Business Models, Ownership, and Financing Strategies

Implications of the introduction of electric road systems on markets and possible business models

Final Report

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Summary

While the challenges facing station-based energy supply systems mainly involve replacing and overcoming propulsion technology, a major challenge facing the implementation of an electric road system (ERS) also includes, to a greater extent, the organizational, financial, and more complicated regulatory issues based on energy-road interactions in different sub-markets. The need for a rapid and substantial decarbonization of the transport system runs counter to the long-term development trend in the system. The question of whether an ERS is seen as part of the (public) road system or the (private) energy system will fundamentally affect the market structure of an ERS. Different ERS configurations can create new business opportunities for road operators. Different archetypes of business models for ERS-related services can be identified which could enable an opportunity for new value creation for the private sector. Policy measures enabling business model development for an ERS should be diversified and target all actors involved.

Without respecting the specificities of the local markets in the countries crossed by the Hamburg-Helsingborg corridor, the implementation of an ERS is likely to fail. Due to the different access and regulation principles for infrastructure and energy in Germany, Sweden and Denmark, there will not be a standardized ERS regulation along the corridor. Individual priorities on decarbonizing road freight will lead to a country-specific balance between policy push and market pull. Differences in the division of responsibilities between public and private actors could also occur along the corridor and lead to different business models. Depending on the time frame for the construction of the ERS corridor, different configurations between the public and private sectors might be needed.

Table of Contents

1 Introduction

1.1 ERS: A step towards sustainable road transportation

In recent years, the electric road system (ERS) has emerged as a technical solution to achieve sustainability in long-haul road transportation. The long-haul freight sector, which is projected to grow dramatically in the coming years, is one of the most difficult societal sectors to decarbonize: at present, fuel cell and battery electric (heavy) trucks are not commercially viable for long haul transport and, considering the volume of road transport of goods, even greatly increased investments in additional railroad capacity would be insufficient to provide low-emission transportation capacity in this segment of the market. Consequently, the electrification of roads has emerged as one of the most promising alternatives to the existing road freight transportation paradigm where vehicle propulsion is currently based on gas and diesel.

An ERS is a road transportation systems based on technologies that support the electric charging and propulsion of vehicles, e.g. cars, trucks and buses. An ERS-compatible vehicle is equipped with a hybrid engine or high-capacity batteries for operation outside the ERS stretches, whereas within the ERS stretches, while connected, electric power is transferred to the vehicles conductively through pickups connected either to overhead lines or in-road rails, or inductively through wireless charging equipment installed in the road.

Compared with alternative electric and non-electric propulsion technologies, an ERS has several advantages: it has the potential to significantly reduce CO_2 emissions, it reduces electric vehicles' dependency on large batteries, and it relies on the existing electric power system. At the same time, an ERS constitutes a new type of technological subsystem ("permanent pick-up") that does not fit with the established structures and institutions of road transportation. In the established structure, the system relies on station-based fuelling and energy storage in tanks. This could also be an alternative for electric vehicles, but in the short to medium term, it is primarily only suitable for lighter weight vehicles.

Thus far, the development of an ERS has primarily been driven by a "policy push" from governmental actors (supported by manufacturing companies and technology providers recognizing the business potential in ERS technology) rather than a "demand pull" from actors in the transport market. Consequently, most ERS activities have thus far been initiated and supported by public funding. While the purpose of this activity is to prepare ERS technology for commercial take-off, previous research has shown that technologies challenging the established technological paradigm often run the risk of failing at market deployment. Thus, identifying the enablers and barriers to an ERS breakthrough is crucial for its further development.

1.2 The ambiguities of ERS deployment

Today's dominant road transportation paradigm is the result of more than 100 years of organic evolution. The transport infrastructure of roads, fuel stations, and services shops, as well as its business ecosystem of road administration systems, petrol companies, vehicle manufacturers, roadside services, maintenance providers, transport forwarders, regulators, haulage companies, etc., has grown successively into a highly intertwined, institutionalized system. Due to the need for extensive upfront capital investments in infrastructure, major roads and highways have typically been a governmental responsibility (even where highways in some countries are operated by private firms under commission), while the manufacturing of vehicles, operations of transports, and the provisioning of fuel are performed primarily by private actors.

A transportation system such as an ERS has a basic similar logic. Due to its systemic nature, the three major subsystems – electrified roads, electric trucks, and electric infrastructure – need to be developed and deployed concurrently. Achieving this coordinated investment, together with a shift from the current system to a new ERS, is a twofold challenge which must be overcome in order to introduce the new road transport paradigm. Extensive capital investment in road infrastructure and power grid extensions have to be initiated at the same time as the development and commercialization of ERS-compatible vehicles and electric power transfer equipment. Without the coordination of these activities, there is a significant risk of a "chicken-or-the-egg dilemma" developing: transport operators are not willing to invest in ERS vehicles because a sufficient ERS network is lacking; at the same time, governments or other actors hesitate to invest in ERS infrastructure because there are too few ERS vehicles in operation. In other words, if there is an insufficient number of ERS vehicles, the extensive investments needed to enable the infrastructure cannot be economically justified, and if the infrastructure is insufficient, the adoption rate of users will never or only very slowly become high enough to reach an acceptable level of utilization.

Furthermore, the introduction of an ERS is not compatible with the traditional division of labour between the actors of the road transportation system. In the established system, the roads are typically owned and provided by government-funded public agencies, while fuel (gasoline and diesel) is provided to vehicles at roadside station services operated by commercial petrol companies. The introduction of an ERS, however, means that the fuel (electricity) is provided to vehicles through electrical transfer equipment installed in the road (or directly on the roadside). This raises a number of issues:

- Who should own and operate the ERS installations (in the road area): the road agency or an energy company?
- Should the road agency supply the electricity to the vehicles, i.e. compete with the petrol companies, or should current petrol or energy companies deliver electricity to the vehicles and initiate this competition?
- Should energy companies deliver electricity to a specific intermediate ERS operator? If so, what kind of actor should that be?
- If energy companies or ERS operators gained revenues from selling electricity to road transport, shouldn´t they also finance (parts of) the necessary construction of ERS infrastructure?
- What legislation regulates the ERS: road legislation or electricity market regulations? What different aspects would the application of either system lead to for the ERS configuration?

Introducing an ERS could also challenge established funding, business, and ownership models of road infrastructure. Since an ERS is dependent on a simultaneous deployment of vehicle technology, electrical installations, and physical infrastructure, its subsystems need to be coordinated, i.e. the ERS needs to be handled as a system. The problem is, however, that no actor controls all parts of the system. On the other hand, if deployed, an ERS will most likely have significant implications for the roles and business models of a number of incumbent actors. One issue, for e.g., is how ERS technology should be categorized. Should it be treated as:

- A part of the road transportations system (i.e. as an alternative way of fuelling vehicles)?
- A part of the electrical energy system (i.e. as a new way of charging)?
- Constituting a new type of transportation system in itself?

Thus, an ERS represents a potential technology shift towards sustainability. But how the successful deployment of an ERS should be accomplished is still ambiguous. There are a number of fundamental, non-technological issues that need to be sorted out. The situation suffers from a lack of concepts that come to grips with the systemic effects of this emerging technology. The deployment of an ERS will probably have significant policy, business, and financing implications for the incumbent system and the actors, which so far have not entered the market, but are preparing to do so. Thus, there is a strong need to investigate the potential business model implications of an ERS for the various actors involved.

1.3 A business model perspective for an ERS

The exact definition of the concept "business model" can be debated. There are a number of definitions, each with a different emphasis and different levels of details and sophistication (c.f. Amit and Zott, 2001; Osterwalder and Pigneur, 2010). However, despite the academic disagreements, there is an emerging, general consensus that the core of a business model comprises three basic elements:

- *Value proposition*, i.e. the organization offers its products and services to its customers.
- *Value creation,* i.e. how this value is created, delivered, and provided to the organization's customers.
- *Value capture*, i.e. how the firm appropriates parts of the value created for its customers.

Thus, a business model directs attention towards the backbone of any successful business, i.e. the activities connecting the firm's technological core to the fulfilment of its customers' needs. As an analytical concept, a business model constitutes a unit of analysis that explicitly spans the traditional, legal boundaries of the focal firm and relates the firm's internal value-creation activities to activities and structures of the firm's business environment. A business model does always have a focal organizational point, such as a firm or a business unit, constituting its point of departure and what it encompasses. However, as an analytical tool, it is a boundary-spanning device addressing how the business of a focal organization is intertwined with the business models of its surrounding organizations.

Consequently, a business model perspective on an ERS requires the scrutinization of how the deployment of an ERS affects the value proposition, creation, and capture of the actors involved. In addition, it encompasses how the business model of each actor interacts with, contests, and/or complements the other business models of the system. However, business models do not emerge in a vacuum. Rather, they are contingent on a number of substantial contextual antecedents determining the conditions for value proposition, creation, and capture for the various actors.

1.4 Research design

WP 2.2 analyses an ERS from a business model perspective. It addresses significant contextual factors that define the underlying business model conditions relating to the deployment of an ERS. Three aspects are analysed. The first is the ERS market environment and how the employment of an ERS affects the market dynamics. The second is the alternative owner configurations of the specific ERS and how these configurations are tightly connected to the potential business models. The final aspect is the alternative ways of organizing and financing the implementation of an ERS during its period of deployment (see Figure 1).

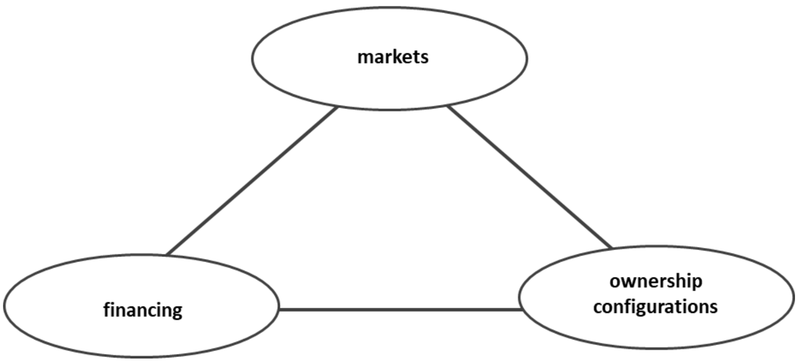

Figure 1: Scope of research
Own figure

Markets: Road transportation is basically a market-driven business which is dependent on parameters such as the price-performance ratio and reliability, as well as on supplementary factors, such as the environmental impact of transportation and value-added services. Since the introduction of an ERS will influence these factors and thus might alter the market balance, it is crucial to analyse how the introduction of an ERS could affect the acceptance of the system. This is elaborated with a market model in Chapter 2 which is complemented by the push and pull mechanism of market development.

Ownership configurations: Since the deployment of an ERS covers the entire spectrum from new vehicles to a shift towards a new source of energy, grid expansion, and ERS technology, the conventional, currently-established ownership configurations involving both the public and private sectors are contested. Identifying appropriate ownership configurations for the

ERS will have a significant impact on the introduction and diffusion of an alternative, sustainable technology to phase out fossil fuels from the sector. These *organization strategies* are discussed in more detail in Chapter 3.

Financing: The deployment of an ERS might be dependent on incentive structures that enable both public and private involvement. Moreover, for the earlier stages of ERS deployment, such as the build-up phase, which is characterized by extensive investments (both infrastructure and vehicles), a higher degree of public sector involvement might be required. Meanwhile, in the long term, the system could be opened up for more private capital investments. These *financing strategies* are discussed in more detail in Chapter 3.

Business model implications: Since the dynamics of the market might change with the introduction of an ERS, the incumbent actors might need to change their business models accordingly. Moreover, as new opportunities arise for the private sector to become more involved in financing, owning and maintaining ERS infrastructure, new business models and new actors could emerge. However, since an ERS is incompatible with the incumbent industries, it is crucial to take into account that the introduction of an ERS will probably require a major and broad sociotechnical change in the road transport system. Consequently, the relationship between business models and sociotechnical processes becomes crucial for its success. These *business model implications* are discussed in more detail in Chapter 4.

Conclusion and findings: In Chapter 5, the *conclusions* and further work relating to the deployment of an ERS are discussed. In the final chapter, Chapter 6, the *findings* for the development of a German-Swedish ERS corridor are presented.

2 The market environment of an ERS

2.1 Changing markets

An ERS is a promising way forward to a more sustainable road freight operation. The idea of dynamic energy charging during travel is based on fundamental changes when compared to a transport sector based on internal combustion engines. However, an ERS affects not only the power train, it also has an impact on all the main components of the overall road transport system, especially truck manufacturing and deliveries, truck operations, energy supply, infrastructure, regulations, and billing. All these components are interdependent. To describe, analyse and manage these dependencies, each component can be modelled as an individual market sector, interacting with the other sectors through demand and supply mechanisms. An ERS in total thus forms an interlinked market environment, where the individual markets sectors are located and connected in a complex network structure. The following image of the structure of the electric roads market is based on a report for the Swedish Transport Administration in 2019, describing those market spheres relating to an ERS (EY 2019) (see Figure 2).

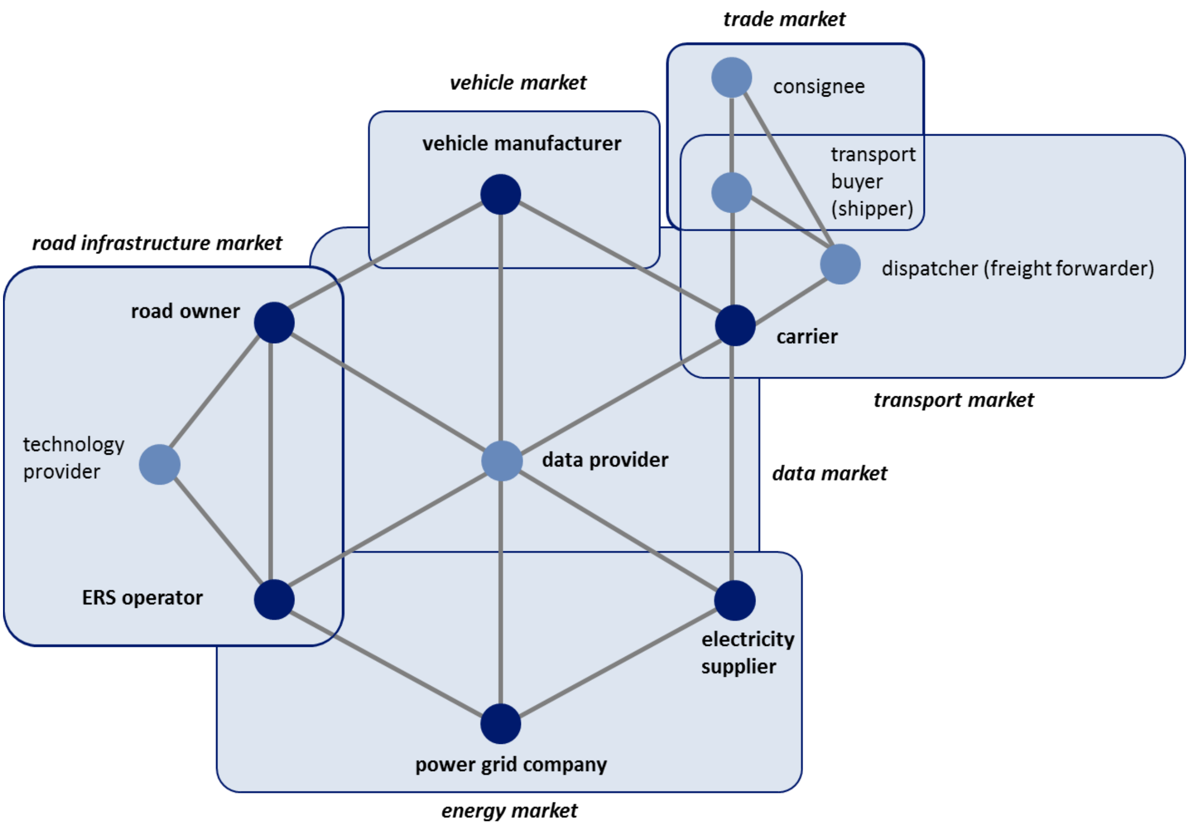

Figure 2: Roles and actors in an ERS

Source: Adapted from EY (2019)

Whereas conventional diesel truck operations are dependent on petrol stations along the roads, the operation of electric roads creates a new kind of demand for energy: charging points are substituted with charging systems along the roads, and fuel is substituted with electric energy. In a fully implemented ERS, charging takes place while the vehicle is in motion. No stopping at charging stations is required. The power supply is embedded in the road system. At the same time, the question still remains as to what extent fast charging “stations” will become an integrated part of an electrified road transportation system. The end result of the development might be a combination of dynamic charging and charging points/stations.

The transition from a primarily “station-based” to a “system-based” energy supply system entails not only changes in the technical fuelling process, but also in the market structures. With ERS, a truck driver’s choice of a certain route or road also becomes the choice of an energy network (assuming that only one charging infrastructure is built per route), while the electricity might still be delivered from different electricity suppliers in line with the current EU regulations for the electricity market. Natural monopolies for power grids can thus form, at least for this specific electricity-based energy system, while vehicles with other energy systems could simultaneously make use the roads. This situation makes it likely that government intervention or market regulations on an ERS will be necessary. A core question of such a system change towards the ERS is therefore the degree of involvement of the government and how much operating flexibility private market players will have in this construct.

Even if considerable government involvement is required for the roll-out phase, such systems could, at a later stage, be increasingly organized by private interests in a competitive market. An historical example of such a process concerns the petrol and service stations along the German motorways. These were originally state-owned to maintain the build-up and functioning of the motorway system in general. As the range of vehicles increased and private petrol stations and repair shops were established near the motorways, the petrol stations were privatized. A public basic supply was no longer necessary to maintain traffic on the motorways.

In Sweden, there is a combination of privately owned petrol stations co-located with public parking and rest areas managed by the Swedish Transport Administration, but under lease agreements primarily from private land owners. In other countries, landfor the establishment of petrol stations and electric charging stations could be provided by the road authority in concession-like structures to private contractors. Consequently, there are at least three alternatives: solely public, solely private, or public-private partnerships.

The implementation of an ERS challenges the existing framework conditions of the market. First, clarification is needed on whether an ERS is part of the road infrastructure market or the energy market and, consequently, which legislation should apply. In Germany and Sweden, the road infrastructure systems on a national level are predominantly owned and funded by public sector organizations and are specifically regulated. In both countries, government-owned institutions (*Trafikverket* and *Autobahn GmbH*, from 2021) are responsible for the management of national highways. The energy market in both countries, on the other hand, is dominated by private companies and controlled by EU legislation. Hence, electricity is a regulated market that enables non-discriminatory network access for every market player, despite the appearance of monopoly-like structures in some areas with strong and traditional local players.

According to the current situation in Germany and Sweden, it is not clear whether an ERS would be legally treated as part of the road system and fall under road legislation, or as part of the energy system falling under energy legislation. It is, in fact, a hybrid. How this regulatory hybrid will be handled is an issue of crucial importance in an ERS strategy: the legal positioning of the ERS in the regulatory framework will have a significant impact on possible business models for ERS operators.

Furthermore, when shifting the energy provision for road transport from a “station-based” to a “system-based” approach, new problems of acceptance are likely to emerge. Because the ERS implies a mandatory dependency on public infrastructure for charging, a potential issue might be that the public sector becomes too involved in the private transport market. A new competitive situation might arise between a government-owned or funded ERS serviced by natural monopoly-structured power grid companies and the private sector-organized petrol firms. Petrol firms might further expand into the electricity and charging market which could lead to a situation where governments cannot subsidize the ERS without the risk of state aid allegations from the petrol firms.

In summary, organizational and regulatory limitations constitute some of the main challenges in the implementation of an ERS. An ERS as a network-structured and system-based model can only be implemented in the market if the various sub-markets (road, energy, truck operations) are addressed using different approaches and degrees of regulation. This situation calls for market structures and mechanisms that work well in network-based surroundings.

2.2 Success factors for commercial initiatives of an ERS

The initiative for implementing an ERS could be an outcome of a political strategy or it could be based on a commercial business opportunity. These two elements may also follow each other over time. The first strategy, referred to as “policy push”, is dominated by public activities: the public sector tries to promote the deployment of a new technology in order to reach superordinate targets like reducing CO_2 emissions. In the second case, referred to as “market pull”, technology implementation takes place via an emerging market demand. Depending on which market is the starting point, the implementation of the ERS will be set up based on different arguments.

In *situation 1* depicted below, the actors in the transport market act as initiators, and request new (ERS) vehicle technology. Consequently, this demand influences the truck manufacturers’ strategic decisions relating to their product portfolio and the developments in the infrastructure and energy markets.

Crucial for the actors in the transport market (i.e. the road freight carriers) are the reasons why they should undertake such initiatives. In road freight transport, efficiency and profitability are a top priority because the transport market is dependent on demand from trade and freight forwarding: decision makers in trade and freight forwarding, e.g. freight procurement managers, primarily require low prices for transport solutions and are used to negotiating with different carriers for the lowest available rates. As carriers are dependent on attractive order placements, price competition in the transport market is quite high.

Thus, carriers require trucks that are cost-efficient since their low margins (compared to those in the manufacturing industry or other service industries) reduce their ability to take greater risks or make investments. In consequence, carriers will adapt to new technologies like an ERS only if they result in a short-term cost advantage compared to conventional vehicles (see Figure 3).

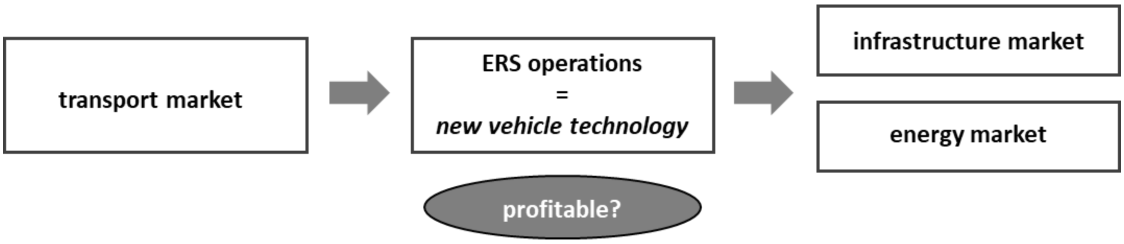

Figure 3: Situation 1: (Internal) Market pull out of the transport market

Own figure

At present, it seems unlikely that an ERS could be implemented purely through such a carrier-driven market-pull scenario, since there are a number of cost dependencies, e.g. additional technology-driven costs (pick-up, hybridization), uncertainties concerning energy prices (net prices, taxes, subsidies), and necessary changes in trip planning and truck dispositions (due to operating ranges) that might result in additional costs rather than cost savings for shippers.

Therefore, a different business model view is currently dominant in ERS discussions. This starts from the opposite viewpoint. Looking at an ERS from the perspective of the energy market, as depicted below in *situation 2*, reveals a completely different form of market pull compared to the first situation, even where the question of profitability is also inherently crucial in this situation (see Figure 4).

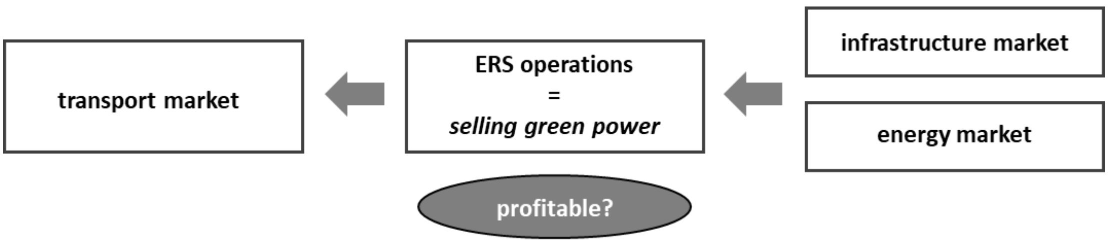

Figure 4: Situation 2: (Internal) Market pull out of the energy market

Own figure

From the energy market's perspective, the deployment of an ERS contributes primarily to a climate-friendly environment, and opens up new business opportunities for actors in the energy market to sell more electricity and network services. Today's discussions on an ERS are mainly driven by this view, conceptualizing the ERS as a possible way to achieve carbon neutral road freight transport and not primarily as a possible competitive advantage in the transport market. In this sense, sustainable energy pulls the development of an ERS, and – vice versa – pushes the road transport market into an ERS.

“Green power supply” has evolved into an important business segment in the electricity market and energy companies involved in this business are in an ongoing search for new business areas and opportunities as markets grow and competition becomes stronger. An ERS could be such a new business area since, at present, it seems to be the primary way forward for electrifying long-distance heavy truck operations. For this reason, important political efforts to introduce an ERS are supported.

CO_2 reduction is accepted as an overall political objective resulting from the Paris Agreement negotiated in 2015 and, as a consequence, carriers have to be pushed to use electricity instead of fossil fuels. Indeed, this change is not possible without the appropriate technical infrastructure (i.e. power grids and catenary networks on the motorways) and without companies producing and selling green power. Thus these fields of action (or markets) become important intermediaries for introducing an ERS.

By using the market model and its different perspectives, the main differences between the transport market’s attitude towards an ERS (profitably operating ERS trucks) and the energy perspective (profitably selling electric energy for the ERS) become obvious. Since neither of these markets can be ignored, the implementation of an ERS will have to be supported and pushed by moderating actions which balance the different sub-markets’ business perspectives. This is necessary, in particular, within the transition stage and during the first pilot projects. Only in the later stages, encompassing larger demonstration projects, is it possible for the real economy of ERS operations to be evaluated without methodological restrictions. At full-scale market deployment, the system has to be viable and function according to market principles (see Table 1).

Table 1: Perspectives on ERS development

Perspective	Phase 1	Phase 2	Phase 3	Phase 4
Temporal perspective	Transition	Pilot projects	Demonstration projects	Deployment projects
		1 to 2-year projects	1 to 2-year projects	40-year investment
Structural perspective	System of systems	Radical innovation	Sociotechnical experiment	Sociotechnical change
Actor perspective	Business challenges for multiple stakeholders, scenarios from a user perspective	Business model dilemma for incumbent firms	Empowerment dilemma for new entrants	Chicken-and-egg-dilemma for policy makers

Source: Tongur (2018), p 59 (headlines adapted)

2.3 Defining the role of the government

Like any innovative transport solution that is based on a simultaneous reconfiguration of infrastructure, vehicle, and power supply, an ERS will require public support in its early development stages. Public support opens up new possibilities for market entry, but also brings in additional goals that should, at the same time, be kept in mind. Unlike for private interests, the public sector objectives relating to an ERS are not solely focused on operational efficiency and businesses operations, but primarily on overall socio-economic and environmental aspects: an ERS is considered a plausible solution to decarbonize road freight, thus contributing to the achievement of climate policy goals such as decarbonization. This means that, for the public sector, the actual reduction in emissions will be of principal interest when it comes to judging the success of an ERS.

In numerous current projects on ERS development, different public measures are used to positively support the market success of an ERS. As an example, technical research focusing on ERS truck equipment (e.g. pick-up devices for different power transfer technologies, DC-DC converters, power metering, and access control) is currently supported by government agencies in different projects in Sweden and Germany.

Subsidies are also being granted for research on ERS infrastructure (e.g. power rails, catenary systems, power transmission) and on possible implications for their surroundings (e.g. planning approval, risk of accidents, bird flight, visual impairment).

A third area of current public funding concerns truck operations on the testing fields. Financial incentives for acquiring ERS trucks are given in order to reduce the costs of truck operations to a level similar to operating a modern diesel truck. In general, providing subsidies or grants for investing in electric trucks and operating them is seen as a more effective way to establishing an ERS when compared to supporting the manufacturers in offering ERS vehicles at an equivalent price to diesel trucks.

Through subsidies and grants, a policy push could support and establish ERS deployment. However, this is considered an intervention in the competition of the transport market and thus funding institutions should ensure there is no prohibited state aid involved in such measures. Thus, the superordinate motivation and legitimation (i.e. “CO_2 reduction”) should remain essential and anti-discrimination rules have to be respected, especially if this kind of support is extended over time to also enable demonstration projects or even market deployment.

The justification for subsidies for an ERS is that they support a process of “incremental change” in the transport market, although with shorter time frames than would otherwise be the case. The main principles of the market (i.e. negotiating for contracts with shippers or freight forwarders through price), however, remain unchanged or change only very slowly. Thus, carriers have the opportunity to change to an ERS but are able to keep their established business procedures. However, this possibility should be limited in time so that the transport market maintains its innovative power.

Considering a (more) regulated infrastructure and energy markets, a policy push must enable and regulate the development of new market opportunities in the energy sector. An ERS opens up a completely new business area that promises relatively high operational profit margins. This might radically change the energy market as these new technical facilities for roads are being developed and implemented with some possible new business models for energy distribution, sales, and storage. Subsequently, through ERS, the energy market might become a developing market for new kinds of grid owners and providers, e.g. road or toll operators that could potentially displace the established companies through price competition.

Ultimately, this means that policy push must be able to support and regulate quite different market principles if an ERS is to become a sustainable market success with a successful market deployment. On the one hand, reducing costs could address the very limited margins in the transport market which make financing more expensive vehicles difficult for truck owners, thus supporting incremental change. On the other hand, enabling new market opportunities could address the relationship between transport, energy, and infrastructure, thus fostering regulated situations usually characterized more by "radical change" (see Figure 5).

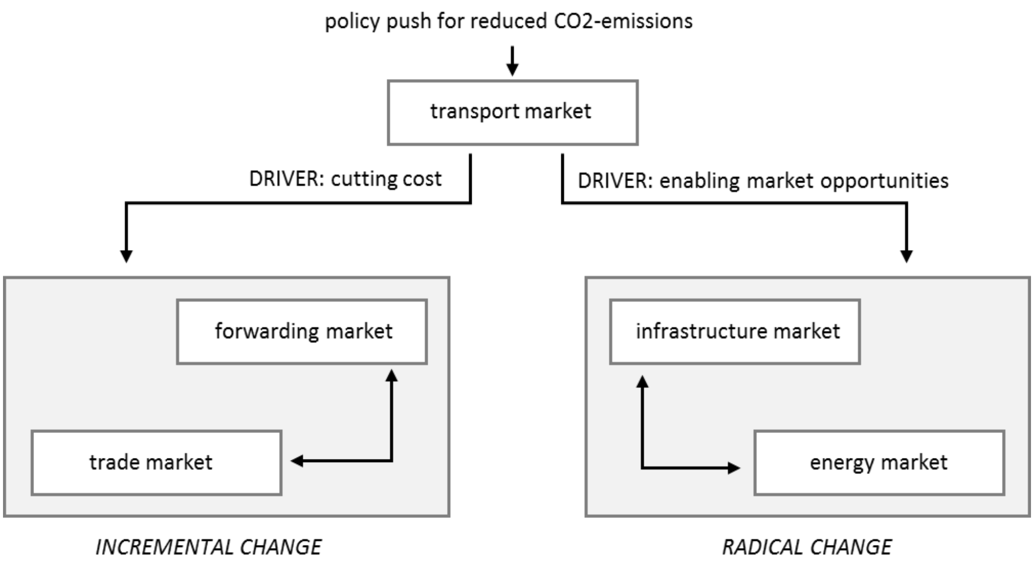

Figure 5: Policy push for ERS introduction

Own figure

In addition to logistics and energy, it is also appropriate to take vehicle manufacturers into account when developing a strategy for public support for an ERS. Focusing solely on either the energy market's needs or the logistics market will ultimately be unsuccessful. Since an ERS is a system-based approach, all market actors and the interactions between them must be taken into consideration. For e.g.:

- For *ERS vehicles*, in addition to companies required to produce ERS trucks or components on a large scale, there are also operator models for users in order to ensure the financing of an ERS truck is as simple, and thus as attractive, as buying a conventional diesel truck.

- For *daily vehicle use* in regular operations, the overall flexibility of trip planning is crucial for truck operators. This means that either a dense ERS network on the roads is needed to ensure that operation ranges are almost never exceeded, or that additional on-board energy systems are standard, i.e. batteries, LNG or fuel cells.
- For the *energy market*, buying and selling electricity is primarily an issue of managing grids, consumption measuring, and the calibration of electric meters. Based on the regulatory requirements in the electricity market, more specific metering and charging systems are considered necessary. For truck operators, however, a success factor for using an ERS could be to keep the billing system as simple as possible, for e.g. through a simple surcharge on road tolls that covers the energy costs.

Finally, the *speed of market change* creates a crucial challenge in a system-based reorganization of the road transport market. While the deployment of an ERS is dependent on network effects (economies of scale and density), and thus needs rapid investment in a core network and the sale of a large number of ERS vehicles, the freight sector prefers continuous development and incremental change, respecting investment cycles in trucks and equipment. For this reason, the question of whether the system (infrastructure, equipment, operations) should finance itself, or to what extent external financing is possible to overcome the restrictions of the existing business models, again plays a decisive role. Ownership and the financing of ERS infrastructure, in particular, will be crucial here. These questions are further discussed in the following chapters.

3 Organization and financing strategies

3.1 Organization of the transport sector

At its most basic level, a traditional road transportation system can be structured into three main subsystems: (1) the physical road, (2) the vehicles utilizing the road, and (3) the fuel provided for the propulsion of these vehicles. In addition, there are three main activities for each of these components: (1) they need to be funded (including produced and procured), (2) they need to be owned, and (3) they need to be operated. Thus, we get a 3x3 matrix where each of the components is related to each of the three activities (see Figure 6).

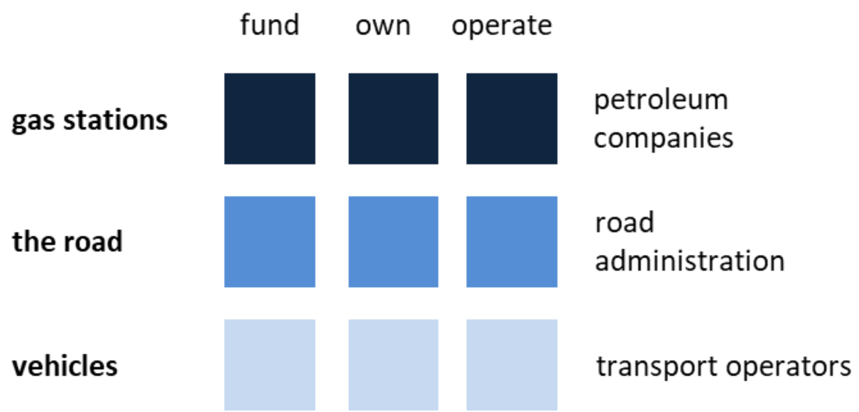

Figure 6: A generic ownership configuration model for a traditional highway

Own figure

Figure 6 also shows the typical division of labour in a traditional public highway in Germany and Sweden serving gasoline or diesel cars, trucks and buses. It includes the public road administration, the various private transport operators (carriers) driving the vehicles on the road, and the private petroleum companies providing the fuel infrastructure for the petrol stations serving the vehicles. In this traditional configuration, the road is funded, owned and operated by a public agency, while the petrol stations and vehicles are organized and financed by private sector actors.

Globally, however, there are many examples of privately operated roads or various types of private-public partnerships, where a private (or public) company performs one or two of these main activities. Such a road could be operated under a concession where the operator’s revenues could be based on road tolls (i.e. traffic volume) and/or road quality (i.e. the fulfilment of functional requirements). Another common form of shared responsibility is between the actors providing the vehicles and the actors using the vehicles. Car rental, leasing, outsourcing of transport operations, or “mobility as a service”, are examples where the funding and ownership of the vehicles are separate from driving the vehicles. For e.g., many truck manufacturers currently offer trucks for leasing.

Consequently, the actor that funds a subsystem, does not necessarily have to be the same actor that owns or operates it. As ERS technologies are introduced into the road sector, many of the established roles are challenged. Different ways of organizing the deployment and structuring the division of responsibilities between the involved actors will determine the basis for potential business models in the future. As shown in Figure 7 below, the current and "old" division of labour in the road market is altered into a new structure with new players and functions.

Figure 7: The configuration model applied to an ERS
Own figure

3.2 Basic business models for an ERS

In principle, there are two basic alternative business models related to the deployment of an ERS: (1) an ERS as a classic highway and (2) an ERS as a service. These two basic models are highly simplified; in reality, there is also an extensive number of variants and intermediate versions. The basic models should, however, be understood primarily as archetypes, providing a conceptual basis for a common understanding of how the ownership configuration of an ERS frames the conditions of possible business models (see Figure 8).

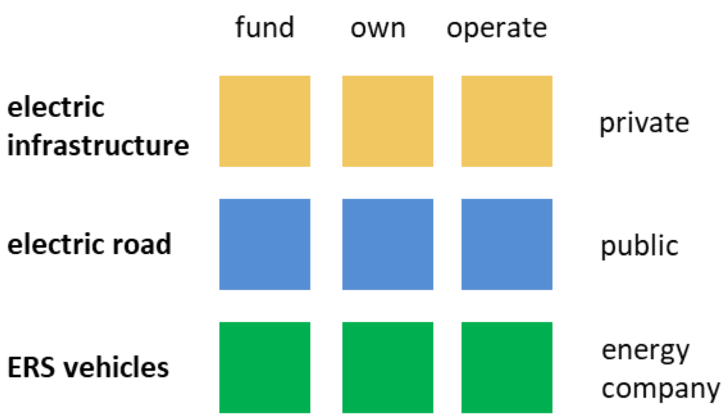

Figure 8: An ERS as a classic highway
Own figure

Both the two models, (1) *an ERS as a classic highway* and (2) *an ERS as a service*, follow the division of labour of the traditional highway described above. The difference to the traditional highway is that the road subsystem is simultaneously an energy system: it is electrified and contains the charging equipment and the ERS technical equipment (e.g. tracks, induction loops, or catenary systems) that need to be installed in the road area.

According to the more classical model (1), a single actor (e.g. a public road administration) funds the construction and installation of the electric road, owns the road, and is responsible for road operations, while the electric infrastructure is provided by an energy company, and the rest of the system is organized by private actors (see Figure 9). The actual construction, maintenance and operation of the ERS could also be provided by procured service providers, i.e. usually private sector corporations.

In the case of model (1) *an ERS as a classic highway*, access to the road is generally free and therefore any vehicle that is technically compatible could use the road and simply pay the energy bill afterwards.

In many countries, however, the freight transport operators pay some sort of obligatory fee or tax in order to have the right to use the road. This takes us to model (2) *an ERS road as a service,* where access to the road is only available to customers who pay for access. In this case, road access is limited, as in the case of the US turnpikes, motorways in, for e.g., France, Italy and Spain, or bridges and tunnels financed and constructed through private-public partnerships. Consequently, the value capture principles differ between the two models. Whether the cost of the ERS should also be financed by such obligatory payment facilities is something that requires further exploration.

The transition to a situation where the transportation service, including the infrastructure, vehicles and energy, is combined into one service might be furthered by the change brought about by ERS technologies. This could be the case, for e.g., as a result of increased capital expenditure for vehicles while energy provision for the transport is reduced. A combination of long-term and short-term variable cost elements transferred to the fee structure could facilitate the transition to the new market situation. There are a number of parallels in different subsections of the transportation market from where inspiration for further elaboration of these possible models could be drawn. In more advanced models, the entire system could be rearranged to become primarily a service offering to the end users, such as mobile phone services.

Whether this is a development that is directly dependent on the introduction of ERS technology, or part of a general trend in transportation markets, is difficult to say. Regarding the more specific organization and financing of the ERS infrastructure, an analysis of the ownership and financing of the core parts of the system is one of the most important aspects.

3.3 Implications for business models

How the system could be configured is restricted with respect to various laws and regulations, as well as national traditions of infrastructure access and ownership. Nevertheless, the design of the system will have a significant impact on the possible development of specific business models for the involved actors.

In Table 2, the two main configuration models are compared with respect to the three dimensions of value proposition, value creation, and value capture. Of all the models, value capture is based on the existence of an ERS road with various kinds of products and services as extensions or “add-ons”. Three additional possible models are also described, where the service content of the ERS provision is increasingly combined with other services.

Table 2: Two basic business models for an ERS and some explorative alternatives

Value proposition	Value creation	Value capture
ERS as a classic highway	Provide an ERS road with open access	Taxes (indirect)
ERS roads as a service	Provide an ERS road + exclusive ERS and/or access to ERS roads	Road tolls/fees
ERS transport as a service	Provide an ERS road + ERS transport	Sales of transport services
ERS vehicles as a service	Provide a road + ERS vehicles "for leasing"	Leasing fees
ERS as a service purchase agreement	Provide a road + ERS vehicles "for free"	Subscription and/or pay per use of the ERS vehicles

Source: Own table

3.4 Financing and ownership alternatives

In Germany and Sweden, governments, regions, and municipalities predominantly act as owners and financers (using taxes or fees) of the infrastructure, while actors in the private sector provide transport services as businesses in the commercial market. This situation is depicted in Figure 9 below. In the upper boxes, ownership is either public (right) or private (left) and utilizes some kind of (mandatory) fee or tax-based financing model to cover its costs. Fees might be charged for a specific road stretch or (at least in theory) for a system of roads. The right-hand model is the model most used for providing road infrastructure. In the upper left box, procured services for the maintenance of the road or public-private partnership (PPP) structures can be found.

In the lower boxes the ownership alternatives are also private (left) or public (right), but financing is provided by the users only, normally based on prices set by the markets. The fossil fuel market and the vehicle market are two such examples. Service concessions with (at least to some extent) market-set prices could be an example in the lower right box.

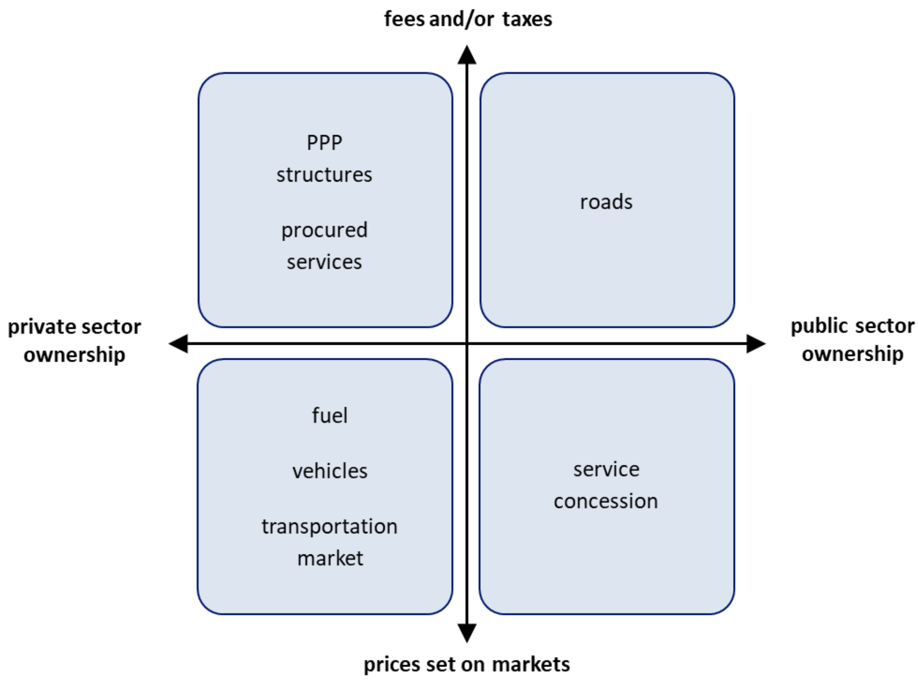

Figure 9: Financing and ownership model for a conventional road transportation system
Own figure

As an ERS is introduced, a number of structures might be altered, as discussed above. Fossil fuels are exchanged for electric power, ERS-compatible vehicles must be introduced, and electricity power grid and power supply companies might have to take on new roles. As illustrated in Figure 10, the introduction of an ERS does not, however, change the basic roles or financing measures in the road transportation and infrastructure market. ERS roads (i.e. the road plus ERS technology for the transmission of power to vehicles on the road) can be provided by the public sector with fees/taxes as the financing source, or with similar financing in PPP structures by private sector providers/owners. As an alternative, the ERS function can be provided as a service concession based on the public sector-owned road, probably with some regulated price.

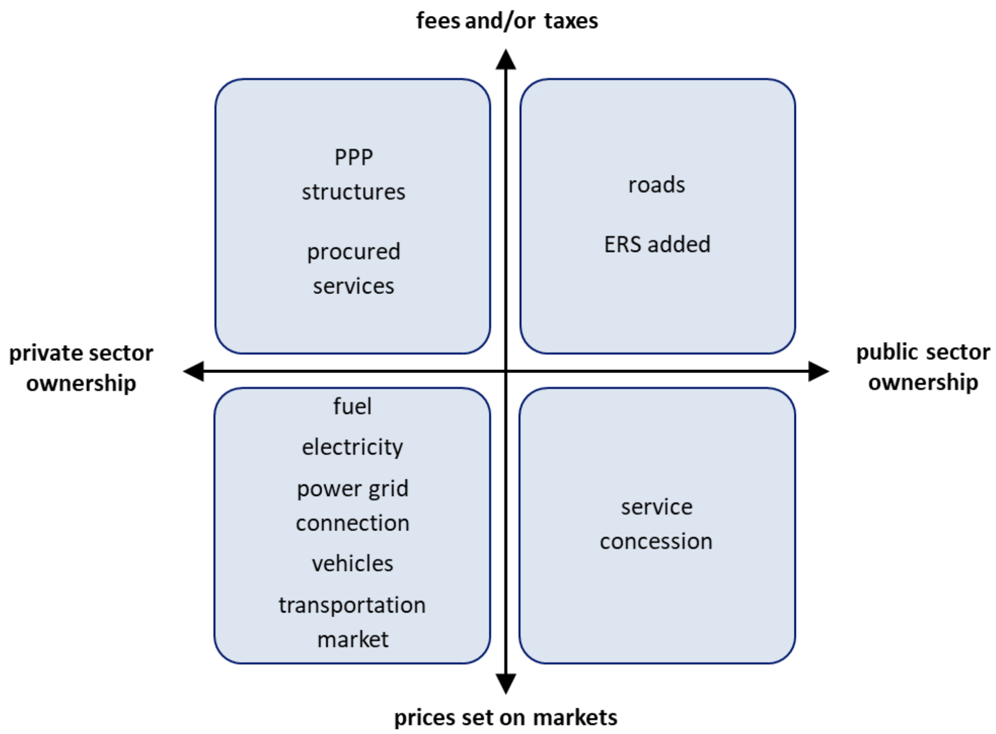

Figure 10: Financing and ownership model for an ERS
Source: Own figure

The major change in the lower left box is that fossil fuel is exchanged for electricity and power grids. The entire fossil fuel infrastructure and distribution system might thus, in the longer term, become obsolete in relation to the electricity infrastructure and distribution system. This, however, would be an operation that would be carried out in the privately owned, market-financed sector of the economy. Vehicle producers would also have to convert their operations to provide ERS-compatible vehicles and the vehicle users would need to learn to use the new technology. Again, this would include transformations in the private sector.

As discussed earlier in the paper, the basic functioning of the transport market will, however, not be affected by the transformation to an ERS. Supply and demand for transportation services will still govern the configuration of the market. The relative prices of electricity and vehicles will decide whether a new competitive situation will prevail for road transport in relation to other transport modes. Taxes set by the public sector could be used to influence the market equilibrium, as is currently the case.

The change process involved in implementing an ERS will likely be challenging for a number of actors in the transportation system. Vehicles might initially be more expensive to buy, while operation costs might be reduced. The general development of digital services might induce changes in the operation of the transport market, for e.g. when it comes to logistical planning and flows in the system. It can be expected that the public sector, in order to enhance the implementation of an ERS, will adjust taxes that affect incentives for market actors and/or take on a more active role as owner/financer of some parts of the transportation system.

In combination, this could lead to a situation where either one market player offers a combined solution, e.g. access to infrastructure and vehicles as a service, as demonstrated in Table 2, or even more advanced models might evolve. It could also lead to a situation where the public sector takes on a wider role in the road transport infrastructure system, including an ERS, thus transforming this system to a configuration more closely resembling the railway system. These different possibilities, however, would have to be supported by considerable changes in the regulatory settings in the EU as well as in most member states. Without excluding this option in the long term, this seems less likely in a short-term perspective. Consequently, the development needs to be closely monitored over time in order to further analyse the enablers and obstacles to a transition.

4 Business model implications for different actors

4.1 Roles and actor relationships in an ERS[1]

Figure 11 shows a future possible organization of an ERS based on the overall structure of the roles that are expected to be included in the system. At the centre of the diagram is a schematic image of the structure of the electric roads market that was suggested in a report to the Swedish Transport Administration in 2019.[2] This chapter is based on that report and adapted to an international setting.

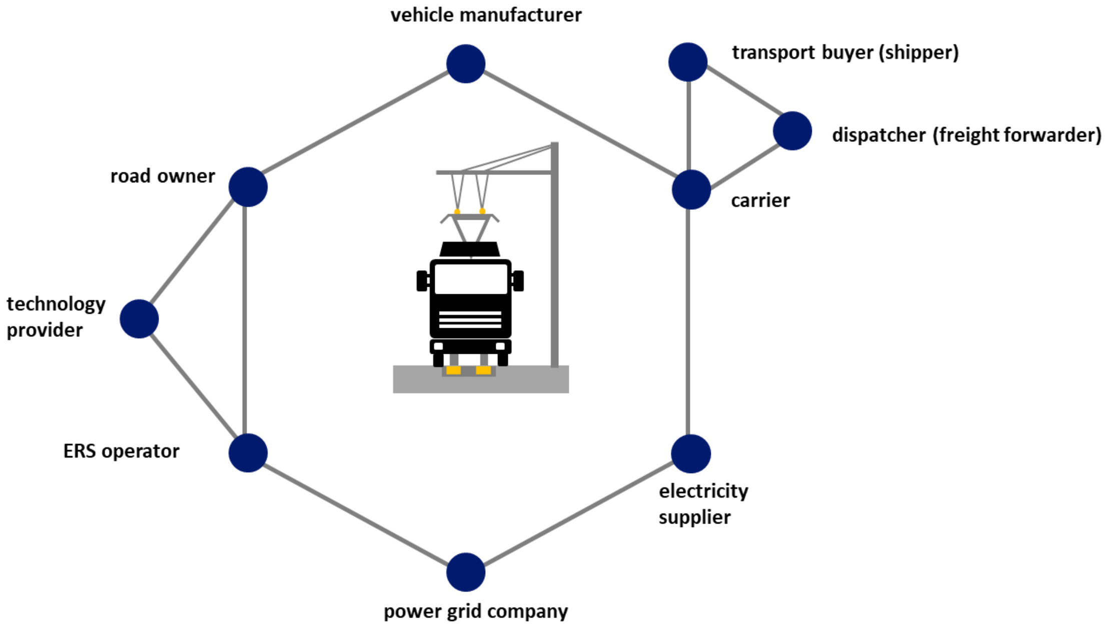

Figure 11: Roles and actors in an ERS

Source: EY Sweden and The Swedish Transport Administration.

The above market sketch depicts a “hexagon” showing the network of actors, the electricity grid, grid providers, and the grid connections to the ERS in the road area. Vehicles adapted to ERS technology should be provided, as well as a number of services and functions, including financing and maintenance. The actors and their roles are discussed in the following paragraphs. Subsequently, a discussion on the relationships between the actors and the value they provide is included.

Road infrastructure manager

A road administration body (or similar) in each country generally has a statutory responsibility as infrastructure manager of the public roads, including the major national roads likely to be electrified. Alternatively, a public entity has procured the road services in the form of a concession and carries out many of the duties of a traditional road administrator. The road infrastructure manager is in direct contact with mainly two actors within the ERS – operators

[1] This section is, to a large extent, based on the report mentioned in Footnote 2.
[2] Roles, actor relations and risks in the electric roads market, EY Sweden for The Swedish Transport Administration, 2019.

(a future role that was suggested in the EY/Swedish Transport Administration report) and electricity grid owners.

The relationship with ERS operators follows from their activities in the road area where the road administrator is normally responsible for operations, maintenance, and matters regarding, for e.g., accessibility. Core elements of the specific road administrator's relationships with electric road operators include operational reliability, monitoring, and maintenance of the ERS, since these roles can affect the road administrator's areas of responsibility.

The road infrastructure manager is also likely to have a relationship with electricity grid owners, as there will be a physical interface in the electric installation between the road area and the electricity grid infrastructure. During the early stages in the deployment of an ERS, it is likely that the road administrator will be heavily involved in the facility as owner of the electric road infrastructure in the road area.

While the responsibility of road infrastructure management is unlikely to change, and the government, via the road administrator (or equivalent), will continue to be the formal manager of road infrastructure for electric roads, there are several different possibilities for the roles in the ERS for providing electric energy. Both public and private ownership and financing of these different parts of the system should be considered.

Operators

At a comprehensive level, the hypothetical operator role can be described as the connecting physical and/or operative link between road, electricity, vehicles and infrastructure. The obvious motivation for businesses to take on the role of operator is to become involved in a completely new market with new business opportunities and revenues that had not previously existed. The incentives for participating in the early stages of this development would be to build knowledge relating to this emerging market and to assume a market position. There may also be incentives for operators to own the electric road infrastructure, since this can lead to a long-term, green investment with stable cash flows over time. However, various different organizational and financial solutions are possible.

The electricity grid companies, which are supply-driven companies and apply long depreciation periods, can be regarded as potential actors in the operator role and as owners of electricity road infrastructure. Telecoms companies, (fossil) fuel actors and electricity suppliers possess knowledge and experience that could be useful to an operator. Neither is it unthinkable that the state, via the road infrastructure manager, would assume this role.

Electricity grid owners

The electricity grid companies that are responsible for connecting the electric road to the grid will have an important role in the development of electric roads, both during the introduction phase as well as in a more extensive development. The electricity grid owner will interface with the owner of the electric road infrastructure as each actor's components in the overall electric installation will be physically connected to the other's components. Electricity grid owners could also potentially have an interest in owning the electric road infrastructure for further development of the ERS.

Electricity suppliers

The role of electricity suppliers in the electric roads market will likely be similar to their traditional role in the electricity market, which includes the sale of electricity and invoicing. Relationships can be directly with users or be channelled via an electric road operator. There is also an interface with the actor that will be in charge of measuring users' electricity consumption, either as a part of the operator role or as a separate service. In order to have free choice of electricity suppliers under the general principles of the EU regulations in the electricity market, it is reasonable that users will be given the possibility of choosing their electricity supplier. However, the exact organization of these services is subject to further analysis both at the EU level and in each member state.

Road users

An ERS has the potential to create competitive advantages for users in the form of lower costs and the possibility of positioning themselves as green logistics actors with sustainable deliveries. Lower fuel and maintenance costs for electric vehicles compared with diesel vehicles are considered the main driving forces for getting users to actually use electric roads, both during the introductory phase as well as in the longer term. It is also possible that users will utilize the ERS even if the total cost is the same as for diesel vehicles, but unlikely that they will do so if the total cost exceeds that for diesel vehicles. Subsidies from the government for vehicle owners will probably be necessary during the introduction of an ERS.

Vehicle manufacturers

Vehicle manufacturers' participation in the introductory phase would be reasonably motivated by obtaining early competitive advantages and eventually by gaining market share. In order to manufacture vehicles in time for the start of operations, information about the section of road in question and the development of the electric road along it needs to be provided early, as these factors will affect vehicle specifications. Vehicles need to be ordered within a sufficient time margin, normally of two to three years.

Defining roles and actor relationships

There are several actors that could take on different roles and be part of shaping the future of the electric roads market. These roles have several interfaces with each other that imply various types of business relations, incentives, and challenges. The role of electricity grid owner appears to be one of the most decisive in the structuring of the system, both in terms of responsibility for electricity distribution as well as being a potential investor in and owner of the electric road infrastructure. The involvement of and business opportunities for electricity grid owners will be determined partly by whether electricity grids for electric roads are regarded as concessionary or not – an issue being studied by the Swedish government and many other authorities and governments in the EU.

4.2 Institutional regimes, relationships between the actors, and value propositions

As discussed above, the actors have relationships with each other that are defined by the regulatory regime and the value propositions that each actor has chosen to exploit. The main market spheres that are technically involved in an ERS are transport (trucks), energy (power and grids), and infrastructure (roads). All actors in these spheres, i.e. truck operators or carriers, truck manufacturers, road and power grid operators, electric power producers, and energy trading companies, would call their respective surroundings a "market". Nevertheless, their respective business environments are structured quite differently. In Europe, this is, in particular, a result of different regulatory and legal frameworks within the EU:

- The basic principle of the **transport market** is competition. Competition means freedom to contract between shipper and carrier, as well as negotiating the conditions of contract. This freedom is guaranteed in European treaties (Article 26 TEU, Title IV TFEU), and regulated through national road haulage legislation. Anyone that fulfils the objective market access criteria is allowed to act in the transport market. EU28 currently lists more than 570,000 licenced road haulage companies, of which around 37,000 are based in Germany and almost 15,000 in Sweden (EU 2018). As a result, there is strong competition between carriers.

- The main principles of the **infrastructure market** are based on access rules and terms of infrastructure use (see Chapter 3). Since infrastructure capacity is limited and roads are expensive to build, it is necessary to organize access and financing. Road tolls are one example. Based on a common EU regulatory framework (Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures), the respective rules are subject to national road legislation. This includes not only tolls but also the right to privatize infrastructure or establish public-private partnerships for building, financing, and operating roads.

- The **energy market**, or electricity market in the case of an ERS, is characterized as a regulated market according to Directive 96/92/EC concerning the common rules for internal markets in electricity. The number of actors is significantly lower than in the transport market. Currently, there are 43 transmission system operators for electricity across Europe and some thousand distribution network operators. For e.g., the number of distribution network operators in Germany is 890 and about 170 in Sweden. The number of access rights for companies that want to sell or trade electricity is higher: in Germany about 1,400, but again, significantly lower than the number of road transport companies. Nevertheless, there are many more companies selling electricity than companies operating petrol stations and selling fossil fuels.

Open competition in the transport market, the almost closed markets for infrastructure, and regulated access to the electricity market contain completely different principles for structuring markets. Assigning the wrong principle to a market by implementing measures that are focused on the "wrong" market environment (e.g. addressing the transport market through measures that have been developed for the energy market) can lead to market failure, and, as a consequence, a failure of the ERS in general. Thus, for each step towards the deployment of an ERS, a clear orientation on which market is the current focus and which market principles are common is essential.

If the acceptance of an ERS is to be achieved in the transport market, actions have to respect the rules of this strongly competitive market. Measures that might work perfectly in closed or regulated markets (e.g. the compulsory use of an ERS) might not be transferable to the highly competitive transport market, or will require fundamental changes in market organization, and thus possibly also, in advance, in the European treaties. If not, competition-based measures like CO_2 pricing would appear to be more meaningful as these assume the existing market structure and companies can respond to them in a common way.

Table 3 shows some examples of the relationships between the individual actors and their value propositions. The table does not claim to be exhaustive. Although the relationships are displayed in one direction only, there can, of course, be double-sided relationships between the actors. To some extent, the value proposition is not always as clear-cut as suggested in the table. In the comments column, the risks and opportunities related to the different value offerings are described.

Table 3: Relations between actors and value propositions

"Pairs" of relationships	Drivers (Value propositions)	Comment – opportunity and risk
Vehicle producer -> vehicle owner	Reduced total cost of ownership, flexibility	+ lower operating costs - higher purchase price
Vehicle owner -> transportation customer	"Greening"/cost reduction	+ sustainable transportation - risk of higher costs unless subsidies introduced
Vehicle owner -> electricity provider	Cost reduction, flexibility in service	+ new market for electricity provider - risk of new taxes being introduced
Electricity provider -> power grid provider	Increased sale of electricity	+ increase sales - high grid fees could be a risk (low volume initially)
Power grid provider –> ERS operator	Means for providing long-term stable profit	+ new business opportunity - long legal processes could delay expansion - risk of low traffic volumes
Technology provider -> road agencies and operators/vehicle owners	New market, enabler for electrification of transport sector, greening	+ new business opportunities - technologies could fast become obsolete
Infrastructure manager -> all other actors	Reduce CO_2, cost reduction, reach policy goals	+ contribute to reaching decarbonization goals - low utilization due to "wrong" technology solution

Source: Own table

It is important to further explore the relationships between the actors in the electric road market, the value offers that they make to other actors, and the opportunities and risks relating to their operations. Ultimately, this will affect the willingness and possibilities for different actors to actually assume new roles in the electric road market. This should be the focus of future analytical efforts in each specific country when designing the ERS.

5 Conclusions and findings

A perspective on business models for an ERS reveals how the deployment of an ERS affects the value proposition, value creation, and value capture of the actors and markets involved in, or influenced by, the system (see Figure 2). In addition, it encompasses how the business model of each actor interacts with, contests, and/or complements the other business models in the system. However, business models do not emerge in a vacuum. Rather, they are contingent on a number of important, contextual antecedents.

Based on this basic understanding of the prerequisites surrounding a system such as road transport and road infrastructure in their past and current structures and, for e.g., the markets for infrastructure, energy, and vehicle procurement, a number of conclusions relating to the business model development for an ERS can be made. These form the core result of WP 2.2 within the CollERS project and are presented below.

#1 | While the challenges of station-based systems, such as petrol stations for alternative fuels or electric charging points, are primarily concerned with replacing and overcoming propulsion technology, a major challenge for the implementation of an ERS also includes organizational, financial and more complex regulatory issues based on energy-road interactions.

While an ERS can be seen as a system-based approach based on dynamic charging, most alternative technologies, such as e-fuels, hydrogen fuel cells, or static electric charging in combination with large batteries, rely on a station-based energy supply system similar to today's supply system with petrol stations at the roadside. An ERS, however, can be used for charging and driving at the same time. The introduction of an ERS requires several changes in the interaction between existing market structures which might, without countering regulations, result in unregulated monopoly structures for roadside electricity grids, for the delivery of electricity, and for ERS vehicle procurement. According to EU law, through the enactment of an appropriate regulation, electricity could become a competitive service allowing for price competition, even if the electricity grid and electricity are combined in the market.

In comparison, the introduction of a hydrogen propulsion system would not necessarily require such regulations in the market structure as it is a station-based system. Refuelling of vehicles, however, would still be linked to the same operational disadvantages (i.e. standing time resulting in non-productive vehicles) as for diesel trucks. The electrification of the road transport system based on charging points would be more similar to the present structure but might require geographical reconfiguration of the charging points if the ranges of the vehicles change. In the same way, an ERS network must be planned so that the ranges of the vehicles are sufficient for "the first and last mile", i.e. before entering and after leaving the electric road in the direction of the destination.

#2 | Different sub-markets in an ERS work in different ways, but ERS operators could establish new links between them.

It is crucial to understand that trade, forwarding, transport, infrastructure, vehicles, and energy constitute different sub-markets which will be affected in different ways by the introduction of an ERS since their logics of value creation are different. As a consequence, each sub-market has to be individually prepared for an ERS and the effects of those measures supporting ERS implementation might be different. Thus, different markets require different incentives for the successful introduction of an ERS.

In this report, we have shown how a market model perspective can be used to understand how the various sub-markets are affected through the introduction of an ERS. This enhances the understanding of how new business and financing models could be introduced to support the deployment of an ERS.

Thus, a successful political strategy for introducing an ERS must include an understanding of the transport market in detail in order to successfully support a “market pull” environment for an ERS. Consequently, the role of ERS operators, in either the public or private sectors, is crucial since they are responsible for establishing the links between the different sub-markets.

#3 | Policy push to reach CO_2 targets could conflict with the logics of the transport market.

The road transport business is strongly focused on cost efficiency, since the carriers are subject to strong competition and cost pressure from trading companies and shippers. The transportation market will not change its basic principles solely due to technological changes in propulsion technology. It will continue to function according to competitive principles. Within such highly competitive environments, prospective users (i.e. carriers as users of trucks) must be offered at least cost parity compared to current propulsion systems and compared to other modes of transport. An ERS that leads to increased transport costs in a situation where alternative, less costly solutions are at hand, is likely to fail.

There are numerous possible measures to support this, primarily during the start-up phase, but also during regular operations. These could include public subsidies for ERS trucks, reducing taxes on electricity, excluding electric cars and trucks from road tolls, increasing fossil fuel taxes, or introducing CO_2 taxes and/or emission trading systems into the market. Direct regulation of CO_2 emissions is another such measure together with direct bans on the use of CO_2-emitting vehicles.

The appropriate mix of measures in each country has to be aligned with the established prices of electricity and fossil fuels in the respective markets, since these may vary a lot, also within neighbouring EU member states.

At the same time, some of these measures could distort the competition. Hence, they are primarily appropriate during the market launch of ERS. When moving on to regular operations, supporting measures must be replaced by other measures that fit with the organization of competitive markets, such as the transport and freight forwarding market.

In a situation where fossil fuels have been phased out, new cost structures in the transport market may be established where higher expected capital costs could be balanced by lower operating costs. This might allow for the regaining of lost tax income for governments stemming from subsidies during the market introductory phases. At all times, however, “policy push”-originating measures must be aligned with the prevailing short and long-term market conditions.

#4 | The need for the fast and substantial decarbonization of the transport system runs counter to the long-term evolution of the system.

There is a need for a substantial and fast reconfiguration of the transport market in order to reduce CO_2 emissions which might run counter to long-term market development. While an ERS needs positive network effects (economies of scale and density), and thus a rapid investment in a core network, the freight sector normally evolves following a more continuous path of transformation and more incremental change, respecting commercial investment cycles that are longer due to the low margins and therefore low investment volumes in transportation equipment. This might require support measures enabling a more rapid implementation of new vehicles, for e.g. tax regulations that allow shorter depreciation periods than normally accepted.

#5 | The question of whether an ERS is conceptualized as part of the (public) road system, or the (private) energy system, will fundamentally affect the market.

The need for a systemic reorganisation through an ERS might entail a need to change the framework conditions, depending on the initial situation. In Germany and Sweden, planning, construction, and maintenance of roads are a public task. All works are carried out by the government, by government-owned companies or by private corporations contracted by the road agency to provide projects or services. The provision of major transport infrastructure assets is organized as a state monopoly (including funding and ownership) and is specifically regulated. On the regional and local levels of the system, other divisions of responsibility prevail, with local government and private sector responsibility for road infrastructure.

The energy market, on the other hand, is dominated by private companies, according to EU legislation, and is regulated with the aim of enabling non-discriminatory network access for every market player despite the existence of geographically-defined monopoly structures (local or regional electricity grid areas with a single provider), and in some areas, such as the railway sector or major facilities like airports, with one de facto provider. when comparing Germany and Sweden, a similar basic structure in the electricity market prevails, although with a higher number of smaller local grid areas in Sweden than in Germany.

Under the current legal regulations, it is not clear whether an ERS would be legally treated as part of the road system and fall under (public) road legislation or as part of the (private) energy system under energy legislation. It is also unclear how this regulatory hybrid will be handled in the event of a conflict between these two legislations.

Differences will become apparent when it comes to possible fee structures and the content of the services provided. In the road case, the public road agency would control the important aspects of market access and the detailed regulation. In the case of the electricity market regulation being the chosen alternative, supervision by a specific electricity market agency in each country would be a dominant aspect in the market setting.

Discussions are ongoing, both at the national level and the EU level, to better define, from a legal perspective, the categorization of the ERS as either an electricity or a road system. The outcome of these discussions will, to a large extent, set the scene for defining the future business model.

#6 | Different ERS configurations can create new business opportunities for road operators.

The way an ERS is organized has a significant impact on how the introduction and diffusion of the technology eventually plays out. Furthermore, different ways of organizing the deployment and structuring the division of responsibilities between the involved actors will determine the constitutional basis for potential business models in the future. However, there are two archetypes for roads as well as for an ERS, providing a conceptual basis for a common understanding in most market settings that were identified:

- *An ERS as a classic highway:* Access to the road is free of charge and therefore any vehicle that is technically compatible can use the road and simply pay the energy bill afterwards.
- *ERS roads as a service:* Road access is limited and the road is only available to customers who pay for it (road tolls, subscriptions, passes, etc.).

Both models (archetypes) are tightly linked to a specific fund-own-operate configuration. Although they indicate a change from today's road administration principles, this could potentially enable new opportunities.

The reorganisation of the road infrastructure market that will follow the introduction of an ERS will challenge the present actors. Incumbent actors, if they aspire to keep their market presence, must show how they can contribute to the evolution of an ERS and how they can support the creation of business models that ensure profitability over time. With the introduction of an ERS, and in particular in the build-up phase of the system, different opportunities to create new innovative business models arise, especially for actors in the private sector. The incumbents are therefore likely to be challenged in many ways by the development of an ERS. However, depending on how the system will be organized (private/public as well as open/closed), and hence what financing strategies might be most feasible, this will have an impact on whether private sector actors will exploit opportunities for becoming involved in the ERS.

#7 | Different archetypes of business models for ERS-related services can be identified which might enable opportunities for new value creation in the private sector.

There is an extensive number of possible business models as well as hybrids of these models. While electrification as such does not necessarily have to lead to new organizational structures in transport markets, the transformation pressure in the market could lead to such developments. Three archetypes of business models for operating ERS trucks which might evolve were identified in the project, providing a conceptual basis for a common understanding:

- *ERS transports as a service:* The road operator is responsible for all system activities, from the road to the transport operations, excepting the electrical power supply which is the responsibility of the energy company.
- *ERS vehicles as a service:* The road operator is responsible for all functions related to the physical road as well as the funding and ownership of ERS vehicles, while the electric infrastructure is provided by an energy company and the vehicles are operated by the private sector. Through leasing, rental, pay-per-use, or similar contracts, vehicles are provided to the carriers.
- *An ERS as a service purchase agreement:* The road operator builds, funds, owns and operates the road, and, in addition, the road operator also provides and operates ERS vehicles "for free" (or at a subsidized low price) to transport operators that are contracted to purchase (subscribe to) ERS services for a specified period of time.

Again, the models are tightly linked to a specific fund-own-operate configuration. Although they indicate a change to the conventional configuration of the current transport sector, they could potentially enable opportunities for new value creation in the private sector and hence new business opportunities and consequently new business models to arise.

#8 | Policy measures to enable business model development for an ERS should be diversified and target all actors involved.

Political measures for the implementation of an ERS in the early market stages should be designed in a way that meets different needs. The sole focus on either the energy market's needs or the logistics or vehicle markets, will ultimately be insufficient. As an ERS is a system-based approach, multiple market spheres must be taken into consideration:

- For **ERS vehicles**, in addition to the companies required to produce ERS trucks on a large scale, operator models for users are required to ensure that the financing of an ERS truck is as simple, and thus as attractive, as buying a conventional diesel truck.
- For truck operators to support **daily vehicle use** in regular operations, the overall flexibility of trip planning is crucial. This means that the system should be configured based on either a dense ERS network on the roads to ensure that operation ranges are almost never exceeded or an additional on-board energy system, i.e. batteries, diesel or hydrogen, and thus a hybrid vehicle, combined with more charging points.

- For the energy market, **buying and selling electricity** is primarily a question of managing grids, measuring consumption, and the calibration of electric meters. Based on the regulatory requirements in the electricity market, more specific metering and charging systems would appear to be necessary.

- For truck operators, however, a success factor for using an ERS could include **keeping the billing system as simple as possible**, for e.g. through a simple surcharge on road tolls that covers the energy costs. In countries without road tolls, a new billing and metering systems would have to be developed. Electricity market regulations might lead to a need for the specific metering of electricity consumption in each vehicle.

6 Implications for the development of a Swedish-German ERS corridor

In general, the considerations relating to the ERS business models in WP 2.2 are not only valid for a particular stretch, but rather aim for general validity. Nevertheless, specific conclusions for the building of a Swedish-German ERS corridor between Hamburg and Helsingborg can be derived from the results, as explained below.

#1 | Without respecting the specificities of the local markets in the countries crossed by the corridor, the implementation of an ERS is likely to fail.

The transport market in Germany, Sweden and Denmark is basically competitive, as is the general rule in the EU. However, there are national differences, for e.g. in terms and numbers of companies, in the level of competition between carriers, or as it relates to profit margins. The price levels and structures for diesel and electricity also differ according to national tax rates and organizational models.

These specificities in the national markets should be taken into account when planning the corridor. The same applies to the energy market and the number of operators of transmission networks. This means that ERS operators can only be successful if they build up their business in a way that is compatible with the respective market conditions related to transport and energy in all corridor-affected countries, rather than imposing a standardized approach for all countries, including their domestic markets.

Inspiration for the further analysis of the cross-border corridor can be found in relation to the Rail Freight Corridors in the EU. RF Corridor 3, covering Hamburg–Helsingborg should be of particular interest. The challenges concerning interoperability are relatively similar and many problems that apply to an ERS have already been discussed in the rail freight sector.

#2 | Due to different access and regulation principles for infrastructure and energy, there will be no standardized ERS regulation along the corridor.

The Swedish-German ERS corridor is located entirely within the territory of the European Union. However, many regulations that have a significant impact on an ERS (electricity market, infrastructure, freight transport market) rely on EU directives and guidelines and not on directly binding regulations. This allows for national leeway, e.g. with regard to operating ERS infrastructures (public vs. private operators, open vs. chargeable access, etc.), ERS vehicles (alternative means of truck procurement), or the number of concessioned energy suppliers.

These national specificities will not necessarily be a problem as long as all member states commit to the goal of working together to create a working environment for the ERS and its users. An even more important key point is to ensure that the same technical standards apply everywhere. This technical interoperability along the whole corridor (or better, at the EU level) is even more important than identical business models in all states.

#3 | Individual priorities in decarbonizing road freight lead to country-specific balances between policy push and market pull.

Since the deployment of an ERS requires a shift in the entire system (new vehicles, new sources of energy, grid expansion, ERS technology, etc.), the current conventional ownership configurations involving both the public and private sector will be contested. Thus, the ownership configuration of an ERS could have a significant impact on how the introduction and diffusion of the technology can be achieved.

Since the initial situations differ in Germany, Sweden and Denmark, country-specific solutions are very likely. Furthermore, different views on how to organize the deployment of infrastructure for an ERS and on the division of responsibility between the involved actors in the three countries will probably lead to different degrees of public involvement in the market. For market deployment, this should not be a problem as long as the system is easy to access for carriers. Among other things, this could mean that the carriers should preferably have a single point of contact (a “one-stop-shop”) who takes on the billing with the organizations involved in the background, regardless of whether they are public or private. This would be similar to roaming facilities in the mobile phone market.

The different policy mix and measures adopted in each member state, of course, have to be based on the common EU regulations, but could be balanced in different directions with regard to policy push and pull. This should be further studied in the future development of the ERS corridor.

In Germany, decarbonizing road freight is – at least at present – policy-driven. Hence, there are strong policy push forces that dominate the implementation of new technologies like an ERS, including trucks and infrastructure. The missing prerequisites for market pull are linked to the absence of the large-scale production of ERS trucks, and thus cost disadvantages, a lack of green power, and thus the CO_2 neutrality of electric trucks that is not yet given, and a relatively strong resistance to fundamental changes in the transport market.

In Sweden, a similar situation to Germany prevails. The policy push is very apparent and supported by political support for ERS development in general and for the Swedish Transport Administration’s ERS program in particular. There is also a strong interest among the ERS’s future actors to participate in the formation of the markets. At the same time, there is still a lack of a supply of vehicles and of concrete market structures for an ERS. Market pull, even where it exists in principle, has therefore had few practical effects thus far in the heavy freight road transport sector.

#4 | Differences in the division of responsibilities between public and private actors can also occur along the corridor and lead to different business models.

The results of WP 2.2 showed that there are a number of conceivable business models for ERS. Some of these business models work universally. In some cases, however, they are also dependent on the tasks in an ERS that are ultimately left to the market by the governments and those who will be licensed to operate in the different ERS sub-markets. Since this decision is made on a country-by-country basis, this could result in potentially different business models for an ERS in the member states along the corridor. This is particularly important since it becomes possible to implement an ERS without changing national principles in the field of road construction and maintenance or without reorganizing the entire energy sector.

#5 | Depending on the time frame for the construction of the ERS corridor, different configurations between the public and private sectors might be needed.

Although considerable government involvement will probably be necessary for the roll-out of new system-based solutions like ERS, there is no reason to believe that such a system could not be increasingly organized by private sector actors at a later stage. A corridor-related example of such a process from the past concerns the petrol and service stations along the German motorways. These were originally state-owned and operated to ensure the establishment of the motorway system. As the range of vehicles increased and a close-knit private network of petrol stations and repair shops was established near the motorways, these were then privatized. The basic supply by the state was no longer necessary to ensure energy supply along the motorways. In contrast, Sweden has a combination of privately owned petrol stations and rest areas adjacent to the roads managed by the Swedish Transport Administration.

If the corridor is not built simultaneously in all countries, but rather realized in sections, this could lead to a combination of different ownership configurations or business models. In one country, the public sector may still be responsible because the system has been recently opened, while in another country a private sector business model has already been established. However, this should not pose fundamental problems, as long as both countries have the opportunity to implement their model independently and interoperability is guaranteed.

7 Background Literature

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8 About CollERS

Between 2017 and 2019, German and Swedish research organizations conducted a joint study with the aim of providing an assessment of different ERS concepts, assessing ERS markets, business models and financing strategies, researching requirements for international ERS interoperability, identifying a suitable ERS freight corridor between Sweden and Germany, investigating the impact of an ERS on the energy system and the environment, and recommending the necessary policy actions to spur ERS introduction.

Within the CollERS project, a corridor route between Helsingborg and Hamburg (424 km) has been examined in detail, taking into account technical, environmental and economic aspects. Based on a traffic flow analysis of the corridor route, it was found that:

- Of the total heavy-duty vehicle mileage on the corridor, 45 % is covered by vehicles with an ERS-suitable driving profile, assuming the corridor is realized as a stand-alone project.
- The CO_2 emissions (well-to-wheel) of heavy-duty vehicle traffic on the corridor route could be reduced by about one-third if the ERS is powered by the expected country electricity mixes for year 2030 and up to 43 % if it is powered by purely renewables. The remaining CO_2 emissions on the corridor would then be caused almost solely by non-ERS vehicles.

The joint study has been funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Swedish Transport Administration.