the uncertainties involved. Although the extent of the State's role varied among the respondents, the majority asserted that the State should assume a substantial role and shoulder a significant portion of the risks and costs to facilitate and expedite the transition. Some respondents also expressed concerns about the current environmental politics in Sweden, suggesting that it hampers the transition process. It was widely agreed that long-term policies are essential for to provide the predictability demanded by various stakeholders.

[21] (SOU, 2021:73)

SCENARIOS

In this section, a summary of previous sections is provided. Additionally, two scenarios are presented to discuss the potential impacts of central incentives on the roll-out of ERS.

SUMMARY OF PREVIOUS SECTIONS

The previous sections examined ERS from multiple angles, including its classification, funding mechanisms, characteristics of road infrastructure investments, and available EU-funding sources. Stakeholder interviews have provided valuable insights. The theoretical background has highlighted that a combination of various funding strategies, such as national budgets, user fees, and PPPs can be utilised to fund and finance the deployment of ERS. Notably, this mixed funding approach has been observed in the UK, USA, and several European countries, including Sweden.

In the context of Sweden, it is likely that national budget allocations, potentially supported by user fees, will serve as the primary funding mechanisms for ERS. Consequently, government involvement in ERS will be crucial. This aligns with the insights gathered from the interviews with stakeholders, who argued that the government should initially play a significant role and bear a substantial portion of the risks and costs to expedite the transition.

Examining the relevant EU regulatory framework and funding mechanisms has revealed that ERS is not currently funded through EU tools like the CEF Transport 2021 – 2027 financial framework. This has been confirmed by Anneli Malmberg, a representative at the Swedish CEF secretary. However, if ERS is classified as an alternative fuels infrastructure, EU funding can be made available through the CEF, potentially within the Alternative Fuels Infrastructure Facility (AFIF) calls.

Analysing CEF Transport statistics, it was found that EU contributions to Sweden accounted for approximately 2 percent of the total CEF Transport budget utilised between 2014 – 2023. Based on WSP's hypothetical investment cost calculation, assuming the construction of 800 kilometres of ERS, a 30 percent contribution from the CEF Transport budget would range between €668 million to €945 million depending on scenario. This would roughly approximate between five to seven percent of the available CEF Transport funds for Sweden. However, there are uncertainties regarding whether Sweden will receive this proportion of funding for ERS, as the allocation also accommodates other countries and transport modes. It depends on whether the EU is keen to financially support ERS deployment, a topic that is discussed further below.

SCENARIO DISCUSSION

KEY TAKE-AWAYS

- → The EU could take two different (although extreme) positions: either to support and incentivise an ERS deployment, or not incentivise it at all.
- → The implications of EU's policy can come in terms of the speed of the roll out, the network connectivity, the signalling value, and the level of user fees.
- → An active and incentivising EU could make member states pursue a faster deployment along connected corridors, as well as signalling to other actors (such as manufacturers and carriers) that there are investment opportunities in ERS.

Qualitative scenarios offers descriptive and visually representations of potential futures, often in forms of diagrams, phrases, outlines, or more commonly narratives, i.e., so-called 'storylines'.[22] In the context of ERS, two scenarios will be discussed to explore plausible paths regarding the potential of EU-funding: 1) the EU's active interest in funding ERS in Europe, and 2) the EU adopting a more passive role on ERS, focusing on other technologies. By contrasting these scenarios, potential implications on the development and deployment of ERS can be identified as well as the potential challenges and necessary strategies for an international large-scale deployment. These scenarios are based on the next multiannual financial framework of 2028 onwards.

It is important to note that these scenarios are simplified illustrations of potential development paths for ERS in Europe. They assume a status quo regarding key policy targets, such as the rate of technological advancement and supply constraints for existing complementary and competitive technologies. The key aspects of future ERS deployment, roll-out speed, network connectivity, signalling value and user fees are elaborated on for each scenario below.

Timeline

The scenarios are closely tied to the timeline of making ERS eligible for funding. Figure 4 illustrates the significance of the Swedish planning process in this regard. The current Swedish transport infrastructure plan covers the period from 2022 to 2033, with a new plan introduced every four years, spanning 12 years. Consequently, the next plan will come into effect in 2026 and then in 2030. Meanwhile, the next long-term budget within the EU, including the CEF funds, will come into effect in 2028.

This timeline has implications for when Sweden can apply for CEF funding, as CEF funding is only granted to projects that are already in progress. If the EU decides in 2028 that CEF can fund ERS, Sweden will need to select ERS projects within the national plan as early as 2026, as the projects must be under construction when Sweden submits the application for CEF funding.

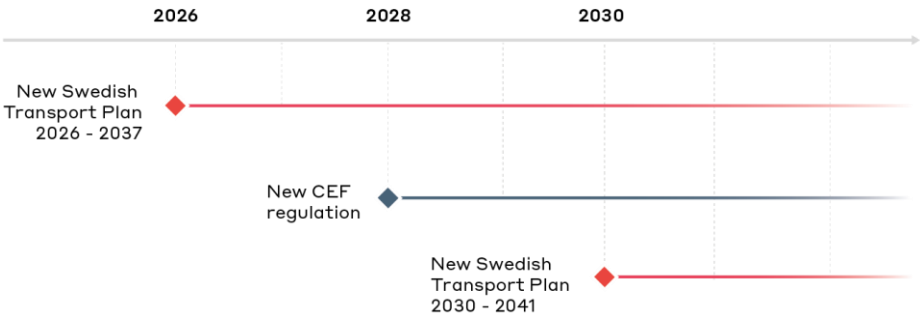

Figure 4. Illustration of the overlap between the Swedish national transport planning and the financial framework in the EU

[22] (European Environment Agency, 2023)

Scenario 1: EU opens to provide financial incentives for ERS.

Roll out speed.

With CEF funding, ERS have the potential to scale up rapidly, covering large stretches of road both at national and European levels. However, a challenge arises due to CEF funding being granted only for projects in the construction phase. Sweden's next transport infrastructure plan, decided in 2026, could consider EU policy signals regarding ERS eligibility for CEF funding. However, by 2026, it is possible that there are already clear policy signals from EU that ERS will be made eligible for CEF funding. In that case the Swedish national transport infrastructure plan should take that information into account when deciding about further investment in ERS.

Network

Not only would the rapidness of the roll-out potentially be affected by financial incentives, but the network connectivity could also be improved. The principal idea behind CEF is to realize European transport policy (primarily the TEN-T network). Thus, by pointing out that ERS is an integral part of TEN-T and that it is eligible for funding, national activity could be focused on those routes.

A major theme in the AFIR is to ensure the infrastructure's full interoperability. Promoting ERS to a more prominent position within the AFIR together with financial incentives would be important tools to enable a coherent network of ERS across Member States. The explanatory memorandum of the AFIR notes that the goal in the Green deal needs a substantial increase in zero- and low-emission vehicles and that this will not take place without a complete network of interoperable alternative fuels infrastructure enabling cross border travel on that infrastructure. The explanatory memorandum also notes that adequately developing such a network requires Union intervention. This is where financial incentives come in.

Signalling value

Availability of CEF funding is likely to send a strong signal to key actors needed for ERS expansion, both nationally and internationally. On the political side, availability of CEF funding would signal that ERS is a technology to be considered in national planning for the achievement of associated policy goals including climate and energy policy targets. Consequently, on the market-side, demand-side actors such as transport companies would start to consider such technology in their choice of transport mode. With potential market demand, the supply-side of the market (the original equipment manufacturers) would consider developing ERS compatible vehicles.

User fees

As for user fees, the levy could be based on different grounds: it could finance of the infrastructure, and/or the operations and maintenance, or it could be set to optimise the use of the infrastructure. The grounds on which fees are levied could be different in different countries. It is likely that several countries will opt for a fee that finances part of the operations and maintenance costs. In Sweden, there is a tradition to set fees and taxes within the transport sector so that it maximises social welfare and optimise infrastructure use. However, as

mentioned in the introduction, the government inquiry suggested a user fee that covers operational costs (SOU, 2021:73).

In any case, it is vital that the user fee is sufficiently low to not scare away users in the initial roll-out phase when the network is small. Hence, the users can't be expected to pay a high fee if the benefit of using the infrastructure is low. From the user's point of view, the costs of buying the ERS vehicle and other associated vehicle costs must be offset by lower operating costs. If the EU gives financial support for investment costs, the user fees could be lightened in countries where user fees are used to finance operations and maintenance.

Scenario 2: EU do not provide financial incentives for ERS.

Roll out speed.

Without CEF funding, it is more likely that ERS would not be scaled up rapidly and contribute substantially to climate and accessibility policy goals. There may be several stretches of ERS in Europe, but they are likely to remain unconnected, such as near terminals and ports. CEF funding would instead contribute to scaling up other technologies such as hydrogen fuel cells and better battery technology.

Network

If the EU do not support a Europe-wide roll-out, the network risks being more geographically disperse with reduced or no interoperability. The activities might be more decentralised without an overarching governing plan for the network. As mentioned above, the ERS stretches in this scenario would probably be limited to geographically separated stretches with a lot of shuttle traffic.

Signalling value

The signal to be market and private actors in this scenario would be that ERS is not a viable market niche for them. Investments and effort would be directed to other efforts for sustainable transport. A logistics firm might conclude that ERS will not contribute to the firm's ambitions to reduce the climate footprint and therefore opt for another solution.

User fees

If the EU do not provide funds, there is a larger share of the costs that will be borne by the users. Hence there is a likelihood of a higher user fee. In countries where the national government fund ERS through the state budget or loans, there is probably a smaller impact on the user fees.

Summary of scenarios

Table 4. Summary of scenarios in terms of rapidness of roll-out, network connection, signalling value, and user fees.

	Aspect	Scenario 1 (with EU funding)	Scenario 2 (without EU funding)
	Roll-out speed	High and possibly incrementing speed if ERS gains support by policy and market stakeholders.	First low then stagnating, as CEF-funding would support alternative technologies to scale up.
	Network	Financial incentives to complete an ERS roll-out along the TEN-T corridors would increase likelihood of a connected system.	Without incentives to contribute to an overarching objective, the ERS sections might be dispersed with low interoperability.
	Signalling value	Market actors would interpret higher certainty for ERS as a viable market niche.	Major market actors likely not to put much emphasis on ERS.
	User fees	Potentially lower user fees	Potentially higher user fees

CONCLUSIONS

The purpose of this report has been to highlight the main challenges in funding a European ERS network and suggest which position Sweden should take. The regulatory overview indicates that the EU could finance and incentivise ERS deployment. However, the current obstacle is that the AFIR has lower ambitions for ERS compared to stationary charging infrastructure and hydrogen infrastructure. Consequently, CINEA states that CEF does not currently provide funding for ERS.

By 2028, the CEF will undergo updates with a new budget and goals, and the AFIR will be reviewed and revised. During this process, Sweden and other countries have a window of opportunity to prioritise ERS. Meanwhile, Sweden's next transport infrastructure plan will be decided in 2026 and subsequently in 2030. The following suggestions are proposed: First, Sweden should promote ERS within the EU, collaborating with other countries like Germany. Simultaneously, Sweden should plan for ERS projects to be ready in the 2030s when there may be financial incentives for ERS.

From a theoretical perspective, this paper emphasises the importance of central support and incentives for ERS. Given the high initial investment costs and network effects of ERS, decentralised initiatives by private or local organisations may insufficient and scattered. The benefits of the system increase with size and interoperability, as logistics companies and carriers are more likely to shift to ERS vehicles if they are confident that it will sufficiently support their operations. The ERS market needs signals to indicate viability to vehicle manufacturers, buyers, voters, and industry organisations.

Could ERS be privately financed? In theory, yes, but in Sweden the Road Act stipulates that the Transport Administration is responsible for planning and constructing national roads.[23] Therefore, government action is necessary, even if private financial initiatives exist.

Regarding potential financial incentives from the EU, the scenario discussion highlighted four key aspects of the ERS deployment. Rapid roll-out is crucial for ERS to contribute to the swift decarbonisation of road freight transport, aligning with the goals of the European Green Deal. An active EU can accelerate deployment and incentivise a connected ERS network, fostering a future market for vehicles and carriers. While the EU cannot directly construct ERS or take other initiatives, it can be explicitly included ERS in the AFIR by outlining requirements and ensuring ERS eligibility for funding through the CEF.

In the meantime, financial support has the potential to stimulate carrier interest for ERS by reducing user charges during the ramp-up phase. One strategy could be to initially keep user fees low to encourage early adopters.

German researchers argue that the next three or four years are crucial for ERS development on a larger scale (IKEM, 2022). This paper aligns with that conclusion. Germany's path decision regarding overhead catenary lines will be made between 2024 and 2026, possibly making Germany interested in persuading the EU to play a more active role in ERS deployment. This presents an opportunity for countries like Sweden and Germany to advocate for greater emphasis on ERS in the AFIR and make it eligible for CEF funding.

[23] The Road Act in Swedish: Väglag (1971:948)

RECOMMENDATIONS

1

Enable CEF Funding for ERS

Sweden and other countries should strive to make ERS eligible for CEF funding by 2028. AFIR needs to prioritise ERS at the same level as stationary charging and hydrogen infrastructure.

2

Secure CEF Funding for Swedish ERS Projects

Sweden should have ERS projects already under construction when applying for CEF funding. This means that Sweden needs to decide whether to invest in ERS on a large scale, either in the upcoming transport infrastructure plans (2026 or 2030). By doing so, Sweden will meet the criteria necessary to apply for CEF funding.

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APPENDIX

PUBLIC GOODS THEORY

In economic theory, goods are primarily defined as pure public goods, private goods, club goods, and common-pool resources (Cornes & Sandler, 1996). These types of goods vary by their level of excludability and rivalry. If a good is rivalrous, one person's use of the good interfere with any other person's consumption of that same unit of the good (for example an apple). If a good is excludable, a person's access to that good is restricted. A classic example of a good that are characterised by a high degree of non-rivalry and non-excludability is that of pure public goods, illustrated in the bottom left quadrant in Figure 1 below. This implies that access cannot be restricted, and that one person's consumption does not reduce the availability of the same good for others. In contrast, private goods, such as cars, exhibit high degrees of rivalry and excludability. Moreover, common-pool resources exhibit higher degree non-rivalry but low levels of excludability, where examples include fish stocks for example.

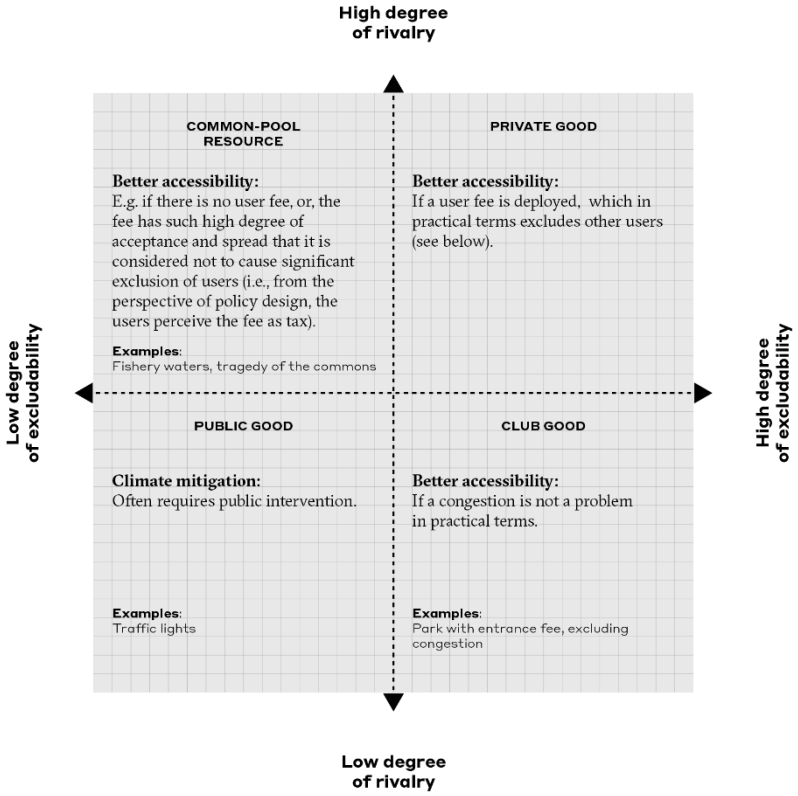

Figure 5. The characteristics of goods have important policy implications.

Pure vs. Impure Public Goods

In contrast to these distinct categories, some goods are more difficult to categorise, such as roads. For every new road user, the more congested the road becomes. Initially, there is no congestion, but eventually, with more and more users, the road becomes gridlocked. These types of goods are known as **impure public goods** and are often partially rivalrous or congestible. In fact, Benson (2016) examined the historical evolution of road provision systems in the UK and arrived at the conclusions that roads are never public goods and that roads

can be characterised as different types of goods depending on the institutional context in which roads are provided. This is because roads, or certain road sections, can differ in congestion levels and exclude certain users. Leach (2003) further states that impure public goods exhibit a higher degree of excludability compared to pure public goods as access to a road can be controlled through toll systems. This means that infrastructure provisions by governments or private firms through user fees becomes possible and that problems with free riding (someone who enjoys the benefits but does not pay) can be reduced. Further, the infrastructure provider can influence the congestion level by either regulating the number of users or the frequency with which the road is used, or both.

Variable-Use Public Goods

Impure public goods can further be divided into two classes of goods: club goods and **variable-use public goods**. Club goods are generally exhibiting low degrees of rivalry but higher degrees of excludability, such as fitness clubs and tennis courts. Club goods can also be said to be replicable, meaning that exclusion from one club does not prevent users from using another equivalent club. Contrary, Leach (2003) argues that variable-use public goods can be either excludable or non-excludable and that roads, bridges, and public transit systems are characterised as such. If these goods are excludable, frequency of use is controlled rather than the number of users. Moreover, variable-use public goods are not replicable, meaning that a road must be provided to all potential users as there is rarely an equally good alternative route. Variable-use public goods are available to everyone, but each road user chooses the frequency with which it is used. Every additional road user increases the congestion level, which negatively affects every other person using that same road and reduces the frequency by which other use it.

Using a road potentially imposes two types of costs on the road user: a monetary cost (such as tolls) and costs related to delays or dangers when road use is high (Leach, 2003). These costs are referred to as congestion costs and depend on the capacity of the road system and the frequency of trips by a road user. Although the government can influence the capacity, the road user decides the frequency of use. Hence, the government's ability to implement an optimal road usage, centres around its ability to implement incentives that effects the frequency of road use. One way is through user fees, such as tolls or congestion taxes, which can control the degree of congestion. This has been evident in both Stockholm and Gothenburg as congestion charges have been effective in reducing traffic volumes since their respective inceptions (Börjesson, 2018).

Electric road systems

ERS can also be analysed within this theoretical framework. If the system is open for all road users (i.e., non-excludability) and does not include attributes of congestion (i.e., no rivalry), it could be categorised as a public good. However, if access to the ERS requires payment, permission, or suffer from congestion it can also exhibit characteristics of club goods, private goods, and common pools.

The classification of ERS, as a good that partly share features of a public good, has important policy implications. Notably, the market will provide insufficient supply of ERS (supply will be smaller than demand, and there is no price mechanism in the market that will adjust this relationship). Similarly, because

national road infrastructure is funded by the Swedish national government, there is no reason to assume that fully privately funded ERS will become a reality in Sweden. According to the Road Act in Sweden, the Transport Administration (Trafikverket) is responsible for planning, constructing, and maintaining national roads.

Hence, determining what type of good an ERS is could have an impact on decisions to manage and fund the ERS. For example, public goods are generally funded by government budgets or loans, private goods from user fees or private funding, and impure public goods from a variety of sources, such as membership fees, user fees, or national budget allocations.

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