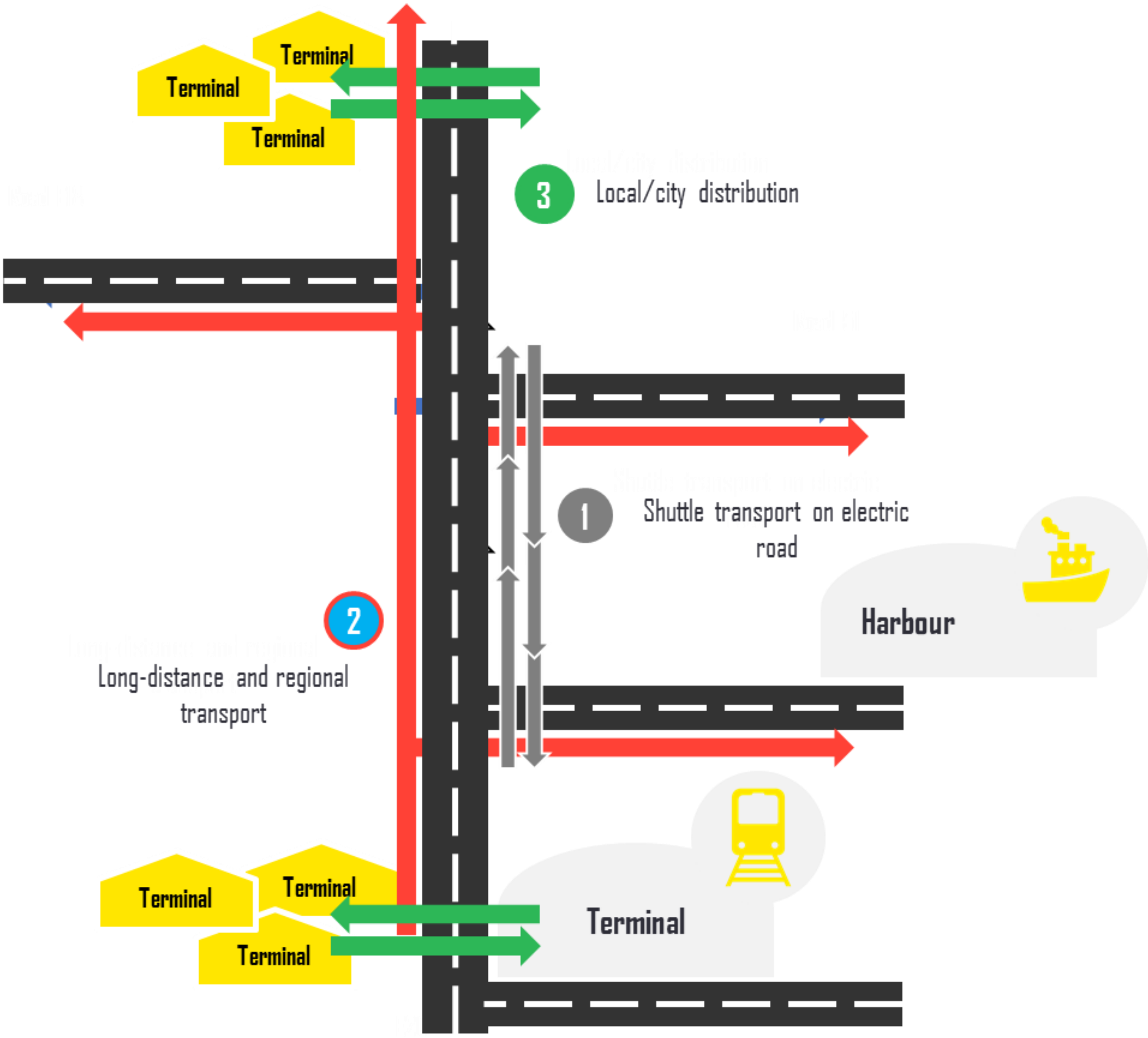
TRAFIKVERKET

REPORT

# Business models for electric road systems for heavy transport

## Report 4: organising an electric road system and calculation model for stationary charging

Report by EY, August 2020



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## Preface

This document presents the latest sub-report in the Swedish Transport Administration's Programme for Electrification of heavy road traffic on the national road network (the Electrification Programme) in the area Business Models - financing and organisation.

During 2020, the focus has been on two main areas.

- Firstly, based on previous reports (Phases 1 - 3) in this sub-project, to deepen the analysis of the electric road system's actors and the potential collaboration between them, as well as various subsidiary activities that need to be provided. The work has shown how the relationships between actors in an electric road system are affected by how the distribution of responsibility within the system is defined, which represents an important basis for the formulation of business models. One starting point for the analysis has been to identify the activities and areas of responsibility that could require the Swedish Transport Administration to take an active role in order that a functioning electric road system can be established.

- Secondly, a financial calculation model for stationary charging has been produced, the purpose of which is to analyse stationary charging infrastructure in combination with battery equipped vehicles from an annual income statement perspective. This provides a basis for being able to make comparisons between different types of electrification for heavy road transport, such as a combination of electric roads and stationary charging. In the next stage, the calculation model will be published.

The analysis has been performed as a close collaboration with the client and project manager Björn Hasselgren. Elin Näsström and Magnus Lindgren of the Swedish Transport Administration also participated in the assignment.

The Swedish Transport Administration (Trafikverket) and the consultants (EY) have held several joint seminars with a wide participation of actors in the developing electric road market, in order to discuss the issues in this phase of the work on the Business Model. Otherwise, the work has been performed in close collaboration with actors at regional and national level, as well as with actors in other countries. The Swedish Transport Administration is grateful for the good, open cooperation with all parties in the collaboration.

The Swedish Transport Administration publishes the reports, but does not necessarily concur with all parts of the analyses and conclusions in the reports. However, they are important documents in the continued work of the Electric Roads Programme.

Stockholm, August 2020

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# *Organisation of the electric road system and calculation model for stationary charging*

*03/07/2020*

Client: The Swedish Transport Administration, through Björn Hasselgren
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**Summary**

In 2017, the Swedish Parliament (the Riksdag) determined the goal of reducing climate impact in terms of emissions of greenhouse gases from domestic transport by 70 per cent by 2030, compared with 2010 levels. One of the instruments for achieving Sweden's climate goal is the electrification or road transport. Part of the solution for achieving this is the electrification of heavy road traffic. [1] [2]

The Swedish Transport Administration (Trafikverket) is performing investigative work on the electrification of heavy transport. Analysis of business models for an electric road system has been done in three earlier phases. Phase four, which is presented in this report, focused on analysing and further investigating questions on business models and organisation of the two pilot sections now being evaluated by the Swedish Transport Administration. An analysis of electrification solutions with stationary charging and battery equipped vehicles has also been initiated. The development of battery solutions has occurred rapidly in recent years. The analysis of stationary charging for heavy vehicles could also, at a later stage, become a starting point for testing systems that combine dynamic and stationary charging.

This phase of the assignment was performed from October 2019 to June 2020 and included a workshop and ongoing dialogue with market actors in the regions that are being investigated for the establishment of a pilot stretch demonstrating an entire system necessary for establishing electric roads. The purpose of dialogue with market actors has been to exchange experience and create understanding and knowledge of an electric road system, as well as of a system for stationary charging.

The work was performed by EY on behalf of the Swedish Transport Administration, where Björn Hasselgren was the project manager. The work was performed in close contact between EY and the Swedish Transport Administration. Knowledge and information has been obtained from documents produced previously in the Electric Roads Programme[1], other internal investigations and analyses at the Swedish Transport Administration and external reports, as well as articles, seminars and conferences.

**Organisation of a system of electric roads for dynamic charging while moving**

Actors and components that an electric road system may consist of have been defined in previous phases of the investigative work. In this assignment, further analysis has been performed to define the activities that will probably need to be included in order to organise a functioning electric road system. The work has shown how the relationships between actors in an electric road system are affected by how the distribution of responsibility within the system is defined, which represents an important basis for the formulation of business models. One starting point for the analysis has been to identify the activities and areas of responsibility that could require the Swedish Transport Administration to take an active role in order that a functioning electric road system can be established.

Different organisational forms may be relevant, depending on how the relationships are defined. The different organisational forms are:

[1] In connection with the completion of this report, the Swedish Transport Administration has decided to widen the scope of the work by analysing electrification of heavy road transport. The new name of the programme is "Programme for Electrification of heavy road traffic on the national road network". In this report, the former name "Electric Roads Programme" has been used.

- Organisation with a unifying party which provides a complete electric road system
- Organisation at component level, where individual actors collaborate to build up an electric road system
- Organisation as a hybrid between a unifying party and at component level

Based on analyses in the project, experience of similar infrastructure projects with a high level of innovation, input from completed workshops and dialogue with actors, some important aspects of the different organisational forms are discussed here:

- **Disposition, control and flexibility:** the ability of the coordinating party (in this case the Swedish Transport Administration or another public party) to directly or indirectly control the development of an electric road system toward desired goals, as well as the flexibility to make changes during the establishment phase if prerequisites or desired objectives change.
- **Effectiveness, quality and innovation:** the prerequisites that enable an electric road system to be established in a cost-effective way, that the system and its operation shall maintain good quality and that initial and ongoing innovation shall be facilitated.
- **The market's abilities:** the organisation's requirements for actors and their ability to undertake desired assignments and perform them with good results.

When taking these three aspects into consideration, all three organisational alternatives have advantages and disadvantages, as well as risks. For the initial phase of the roll-out of a pilot electric road, a hybrid organisation would probably be advantageous. This form of organisation provides prerequisites for handling mature and immature components separately and setting limited requirements for the level of development of the market, while at the same time promoting a certain innovation and effectiveness by keeping certain components together. Furthermore, a hybrid organisation can avoid the greater level of complexity in the interface between components that arises in a fully divided alternative.

**Description and analysis of a system with stationary charging infrastructure and battery-equipped vehicles**

A financial calculation model for stationary charging has been produced, the purpose of which is to analyse stationary charging infrastructure in combination with battery equipped vehicles from an annual income statement perspective. This provides a basis for comparisons between different types of electrification for heavy road transport, such as a combination of electric roads and stationary charging.

In order to create a better understanding of the structure of systems for stationary charging, an analysis of scenarios has been performed in which a small, a medium sized and a large-scale system of stationary charging infrastructure have been analysed. The calculation model has been divided into the actor categories owners of charging infrastructure (subdivided into semi-public and public charging infrastructure) and carriers. The transport market, and thus the carriers, has been divided into the separate sub-markets for long-distance transport, regional transport and city transport. It has been assumed that charging in depots will be a dominant form of charging of battery-equipped heavy vehicles.

On the basis of the input values that have been applied for the different scenarios, the calculation model gives an indication that it could be possible to achieve commercial profitability in a system of charging infrastructure and battery-equipped vehicles, in the longer term. The input variables that affect the results from the calculation model are the comparative costs of diesel and electrical operation, investment costs of charging infrastructure and battery-equipped vehicles and the level of utilisation of the stationary charging infrastructure. If diesel is cheaper to use than electricity, there is less incentive to use electricity.

Investment costs, such as the annual output-related cost of charging stations and the additional cost of battery-equipped vehicles, as well as the level of utilisation of the stationary charging infrastructure, are factors that affect the results. The analysis shows that a sufficiently high level of utilisation is required to achieve profitability for the stationary charging infrastructure, although this level of utilisation is relatively low seen from an annual perspective.

It is important to note that the results reported from the basic calculations of the calculation model and the three scenarios must be seen as preliminary. They should therefore mainly be seen as a basis for further discussion and something from which scenarios can be further developed.

**Recommendations for the next step**

Electric roads and stationary charging have been discussed in this report and are judged to be technologies that would probably affect each other and interact in a growing market for the electrification of heavy vehicles. These electrification technologies may also need to be seen in relation to other technical developments that are occurring, such as fuel cells and hydrogen. The recommendation for further work is thus to extend the analysis for electric roads, now with the addition of stationary charging. This will enable comparisons between different electrification alternatives for heavy road transport. Analysis may also be needed so as to understand what role the Swedish Transport Administration might have and what degree of involvement is required.

Two main areas should be analysed in the next step:

1. **Deeper analysis of business models, interfaces and distribution of responsibilities between different actors with regard to different electrification technologies for heavy vehicles**
   With new electrification alternatives for heavy vehicles, such as electric roads, stationary charging etc., actors will need to interact in new markets. There may also be new actors, which may mean that a number of new, and in some cases complex, relationships may need to be formed. It will therefore be important to further analyse interfaces and distribution of responsibilities between different actors, so as to create an understanding of how the different electrification alternatives can be formulated and influence each other.

   On the basis of interfaces and distribution of responsibilities that are developed between actors, it is also important to understand how business models for different electrification alternatives can arise. To create an understanding of what markets for different electrification alternatives could look like, deeper insights must be arrived at as to what driving forces and incentives the different actors have. Experience gained in the work on business models for electric roads can be taken into account in continuing analysis of business models for other electrification alternatives. Another aspect to bear in mind is how different electrification alternatives and their associated business models can interplay, as well as any need or opportunity to combine these business models. The recommendation for the next step is therefore to continue to analyse business models, interfaces and distribution of responsibilities so as to be able to identify the opportunities and challenges of the different electrification alternatives.

2. **Extend the analysis of cost structures and business opportunities between different electrification technologies, to be able to weigh up different alternatives against each other.**
   Comparison and analysis should be performed of different electrification alternatives. As a first step, an analysis is proposed of the two calculation models that has been devised for electric roads and stationary charging respectively. The calculation models' cost and income calculations

are an important support for this analysis to work and can be supplemented with similar models for fuel cells, for example. Scenarios with different combinations of electric roads, stationary charging and fuel cells may need to be discussed so as to understand the differences between these and also how the development of the electrification of the national road network for heavy transport should occur. The recommendation for the next step is therefore to extend the analysis of cost structures and business opportunities to also include fuel cells and also to compare different electrification technologies.

# CONTENTS

# 1 INTRODUCTION

## 1.1 BACKGROUND

Heavy road traffic accounted for approximately 21 per cent of greenhouse gas emissions from domestic road transport in 2018 [3]. In 2017, the Swedish Parliament (the Riksdag) established the goal of reducing climate impact from domestic transport by 70 per cent by 2030, compared with 2010 levels. One of the tools for achieving Sweden's climate goal is the electrification of road transport, part of which is electrification of heavy transport. [1] [2]

In November 2017, the Swedish Transport Administration (Trafikverket) submitted a roadmap for electric roads to the government, highlighting the need for continued investigation and analysis, including in the area of business models. Since 2018, EY has been commissioned by and has worked together with the Swedish Transport Administration to investigate business models for electric roads in three phases, each phase of which has resulted in a published report. The first report, *Business models for electric roads*, was published in August 2018. A further report was published in February 2019 that discussed roles, actor relations and risks in the electric roads market. The third report was published in September 2019 and discussed a future role as operator in an electric road system as well as commercial conditions for electric roads. [4] [5] [6]

According to the government's decision, electric road technology is to be tested on a longer stretch of road than the demonstrators for electric road technologies. For the pilot phase, the establishment decision for the National Transport Infrastructure Plan 2018-2029 laid down that the Swedish Transport Administration has at its disposal SEK 300 million for investment in a pilot electric road and that a further SEK 300 million is expected to be financed by private actors. The sum total of SEK 600 million shall be used for the implementation of the pilot phase.

In June 2019. the Swedish Transport Administration informed that two sections of road, one in the Örebro County Region and one in the Stockholm Region, represented potential pilot sections for a pilot electric road and that a formal road plan adapted for electric roads should be developed for each section. The pilot installation is intended to be a full-scale test of an electric road system (ERS), including business model. In the development and implementation of the business models, the Swedish Transport Administration has had a continuing need for support, including analysis of financial and organisational aspects, profitability calculations, costs and charge models. It is this fourth phase of the investigatory work on business models that is presented in this report.

There are rapid developments in the market both in the area of different ERS technologies and in terms of alternatives or complements to ERS. Testing of ERS technology is ongoing in a number of demonstration projects for the purpose of creating knowledge of the construction, operation and maintenance of electric roads. The knowledge gained from the demonstration projects, together with a number of other activities,  represent a basis for future decisions on requirements for electric road technology. New technologies, such as electric roads, are growing in interplay with a number of other actors and the Swedish Transport Administration will not be alone in deciding which technologies will finally come to dominate the market. Close collaboration with other actors will therefore be decisive for the Swedish Transport Administration's continued work on electrification.

Technical solutions for battery-equipped vehicles and stationary charging have developed rapidly in recent years, which indicates that battery solutions for heavy vehicles could be an alternative for electrification alongside ERS. This means that a combination of electric roads, or dynamic charging, and stationary charging will be a scenario and a combination that will need analysis - for example how these solutions could complement or compete with each other.

Previous work has analysed business models for an electric road system at a general level. Analysis has also begun so as to create a deeper understanding and to be able to apply a concrete business model to the pilot projects. This report investigates possible organisational alternatives for the actors involved and the relationships between actors in an electric road system.

## 1.2 Purpose

During this fourth phase of investigation of the electrification of heavy road transport, EY has assisted the Swedish Transport Administration in developing organisational forms and in how a business model could be applied in practice on the pilot sections being investigated by the Swedish Transport Administration. An initial analysis has also been performed of systems where stationary charging of battery-equipped heavy vehicles is combined.

## 1.3 Method

This assignment was performed during the period October 2019 to May 2020. This report has been prepared in close collaboration with the Swedish Transport Administration, where Björn Hasselgren was the project manager. Elin Näsström and Magnus Lindgren of the Swedish Transport Administration have participated the work on an ongoing basis.

The project's working group, consisting of the Swedish Transport Administration and EY, has collected information by studying previously produced documents in the Electric Roads Programme, from collaboration with the regions that have been selected for the pilot project, from reports of development projects in Sweden and other countries and from articles, workshops and conferences. Working meetings have been held regularly throughout the work. The working group has also reported regularly to the Electric Roads Programme and coordinated with the programme's other projects and work.

A workshop was held on 23 January 2020 with actors of relevance to the electric roads market. The purpose of this was to initiate a dialogue with market actors and authorities on the basis of the project's analyses and hypotheses. Getting these actors together in dialogue was also a way of creating a common picture of how actors who could be active in a growing electric roads market envision the development of electric roads, as well as to discuss stationary charging.

In addition to this workshop, ongoing dialogues with a number of actors have continued during the implementation of the assignment. This was to obtain a deeper understanding of the market and ongoing developments, both in the business models and in relation to a pilot electric road. There have also been dialogues on stationary charging for heavy transport. The project's work has been presented at seminars at the leading actors for one of the potential pilot sections, Örebro County Region. A financial calculation has been produced as a first step in the analysis of stationary charging for heavy transport. Assumptions, input values and results from the calculation model have been harmonised with market actors, primarily potential charging station owners, distribution system actors, electricity trading companies and carriers.

## 1.4 Limitations

The content of this report is based primarily on dialogue between the project group and market actors at workshops, individual meetings and the working group's analyses. This means that the results are limited to the qualitative views that have arisen from participants. The assignment has focused on working hypotheses and analyses relating to the organisation of the pilot sections that have been selected in the Electric Roads Programme. However, a considerable part of the assignment has consisted of calculation work on the battery-equipped vehicle and stationary charging alternative.

Potential technologies for electric roads are one of the questions investigated by the Swedish Transport Administration, with the support of the demonstration projects, various projects in the Electric Roads Programme and a number of research initiatives. The Swedish Transport Administration has a neutral position on the question of choice of technology, as do this assignment and this report.

The assignment has not included legal analyses. The legal aspects are investigated within the Electric Roads Programme and it is important to bear them in mind in future work, since they play a great part in defining the prerequisites for the system's commercial formulation and organisation.

The starting point for the analysis of business models for the pilot electric road phase has been the application of business models and calculation model for the two pilot sections. Preparations for the pilot phase have however taken more time than expected, which means that this part of the analysis could not be fully completed within the time available for this assignment.

The purpose of the calculation model for stationary charging is to create an easily comprehended understanding of the financial sustainability of the market for stationary charging and battery-equipped vehicles, as well as its various actors. The calculation model is structured in a similar way to the calculation model for electric roads, with input values from the socio-economic calculation methodology and manuals (ASEK) as a starting point [7]. The results from the calculation model are limited to focusing on financial sustainability for different actors at system level. The perspective is a system for stationary charging seen from an annual income statement perspective and at a specific point in time.

Thus, the calculation does not take into account the socio-economic effects of stationary charging infrastructure. The calculation model should not form the basis for any investment decision, but should primarily be seen as support in the general consideration of how the market for stationary charging infrastructure may develop in future.

The input values in the calculation model for stationary charging are based on qualified estimates, assumptions and facts from various market actors, as well as ongoing projects in the Electric Roads Programme. As a next step, these estimates and assumptions need to be verified and refined.

### 1.5 Assumptions and starting points - the Swedish Transport Administration's role

This report forms on the basis that, in any future development of electric roads in Sweden, the Swedish Transport Administration's role will be to create a framework and prerequisites for such a development. It is not part of the Swedish Transport Administration's assignment to define all business relationships in an electric road system. The Swedish Transport Administration's role may vary over the course of time, however. The Swedish Transport Administration has had a driving role in the development and building of a pilot section, on behalf of the government. It is, however, not self-evident that the Swedish Transport Administration would have a similarly active role in a more long-term and large-scale roll-out.

Thus, this investigation has taken as its basis that the Swedish Transport Administration is one of several actors in an electric road system. Section 2 describes potential scenarios for the Swedish Transport Administration's role in the organisation of the market with the introduction of a pilot electric road. The Swedish Transport Administration’s task is to be responsible for the long-term planning of the transport system for all means of transport, as well as for the construction, operation and maintenance of national roads and railways. The Swedish Transport Administration is also responsible for installations within the road area. ERS could be defined as part of the installations within the road area and thereby included in the Swedish Transport Administration’s responsibility for the provision of road facilities. However, ERS will bring installations within the road area that have not historically been included in the Swedish Transport Administration’s area of responsibility in respect of roads. One example of this is that, in an ERS system, the transfer of electricity could form part of the installations within the road area.

Systems for battery-equipped vehicles and stationary charging infrastructure can be seen as a more mature sector than electric roads, in that both vehicles and charging infrastructure already exist for private cars. Moreover, the infrastructure can be installed outside the road area. To summarise, this means that the Swedish Transport Administration’s role in such a system can be assumed to be more limited than in an ERS system.

# 2 ORGANISATION OF AN ELECTRIC ROAD SYSTEM

Cost estimates, together with results from the financial calculation model, as presented in the report *The electric road system's actors and financial conditions – An analysis of the operator role and short and long-term scenarios* (2019), show that it is difficult to achieve commercial sustainability for electric roads at an early stage because of the large investments and low volume of transport using the electric roads [6]. This indicates that government support could be needed at an early stage, to support investments in electric road development. A clearly defined mandate from public parties that the development of and long-term investment in electric roads will occur could reduce uncertainties about future developments.

In previous work, actors have been identified who could be included in a business model for the development and operation of electric roads, see Figure 1.

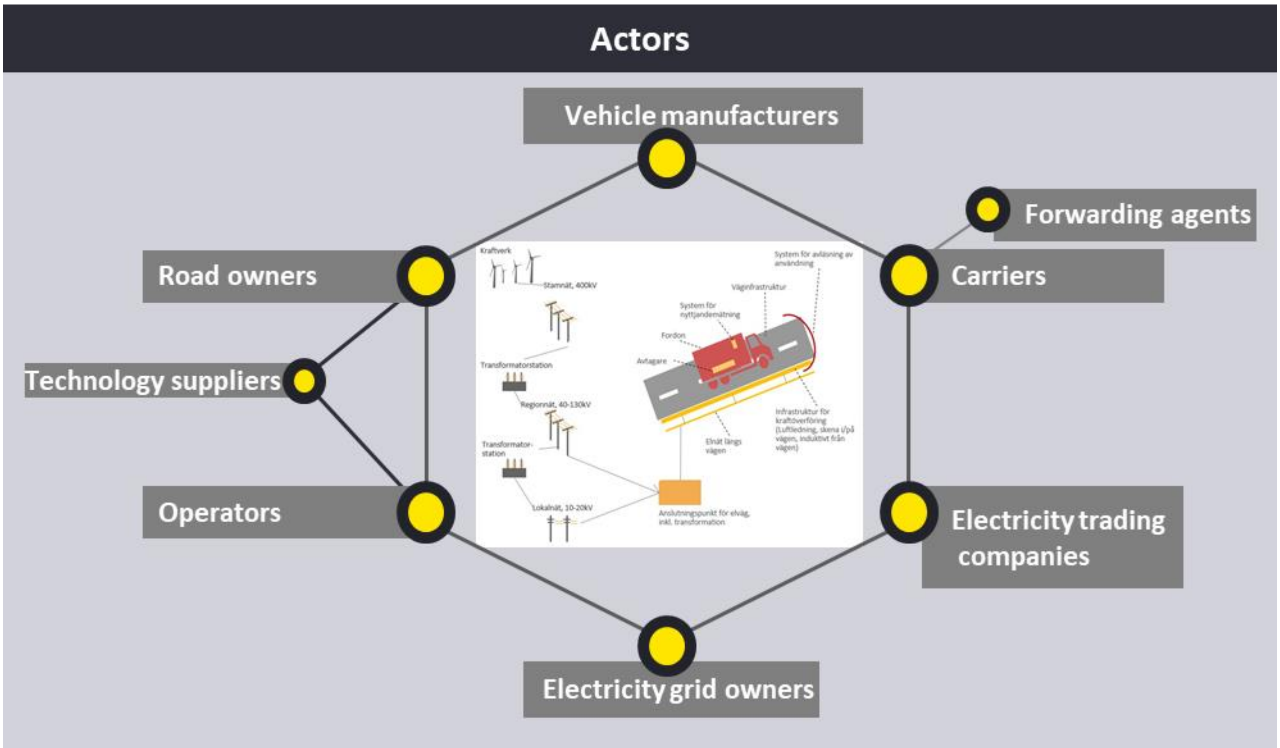



***Figure 1 Diagram showing actor categories in an electric road system***

In addition to the actor categories identified, earlier analyses have shown that a number of activities would be needed in order to build up an electric road system [6]. These activities include, for example, construction and operation of ERS infrastructure, the provision of payment solutions, construction of electric grids and adapting vehicles to be able to drive on or from electric roads. These activities are shown in Figure 2. How the relationships between actor categories are built up and how the distribution of responsibilities is defined give the basis for the business model.

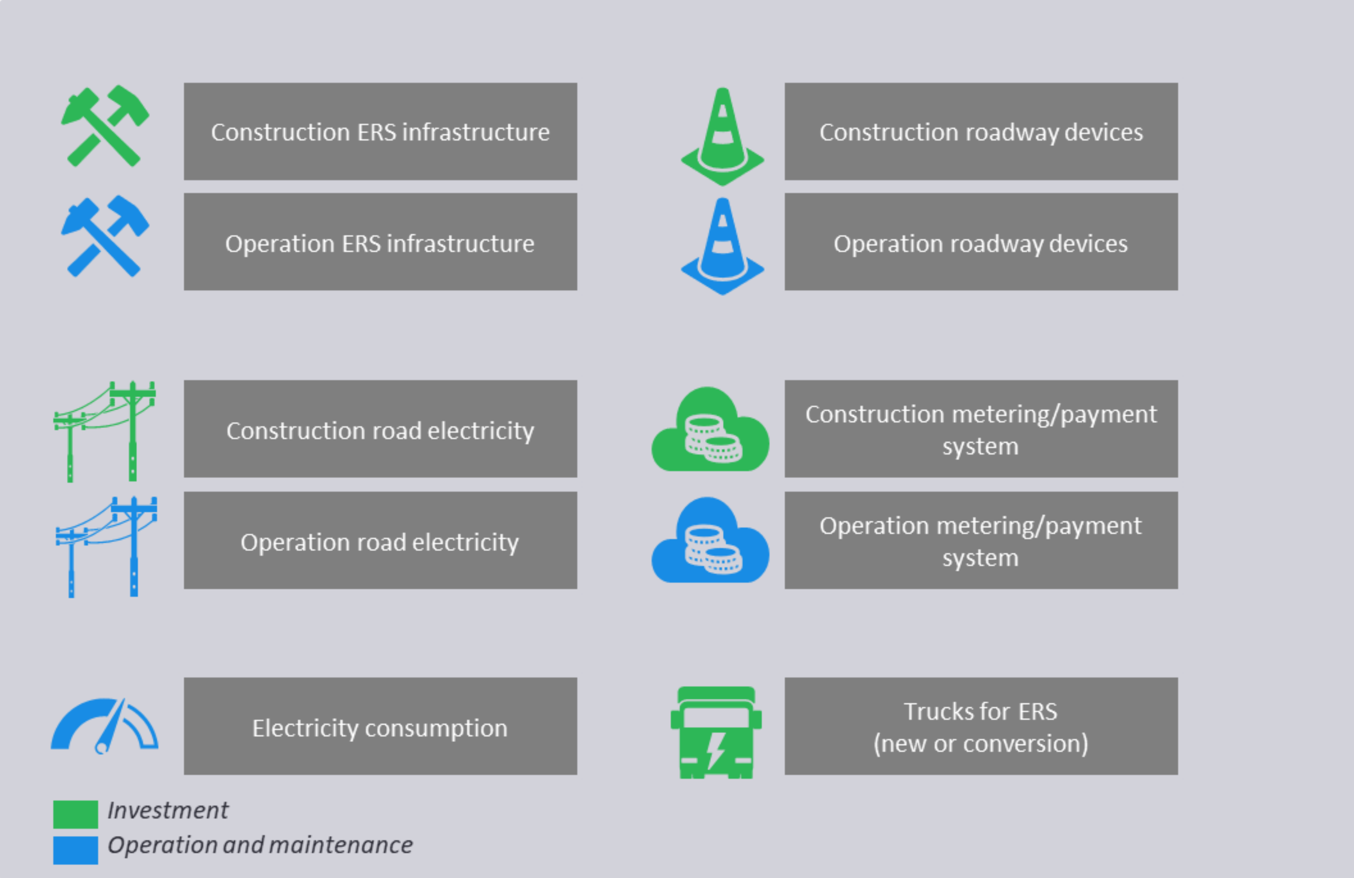



***Figure 2 Activities linked to the components of an electric road system (development and operating phase)***

For some of these activities, it has been assumed that existing markets will be able to meet the needs of an electric road system. One example is the purchase of transport from carriers or shippers by the owners of goods. This is a market that works well and where the introduction of electric roads and electricity as an energy supply for heavy vehicles should not change the relationships between sellers and buyers. The basis for the analysis in this phase has been, given the Swedish Transport Administration's role, to look at what activities and relationships exist where the Swedish Transport Administration could have a decisive role in ensuring that an electric road system could be developed.

Figure 3 below essentially shows four areas where public sector parties may need to support the development of an electric road system. These are:

- Construction and operation of ERS infrastructure
- Construction and operation of supplementary roadway devices that are linked to ERS infrastructure
- Operation of electric power supply to electrified roads, between the connection point and ERS technology
- Systems for metering and payment

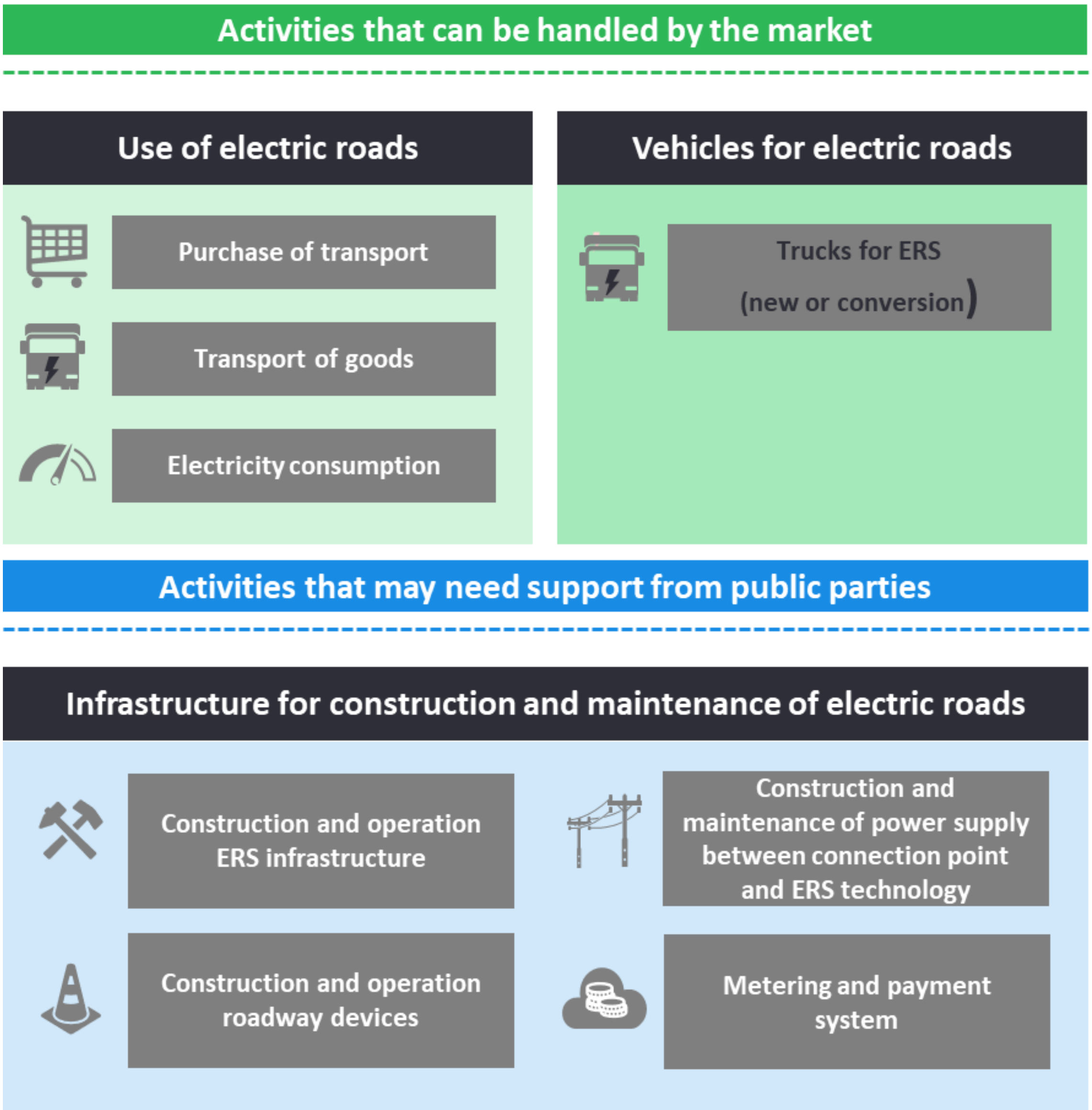
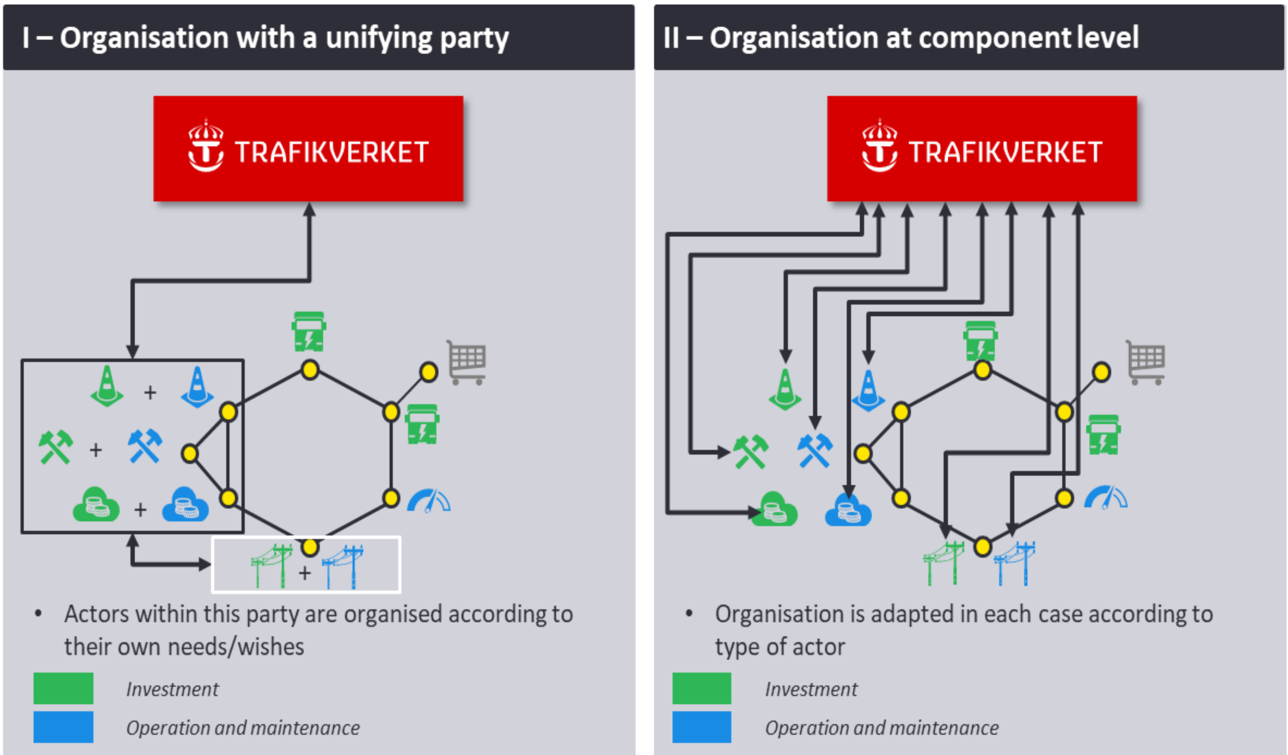



***Figure 3 Activities that can be handled by the market and that may need support from public sector parties***

Support to vehicle owners for the purchase of vehicles adapted for electric roads could be needed so that the market can be established. Such support has been proposed by the government, by extending the electric bus premium to cover all types of electric powered commercial vehicles. During an introductory phase, the Swedish Transport Administration may need to take greater responsibility for investment in electric road technology than would be necessary in a longer term perspective. The same could apply to support for stationary charging infrastructure, where the Swedish Transport Administration has had and will continue to have a role through specific assignments from the government.

The Swedish Transport Administration's role in an electric road system may vary depending on how any future electric road market is organised. Figure 4 illustrates different alternatives for the organisation of an electric road market. According to alternative *I – Organisation with a unifying party*, the Swedish Transport Administration would have one other party responsible for creating all parts of a functioning electric road system, such as investing in infrastructure, operation and maintenance.

As an opposite to this alternative, the Swedish Transport Administration could instead have contract parties at component level, as seen in Figure 4 as *III – Organisation at component level*. Here each contract party would mean that the Swedish Transport Administration would have a separate relationship with each actor, where all the Swedish Transport Administration's relationships with actors would together form a functioning electric road system. From these alternatives, there could be a number of different versions of how organisation could occur, with a greater or lesser division of activities, which is named *II – Organisation as a hybrid between a unifying party and at component level*.



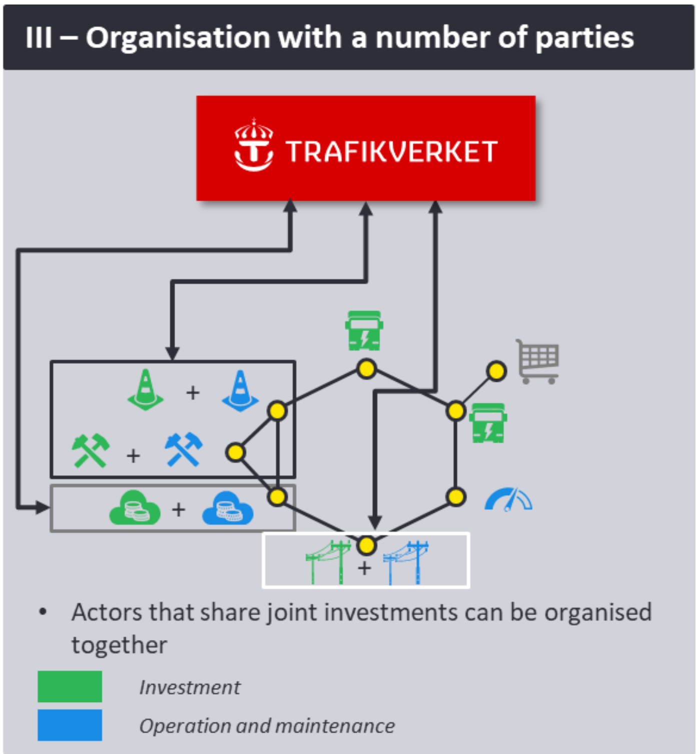



***Figure 4 Alternatives for the Swedish Transport Administration's relationships with actors in an electric roads market***

Establishing an electric road system is characterised by a high level of innovation, new technical solutions and a number of risks linked to the growing market. For example, there is the risk that the electric road would not be used to a sufficient extent to generate the traffic volumes, and thereby the income, needed to achieve a profitable system. Calculations and assumptions made thus far indicate relatively low income and considerable costs for the operation of an electric road in a pilot. A possible scenario could be for the Swedish Transport Administration to offer a private sector actor a fixed payment for providing or operating the system according to a certain specification, combined with variable compensation of costs and incentives where increased usage would give higher payments.

Such a model could cover the increased costs of more administration, more wear to the system etc. and also give the actor an incentive to attract new users and provide as attractive a product and service as possible. Another possible scenario would be to only have a fixed remuneration, but this would reduce the incentive for the actor to ensure and increase usage of the electric road system.

## 2.1 Forms of organisation of an electric road system – relationship between the Swedish Transport Administration and other actors

This section provides a description of the three scenarios for organisation of electric roads presented above.

### 2.1.1 Organisation with a unifying party which provides a complete electric road system

This alternative shows a situation where a collaborating party has total responsibility for how actors and activities are organised in an electric road system. This party would thus be responsible for investment, construction, operation and maintenance of the components in an electric road system and also ensure that the entirety functions according to requirements set between the Swedish Transport Administration and the party. Further development of technology and the system as a whole is also a responsibility that could be assigned to the other party. Under this party, with overall responsibility, the organisation could look different and consist of a number of collaborating actors or suppliers.

For this type of organisation, the Swedish Transport Administration can set requirements for a function, such as a functioning electric road system, rather than requirements for details of how the execution shall be organised and underlying technical solutions. This would mean that the form of implementation, such as who is responsible for what, is organised within the framework of the organisation of the party with overall responsibility.

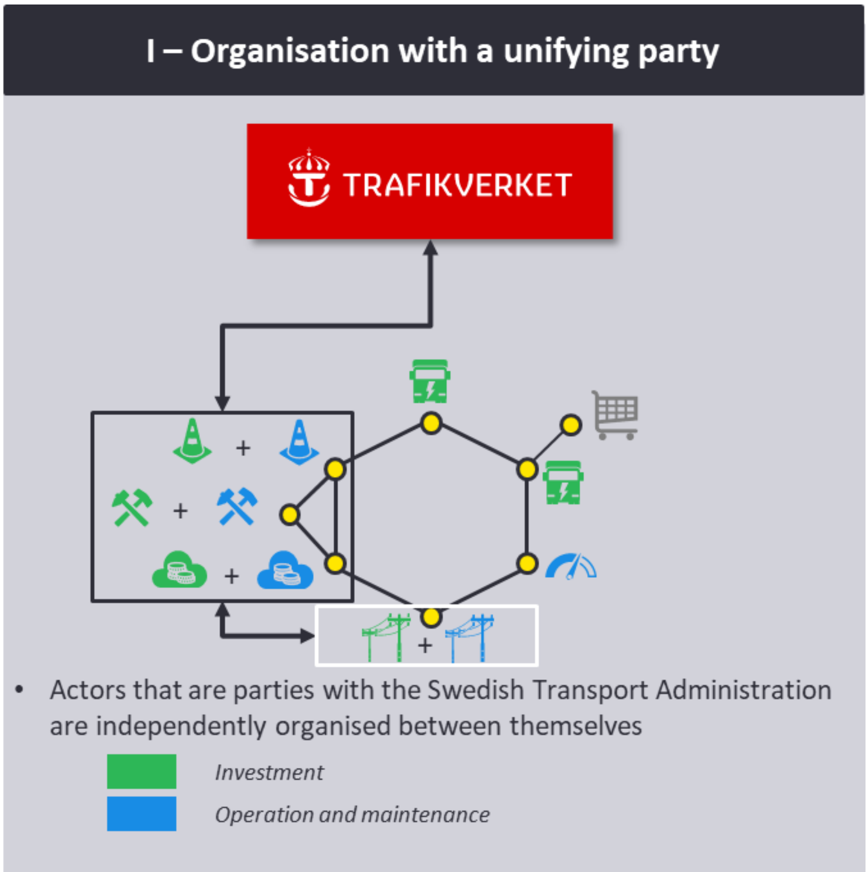



***Figure 5 Organisation with one collaborating party***

Based on this organisation, payment could theoretically consist of user charges paid by the users of the electric road, where the responsible party receives income from usage of the system but is also responsible for most of the costs. In such a model, this party could be responsible for the payment solution and largely have the installations at its disposal. In practice, legislation on road financing and charges for roads could limit the opportunities for directly passing the income from transport to an external party.

### 2.1.2 Organisation at component level, where individual actors collaborate to build up an electric road system

One alternative for organising actors and roles in an electric road system could be to divide the system up at component level. This could be illustrated as a solution where all activities are seen as separate parts, whose dependence on each other would need to be regulated via a coordinating partner. This role could be a natural one for the Swedish Transport Administration, as shown in

Figure 6. In this scenario, the Swedish Transport Administration would have interfaces with several parties. These parties in turn are responsible for different parts of the system and it could be the Swedish Transport Administration's responsibility to organise these in an effective way that promotes innovation and quality.

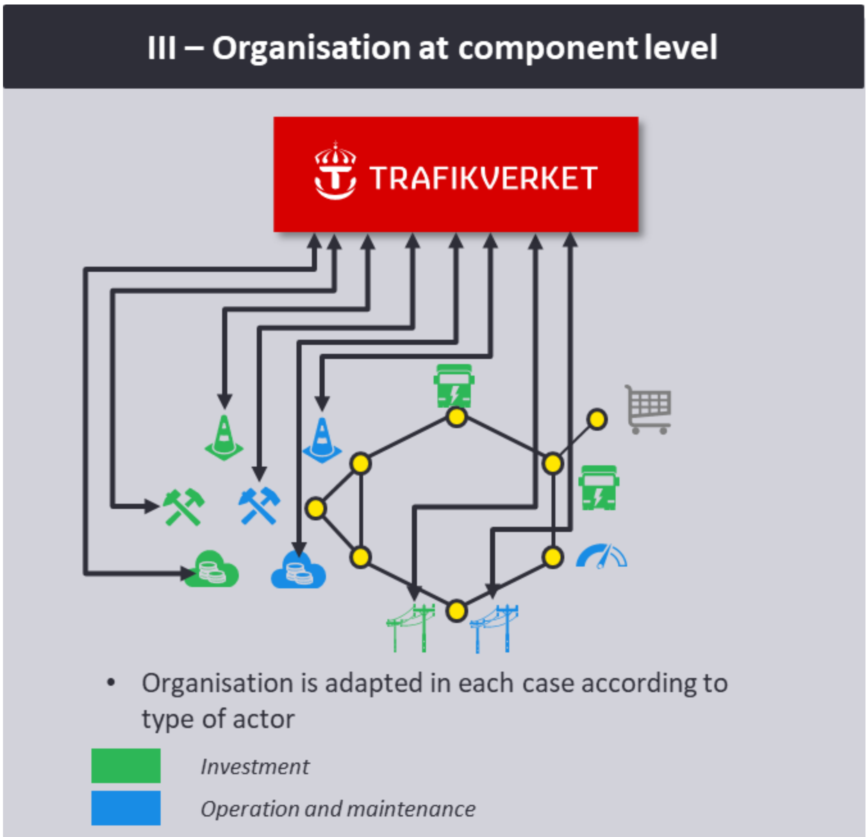



***Figure 6 Organisation at component level***

To achieve an effective organisation, the interface between the Swedish Transport Administration and the actor for each activity would need to be defined. Interfaces between the different actors would also be regulated through each actor's relationship with the Swedish Transport Administration. This means that, for each arrow in Figure 6, the Swedish Transport Administration defines what the relationship/contract shall contain, what requirements the Swedish Transport Administration sets for the other party, how the payment system works, what the consequences of a breach of contract are etc. This could also mean that the Swedish Transport Administration and other actors need to ensure together that incentives are integrated into a governing model that promotes both resource effectiveness and a functioning total system.

### 2.1.3 Organisation as a hybrid between a unifying party and at component level

A third form of organisation could be an organisation of the electric roads market in which the Swedish Transport Administration has a limited number of collaborating parties. This form can be seen as a hybrid of the two organisational models already described. The system's activities are divided into a number of packages or parties based on logical and functional connections.

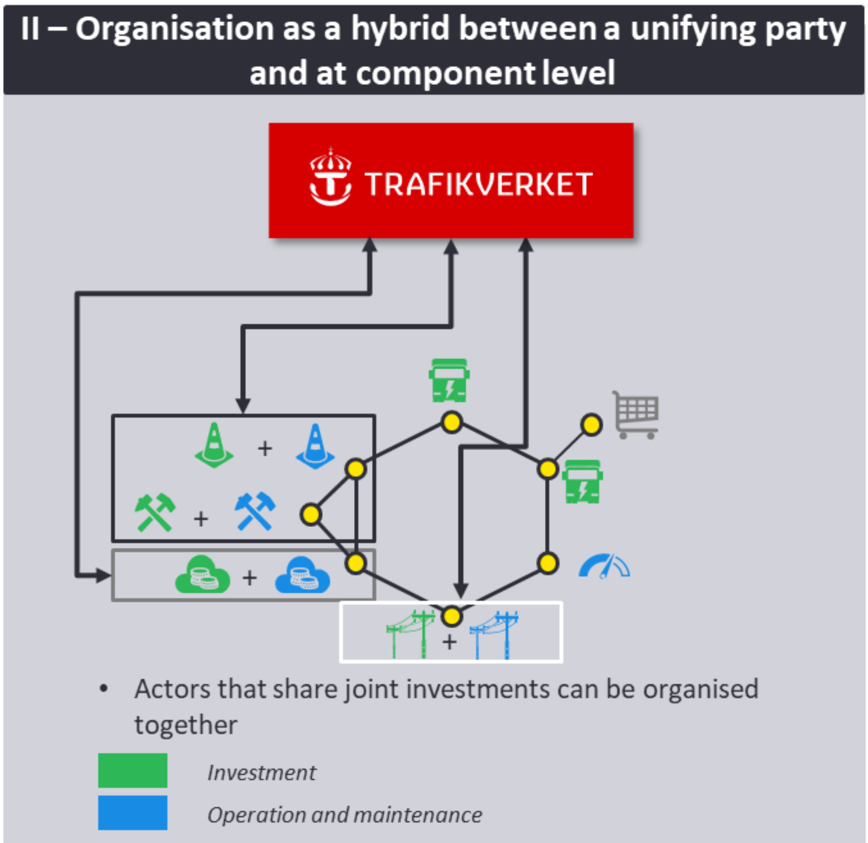



Figure 7 Organisation as a hybrid between a unifying party and at component level

## 2.2 ASPECTS TO CONSIDER IN THE APPLICATION OF DIFFERENT FORMS OF ORGANISATION

Based on analyses in the project, experience of similar infrastructure projects with a high level of innovation, input from completed workshops and dialogue with actors, three aspects of the organisational forms can be illustrated:

- **Disposition, control and flexibility:** the ability of the coordinating party (in this case the Swedish Transport Administration or another public party) to directly or indirectly control the development of an electric road system toward desired goals, as well as the flexibility to make changes during the establishment phase if prerequisites or desired objectives change.
- **Effectiveness, quality and innovation:** the prerequisites that enable an electric road system to be established in a cost-effective way, that the system and its operation shall maintain good quality and that initial and ongoing innovation shall be facilitated.
- **The market's abilities:** the requirements of the organisational model for actors and their ability to undertake desired assignments and perform them with good results.

Below are some general remarks on these aspects, which are realised in many projects at the Swedish Transport Administration, but which could also be relevant for the establishment of an electric road system. These do not address which parts of an electric road system the Swedish Transport Administration should be responsible for or what parts of a system it would be within the Swedish Transport Administration's mandate to order. The comments below are not intended to be subject to decisions or to presuppose any particular role for the Swedish Transport Administration.

Disposition, control and flexibility

The Swedish Transport Administration's opportunities for direct control of each component increase with the application of a more divided organisational form, since this would mean that each relationship in the system is controlled and has defined requirements. This would give the Swedish Transport Administration a power of disposition which could be desirable for pilot sections where new technologies are to be introduced. A divided form of organisation would also facilitate adapting relationships in terms of distribution of responsibilities, contract length and requirements, based on each component's circumstances. For example, the electric road technology could be seen to be immature and thus more risky, while connection of an installation to the electricity grid and maintenance of roadway devices are more technically mature and more predictable.

An organisation with one party collaborating with the Swedish Transport Administration means there is one interface with the Swedish Transport Administration to manage. This interface would need to cover all aspects of the system. The Swedish Transport Administration needs to decide what requirements shall be set in detail for the performance of the service and technical parameters, as well as what can be left for the supplier to find the best solution for. Having one collaborating party could make the Swedish Transport Administration's tasks easier, because dialogues and responsibility requirements can be limited to only one party.

To a similar extent, a model with one party means the Swedish Transport Administration could have fewer opportunities for control and disposition over how the other party decides to organise itself. If an individual component or service in an electric road system does not live up to expectations, it could also be more difficult for the Swedish Transport Administration to detect this at an early stage and take the necessary action.

When it comes to achieving flexibility, the key factor is felt to be how contracts are formulated rather than what organisation is chosen. A divided organisation could mean that terms and conditions can be individually adapted for each part, but it would also mean that changes in respect of one party may mean that knock-on effects for other parties need to be handled.

Overall a hybrid organisation, where components are divided into logical packages or actor groups on the basis of activities, is desirable on the basis of the above named aspects. One such area that logically hangs together is maintenance of roadway devices/infrastructure. A divided organisation might lead to such complexity in the interfaces between the respective components as would be difficult to predict and manage effectively. Finally, it should be noted that the opportunity to define requirements for technical standards, service parameters etc. is not affected by organisational form.

Effectiveness, quality and innovation

Generally speaking, the more mature a system or process is, the easier it is to divide it into individual components with clear interfaces and to optimise each part. Given that electric roads are a growing and relatively immature system, it could be beneficial to have one collaborating party. It is highly likely that unforeseen needs, problems and innovation opportunities will arise, where several mutually interdependent components are affected.

A combined form of organisation allows actors the freedom to be innovative and to organise the work effectively. During implementation and commissioning, having a combined organisation means that one party has collective responsibility, even if this party in turn organises sub-contractors.

The market's abilities

In choosing an organisation, the market's ability to be organised according to the three forms described above should be evaluated, since a combined organisation and hybrid forms mean a greater requirement for maturity among the market's actors. Given that there is currently no established market for electric roads, there is a general risk that there are so few actors with the ability to act as a combined party that it would be difficult to achieve sufficient competition and market effectiveness.

Organisation as a hybrid between one party and component level has the advantage that the market can be organised into packages with logical connections and similar maturity. This makes it easier for actors to judge their risk taking, organise themselves and compete effectively.

To summarise, this aspect would indicate a divided or hybridised alternative.

When taking the three aspects described above into consideration, all three organisational alternatives have advantages and disadvantages, as well as risks. For the initial phase of establishing a pilot installation, a hybrid organisation would probably be advantageous. This form of organisation provides prerequisites for handling mature and immature components separately and setting limited requirements for the maturity of the market, while at the same time promoting a certain innovation and effectiveness by keeping certain components together. Furthermore, a hybrid organisation can avoid the greater level of complexity in the interface between components that arises in a fully divided alternative.

# 3 TRAFFIC FLOW ON THE PILOT SECTIONS

This section describes the traffic flow on the possible pilot sections that needs to be analysed in order to be able to assess sub-markets and income opportunities for an upcoming ERS pilot. There was an intention to apply the calculation model for electric roads to the input data from the pilot sections but conditions for such an analysis were not found within the framework of this assignment. Instead, it is proposed to apply the calculation model to the input data from the pilot sections in a future phase.

The possible future business models for electric roads have thus far been mainly analysed conceptually, including in dialogue with the market's actors. As part of the analysis of business models for electric roads, meetings and dialogue with local actors have been performed so as to create a picture of their circumstances and their interest in converting to electricity for power supply. Örebro County Region and Stockholm Region have had parallel dialogues with local market actors to create an understanding of the respective local markets. This work is ongoing within the Swedish Transport Administration and in the two regions. Some preliminary observations can however be made to give an indication of how an electric road system could be organised from a business model perspective and these are the starting points below.

The analyses performed in this phase have given the insight that measuring annual average daily traffic (AADT)[2], as has previously been done to understand traffic volume, cannot give the level of detail that is needed. This is because AADT cannot give a total picture of the different traffic flows on a section of road. This entails that the analysis has gone over to identifying what the different traffic flows could look like. To exemplify this, different traffic flows have been applied for the pilot sections, as presented below.

E20 section Hallsberg - Örebro

One of the pilot sections that has been analysed in this assignment is the Hallsberg – Örebro section of road E20. Based on the work of analysing the electric roads market, the Swedish Transport Administration has primarily identified three categories of flow along the Hallsberg-Örebro section that could indicate different uses of this section, as illustrated in Figure 8.

[2] "ÅDT" in Swedish.

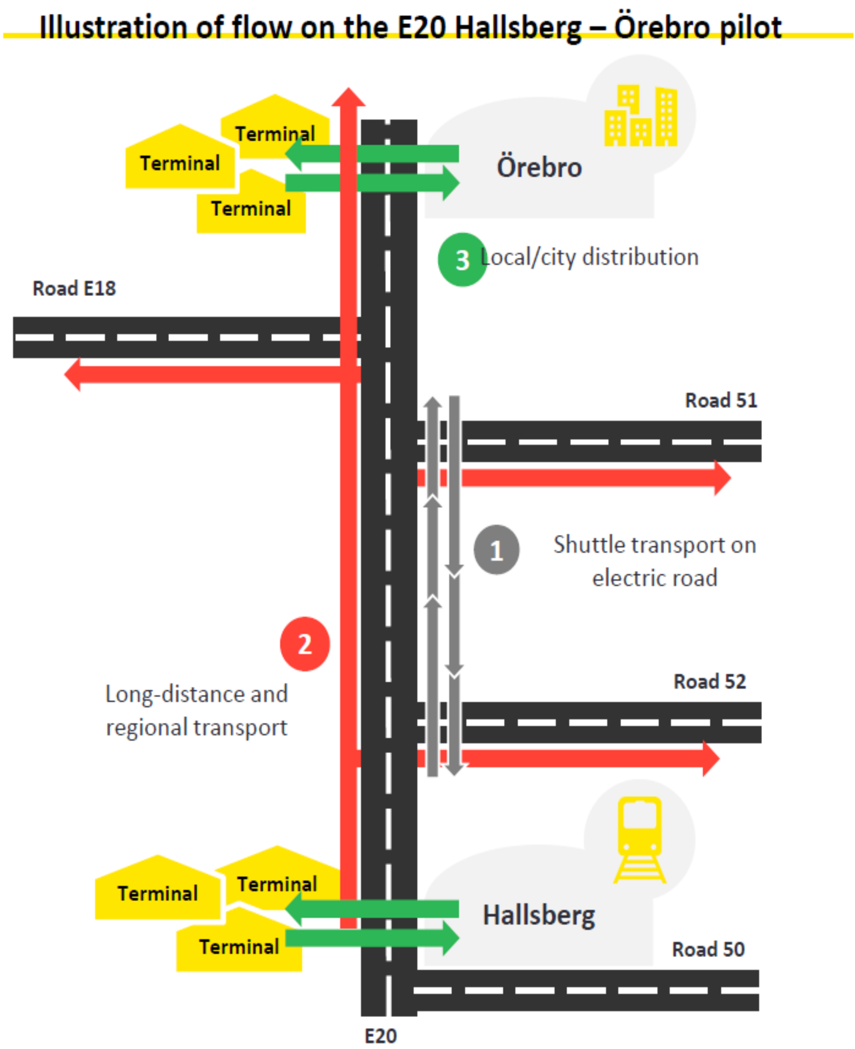



***Figure 8 Illustration of possible flows for the E20 Hallsberg - Örebro pilot section***

One part of this potential pilot section is included in a logistics flow between two large logistics and terminal areas, one in Hallsberg and one in Örebro, which indicates that there is a recurrent traffic flow on the section between these terminals. It is possible that this type of shuttle transport, which is marked as number 1 in Figure 8, could be interested in using a pilot electric road and could quickly convert the vehicles to be able to use dynamic charging.

Another possible traffic flow on the section is that of heavy vehicles that pass along the potential electric road as part of a longer driving distance, flow number 2 in Figure 8. For example, a transport could start from a terminal here with a final destination outside the pilot section or a transport could start its journey in another part of the country and pass along this pilot section on its way to the final destination. This type of transport is less likely to use the electric road installation in a pilot electric road, but on the other hand is more likely to in the longer term.

A further traffic flow on the Hallsberg-Örebro section consists of vehicles driving from one of the terminals into the respective city centre, thus having a more local driving pattern, which is illustrated as flow number 3 in Figure 8. These transports could use the electric road, although probably to a lesser extent. It can be considered unlikely, however, that the vehicles would use the electric road as their main energy supplier.

Road 73 Nynäshamn - Västerhaninge

The Nynäshamn – Västerhaninge section of road 73 has a number of similarities with the E20 Hallsberg-Örebro section in terms of traffic flows, but there are also some differences. Figure 9 illustrates the different traffic flows for the Nynäshamn – Västerhaninge pilot section.

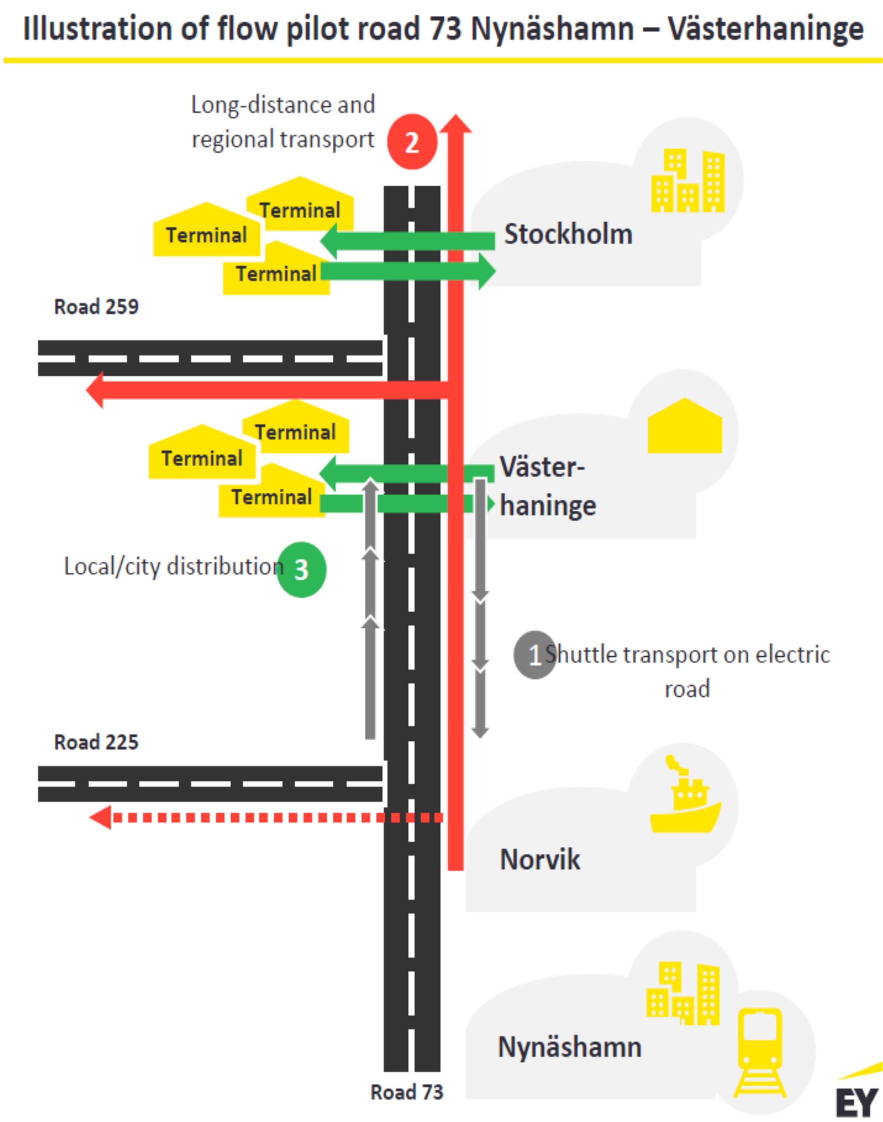



*Figure 9 Illustration of possible flows for the road 73 Nynäshamn - Västerhaninge pilot section*

What characterises this section of road 73 is that in the southern part, close to Nynäshamn, there is the recently opened Stockholm Norvik Port , which is expected to generate an increased flow of goods and transport locally, regionally and nationally. This increased flow is expected to lead to more transports between the Stockholm Norvik Port and Jordbro, as well as on towards Stockholm. This traffic flow could be characterised as shuttle traffic, as flow number 1 in Figure 9, where individual vehicles might use the electric road several times on the same day.

Flow number 2 in Figure 9 represents the long-distance and regional traffic that might pass through the section, which has the Stockholm Norvik Port  as either starting point or final destination, to transport goods into the country or take goods for onward transport by sea. It is less likely that this type of transport would use the electric road in a pilot.

There may also be a traffic flow between terminals and the city centres, shown as number 3 in Figure 9. This could pass along the electric road and use dynamic charging to a certain extent, although this is less likely.

# 4 DESCRIPTION OF STATIONARY CHARGING INFRASTRUCTURE

This section describes a system of stationary charging infrastructure for battery-equipped heavy vehicles, with a focus on financial consequences for different actor categories and for the system as a whole. This section represents a complementary analysis to the presentation above and does not relate to the analysis of organisation of actors in an electric road system or the ongoing investigations of pilot sections in sections 2 and 3.

## 4.1 BACKGROUND TO THE ANALYSIS OF SYSTEMS FOR STATIONARY CHARGING INFRASTRUCTURE

The development of battery technology and stationary charging has been rapid and has shown that it could be possible to equip also heavy vehicles with batteries [8] [9]. From a preliminary comparison of the calculations that have now been made and those for electric roads that were made in 2019, it appears that stationary solutions involve lower investment expenses. Another preliminary assessment is that the legal barriers that the Swedish Transport Administration identified for electric roads do not appear to be as complicated for charging infrastructure. A number of commercial vehicle manufacturers have also demonstrated an intention to introduce heavy vehicles equipped with batteries, initially trucks with a gross weight up to and including 28 tonnes. Lessons can also be learned from the electric bus market and the introduction of electric buses. This is the main reason for analysing alternatives with charging infrastructure and battery-equipped heavy vehicles, as an independent system or in combination with electric roads.

Figure 10 is an illustrative example of how sections of electric road and charging points could be combined on one road. Electric road, marked in yellow, could be found on some parts of a road with a high traffic volume of battery-equipped vehicles. On adjacent road systems or terminals outside the sections of road equipped with electric road technology, there could be charging points for battery-equipped vehicles to use via stationary charging. Along major roads, public charging points, such as at petrol stations or lay-bys, could also be relevant so as to give heavy vehicles the opportunity to charge their batteries.

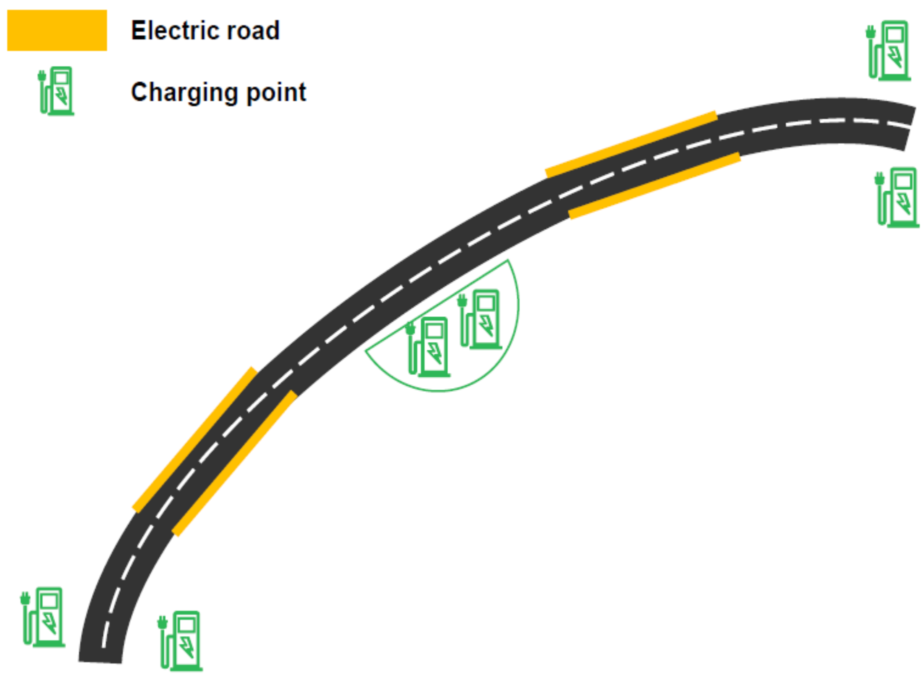



*Figure 10 Illustration of a combination of electric road and stationary charging on a section of road*

### 4.1.1 Purpose of the calculation model

The purpose of the calculation model for stationary charging is to analyse charging infrastructure as an independent system. This provides a basis for being able to make longer term comparisons between different types of electrification for heavy transport, such as a combination of electric roads and stationary charging infrastructure.

The model can be used as a basis for discussion and to form a picture of the commercial sustainability of a system with stationary charging infrastructure and battery-equipped vehicles, given different scenarios for size of system, costs etc. The model makes it possible to vary the different input values and assess the result for the system as a whole, as well as for individual actor categories.

### 4.1.2 Structure of the calculation model

The calculation model for stationary charging has been produced with the same conditions as the financial calculation model for electric roads. In the same way, this model shows the results for a system of stationary charging at a given point in time, with the focus on an annual income statement perspective. With different assumptions of costs and size of system, the model can reflect the situation at a given point in time, such as a specific year.

The model is based on the investments needed from different actors to build a stationary charging system, as well as related operating and maintenance costs of the system's components. The starting point for the calculation model is to make a margin calculation in which the costs for a system with stationary charging and battery-equipped vehicles are compared with the corresponding costs of a system with diesel power.

Based on the work that has been done, and in line with the increased understanding of electric roads and the stakeholders who could potentially use electric roads, a need has been identified to understand which vehicles might use electric roads. This is so as to be able to investigate the financial prerequisites for electric roads. Based on the analyses that have been performed and the data that is available, it has been found during the work that measuring annual average daily traffic (AADT), which was used in the calculation model for electric roads, cannot give the precision or level of detail for different driving patterns, that is needed for an understanding and the full picture of vehicle movements and how the transport sector functions.

A more developed form of data capture is needed so as to give a deeper understanding of how heavy vehicles are used and thus what their needs are and how these shall be met. In the absence of such more developed data, the analysis in this stage has instead been aimed at identifying different parts of the market with different average properties and characteristics. Further analysis can be done to understand how the different parts of the market might use electric roads and the extent to which other alternatives are possible.

Actors in the calculation model for stationary charging

The actors whose circumstances have been analysed in the model are:

- Vehicle owners or carriers
- Owners of stationary charging infrastructure

For carriers, the margin costs of using battery-equipped vehicles, with energy from stationary charging infrastructure, have been compared with those for diesel operation.

The business model for owners of stationary charging infrastructure, who offer charging either at public charging points or as semi-public charging points/destination charging, is based on these actors charging the user a mark-up over and above the electricity cost when charging. This mark-up shall cover depreciation on investments/connection costs, ongoing costs and a profit margin. For charging infrastructure in the carrier's own depot or parking area, only coverage of costs is needed, with no further margin. Thus, public and semi-public charging is assumed to be a service at market price, while charging infrastructure in an actor's own operation is a pure cost item.

The calculation model has provided data to enable analysing a business model at system level. An analysis of the specific business solution for each actor is not included in this analysis but needs to be done separately. However, the model does give a calculated financial result for the different categories of actors.

<u>The different parts of the calculation model and methods for calculation</u>

The calculation model consists of three steps: one for input values, one for calculations and one in which results are reported. The part for input values specifies the data that forms the basis for the specific scenario to be investigated. All parts have adjustable values so that different scenarios can be investigated. The input values are divided into different categories:

- Stationary charging infrastructure, sub-divided into charging at depots, semi-public charging and public charging
- Vehicles, sub-divided into long-distance, regional and city transport
- Fuel

The model also includes reporting of reduced $CO_2$ emissions, based on emission factors for $CO_2$ and the transport's fuel consumption

In the second step, the input values that were defined in step one are used to calculate investment, costs and income for the system's actors. In this part of the model, the responsible actors for each investment component in the system are defined. For example, it shows which actor is responsible for construction as well as for operation and maintenance of public charging infrastructure. The different components that are calculated are:

- Investment expenses, costs of depreciation and interest, as well as operation and maintenance of depot charging, semi-public charging and public charging. This also includes investment expenses for laying the necessary electrical connection to the charging station.
- Investment expenses, costs of depreciation and interest, as well as operation and maintenance (additional costs) for battery-equipped heavy vehicles compared with diesel vehicles
- Cost of electricity, including a standardised amount for output and transfer charges, as well as a price mark-up for semi-public and public charging
- Cost of diesel (used as an output value for the margin calculation)

Depreciation periods for investments are adapted for the different components. Operation and maintenance are given as a percentage of investment expenses.

In the last step, the results for the system and for each actor are given on the basis of the stated input values and calculations. The results cover annual costs (including depreciation of investments, operation and maintenance and any other costs), annual income and results. Income for charging infrastructure owners (other than for depot charging) corresponds to the income from the mark-up on semi-public and public charging.

In cases where a positive result is shown in the calculation model for the entire system, this indicates that there is commercial sustainability in the system. Even in cases where a negative result is shown for the system as a whole, it is possible for the model to show a positive result for one actor but not for another.

For the state, costs are shown as loss of tax and VAT from sale of diesel and income as additional tax and VAT from sale of electricity. This calculation module is intended only to give an estimated calculation of net tax and VAT effects.

Input values and sources

Part of the work on the calculation model for stationary charging and the scenarios presented in the next section has been to identify the input values to apply in the model. The calculation model's input values have been based on research on stationary charging and have been calibrated with actors in the energy industry, the automotive industry and academia. [10]

The sources for the input values that the analysis has been based on are largely the report "Kunskapssammanställning stationär laddning till tunga lastbilar" (Summary of knowledge on stationary charging for heavy goods vehicles - Karlström, 2020) [10] and ASEK (analysis method and socio-economic calculation values for the transport sector) version 7 [7]. There are also assumptions that have been discussed and verified with market actors to a certain extent. As far as possible, the model has been based on ASEK, which contains recommended calculation values for producing socio-economic analyses and traffic forecasts. In parallel with this assignment, a socio-economic analysis of stationary charging infrastructure has also been worked on. There have been dialogues on input data etc. with the sub-project within the Electric Roads Programme that is preparing the socio-economic calculations for systems with stationary charging.

It is important to note that the results reported from the calculation model for the scenarios that have been analysed shall be seen as preliminary results produced on the basis of available data. There is great uncertainty in the basis for input data and assumptions, for example in the form of the development of the market, future manufacturing costs or any competing technologies, which has meant that the analysis is based on a number of assumptions. These values also have a great influence on the results. The results that are presented in the next section should therefore be seen as a starting point for discussion and for a continuation in developing the scenarios.

### 4.1.3 Demarcations and limitations

- The calculation model is based on an annual financial income statement perspective and thus shows costs, income and results for a given year. This means that the model does not calculate discounted cash flow over time, cash flow or balance sheet effects.
- The calculation model cannot, and should not, be used as a basis for investment decisions but should rather be seen as a tool that can show what further analyses might be interesting to perform.
- The assignment decision was to keep the calculation model at general system level, which means that more detailed calculations and analyses of business solutions for individual actors and investment components may be required.
- The calculation model has not included socio-economic effects. For socio-economic effects, there is a parallel, ongoing socio-economic calculation for systems with stationary charging.
- The values that have been used for analysis of investments, operating costs and income must be viewed with caution. In the long term, the values and results are primarily an indication of what the commercial sustainability of the system may be like. For example, it is probable that

more and more knowledge will be accumulated over time, which may mean changing these input values.

## 4.2 A SYSTEM WITH STATIONARY CHARGING AND FINANCIAL CONSEQUENCES

This section describes the types of stationary charging that have been analysed in the calculation model and the markets for heavy vehicles that have been included in the analysis.

Figure 11 is an illustrative example of what a system with stationary charging might look like. The charging types for stationary charging and the markets for battery-equipped heavy vehicles are explained in more detail in the following section.

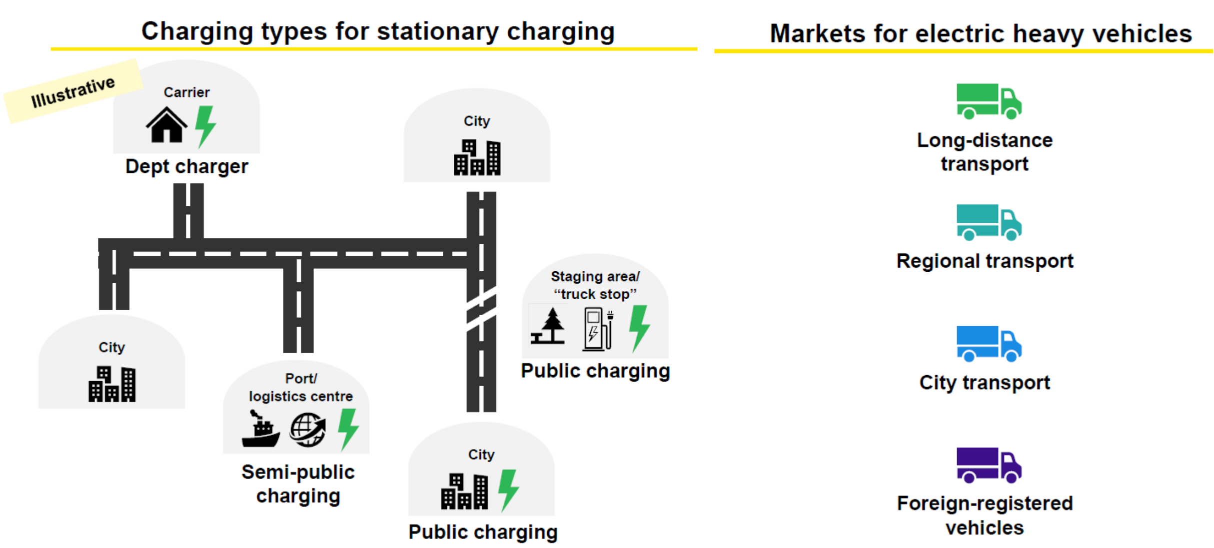



***Figure 11 Illustrative example of charging types for stationary charging and the markets for battery-equipped heavy vehicles***

### 4.2.1 Types of stationary charging

The analysis of stationary charging for heavy vehicles has shown that such a system could consist of different types of charging, where some charging can occur in public charging stations and some charging in parking areas or in depots for parking, maintenance or repairs. In order to capture different types of charging, three forms of stationary charging have been included in the analysis, as shown above in Figure 11:

- Charging at depot/terminal
- Charging at semi-public charging station
- Charging at public charging station

<u>Charging at depot/terminal</u>

Charging at depot occurs when the battery-equipped heavy vehicle is stationary for an extended period, such as at a carrier or a logistics centre. This type of charging can occur at night, for example. It is also possible for depot charging to occur at parking areas along the road where the heavy vehicle is stationary for an extended period. For depot charging, a relatively low charging output, estimated as 22 – 50 kW per charger, has been applied in the analysis since charging is assumed to occur over a long period. [10]

A starting point for the analysis has been that a carrier invests in one depot charger per battery-equipped vehicle, at the carrier's expense. However, the exact location or utilisation of this charger is not analysed here [10]. Since depot charging occurs in a private area, it is assumed that the electricity price for depot charging can be used as an input value without mark-up. This can thus be seen as the charging with the lowest cost and there should therefore be an incentive for carriers as an actor group to ensure that as great a proportion of the energy supply as possible comes from depot charging.

Charging at semi-public charging station

Charging at a semi-public charging station occurs at places where the vehicle delivers or picks up goods, for example at unloading and transshipment centres such as logistics centres, ports or freight centres. For this type of charging, the vehicle is assumed to take the opportunity to charge at a semi-public charging station while it is stationary. It is assumed that semi-public charging is used when the purpose of stopping is not primarily to charge, but if the opportunity arises then it is probable that the vehicle will use the charging station. This assumption means that no time is lost when charging.

For this form of charging, a relatively high output of 150 – 350 kW per charging point has been applied in the analysis. A higher output than in depots has been assumed since the vehicle is stationary for a shorter period of up to a couple of hours. On the other hand, charging at a semi-public charging station is assumed to be for a longer time than at a public charging station. [10]

In the analysis, the business model for owners of semi-public charging stations is based on a mark-up in addition to the electricity price being charged to the user, which is intended to cover the infrastructure costs plus a profit margin.

Charging at public charging station

In this calculation model, charging at a public charging station is defined as charging with a higher output than with depot and semi-public charging. In the calculation model, this form of charging is assumed to be used mainly by vehicles that have a long daily driving distance where the battery’s capacity is insufficient for the distance driven each day. Achieving rapid charging requires chargers with a high output. The analysis has assumed an estimated average output of 350 kW-600kW per charging point. Some charging stations may have a higher output. [10]

It is probable that a public charging station would have access to several charging points that would enable more than one battery-equipped heavy vehicle to charge simultaneously. The financial calculation for owners of public charging has been based here on a mark-up on the electricity price being charged to the user when charging to cover the costs of the infrastructure plus a margin. Because high-output chargers need higher investments than other charging points, the mark-up for public charging has been assumed to be higher than for semi-public chargers. If charging points with a high charging output in the daytime could be used for charging with a lower output at night, this could lead to a different average cost structure for public charging points, but this possibility has not been allowed for thus far in the calculation model.

### 4.2.2 Division of heavy vehicles into four markets

The analysis of vehicle types and carriers as an actor group has been done on the basis of a subdivision into four different sub-markets. This is so as to reflect the varying driving distances and driving patterns of vehicles in each market. The sub-markets of battery-equipped heavy vehicles that have been used in the calculation model are:

- Long-distance transports
- Regional transports
- City transports
- Foreign-registered vehicles

What characterises these different markets is the vehicles' driving patterns. To be able to perform the analyses in the calculation model, it has been assumed that the vehicles' weight class can be used to place vehicles in the different sub-markets. Distributing battery-equipped vehicles into classes on the basis of weight class is an approximation, partly because the boundaries between the different vehicle classes in the different markets are fluid. For future analyses it will be essential to have more correct data on vehicle movements.

Long-distance transports have been defined as the heavy vehicles with the longest driving distances. In order to be able to make calculations, the long-distance transport market has included vehicles of weight classes over 28 tonnes with an average annual driving distance of 90,000 kilometres and a diesel consumption of 0.31 litres per kilometre [10] [7]. It has been assumed that this market will largely make use of the public charging infrastructure and will also be a user of the semi-public charging infrastructure.

In order to be able to make calculations, the regional transport market has been defined as heavy vehicles between 16 and 28 tonnes with an average annual driving distance of 60,000 kilometres and a diesel consumption of 0.25 litres per kilometre [10] [7]. It is probable that regional transports can cover their energy needs to a greater extent from depot charging, given the shorter distances driven each day and lower energy needs. This market has also been assumed to be a user of the semi-public and public charging infrastructure.

The city transport market has been defined as city distribution and local driving of heavy vehicles between 3.5 and 16 tonnes with an average annual driving distance of 45,000 kilometres and a diesel consumption of 0.19 litres per kilometre [10] [7]. City transports have the lowest daily distance driven of the three categories. This means that vehicles in the city transport segment can cover most of their energy needs from depot charging, which is also the most cost-effective form of charging for the carrier.

Part of the transport activity on Swedish roads is performed by foreign-registered vehicles [11]. It can be considered probable that a certain number of these vehicles may use stationary charging in Sweden in a developed system. Foreign-registered transports have been included in the calculation model and affect the system by contributing a further income stream for charging infrastructure owners of semi-public and public charging. If the level of utilisation of existing semi-public and public charging stations becomes too high, this may also mean that further charging stations would need to be added to the system.

In the model, a standardised value of a further 15 per cent has been added to the total for foreign-registered vehicles, in addition to the vehicle kilometres driven by Swedish-registered heavy goods vehicles in Sweden. The additional transport from foreign-registered vehicles has been allocated to the long-distance and regional transport markets. These vehicles have been assumed to charge around 20 per cent semi-public and around 40 per cent public rapid charging. It has been assumed that the remaining 40 per cent energy requirement would be charged from public low-output charging, for example in secure staging areas. This latter energy requirement has not been included in the calculation model.

The calculation model includes a vehicle compensation to the extent that load capacity is limited when the vehicle is equipped with batteries. The reduced load capacity could correspond to a reduction in available payload weight or volume or lost working time when charging. In the calculation model, this factor has been given as a percentage of the reduced load capacity. In the calculation model, this lost load capacity has been compensated with further vehicles, including driver salaries connected with these vehicles. Since the analysis has been at system level, the need for further vehicles is calculated as a whole for the three different markets. The individual actors/carriers have not been taken into account. It is assumed that the lost load capacity will be reduced over time as the technology develops.

Measurements of road transport loads in heavy vehicles performed by the Swedish Transport Administration indicate that for some categories of vehicles there may be a need to increase the percentage of additional vehicles if these are to be equipped with batteries [12]. This aspect needs further analysis.

## 4.3 Analysis of scenarios and overall financial consequences for actors

This section describes the three scenarios for stationary charging infrastructure that have been investigated and analysis for what indications of financial consequences emerged.

### 4.3.1 Description of scenarios for the development of stationary charging infrastructure

In order to create an understanding of the more long term development and commercial sustainability of stationary charging infrastructure, three scenarios have been investigated with the aid of the calculation model:

- A scenario with a *small system* of stationary charging, which can be considered to be an initial stage in one or more geographically limited areas
- A scenario with stationary charging in a *medium sized system*
- A scenario for a *large system*.

A more developed system, corresponding to the *large system*, may be assumed to lie about 20 years in the future. The other scenarios may be assumed to be gradually upscaled until this final point. It would be a reasonable assessment that the first step of development could be taken within a couple of years. Figure 12 illustrates the three scenarios that have been analysed. This figure also reflects the reasoning that has been applied for the development of stationary charging infrastructure.

The analysis is based on the reasoning that an initial *small system* has infrastructure that would be established in a small geographical area. The black circles in Figure 12 can be seen as separate small stationary charging systems, which still permit transport in a larger geographical area, depending on charging output and battery size. The scenario is based on the assumption that the stationary charging infrastructure for heavy transport would initially be built around the major conurbations, since this is where the traffic flow is highest.

For the *medium sized system*, it is assumed that the more local initial systems are developed with more charging points for stationary charging infrastructure and also that more charging infrastructure will be added in smaller towns and other geographical areas. For the *large system,* it is assumed that there will be further stationary charging points in the areas that have already been established and also that many geographical locations will be expanded, which gives greater geographical coverage overall. It has also been reasoned that over time the medium sized system will grow together into a larger network of stationary charging infrastructure.

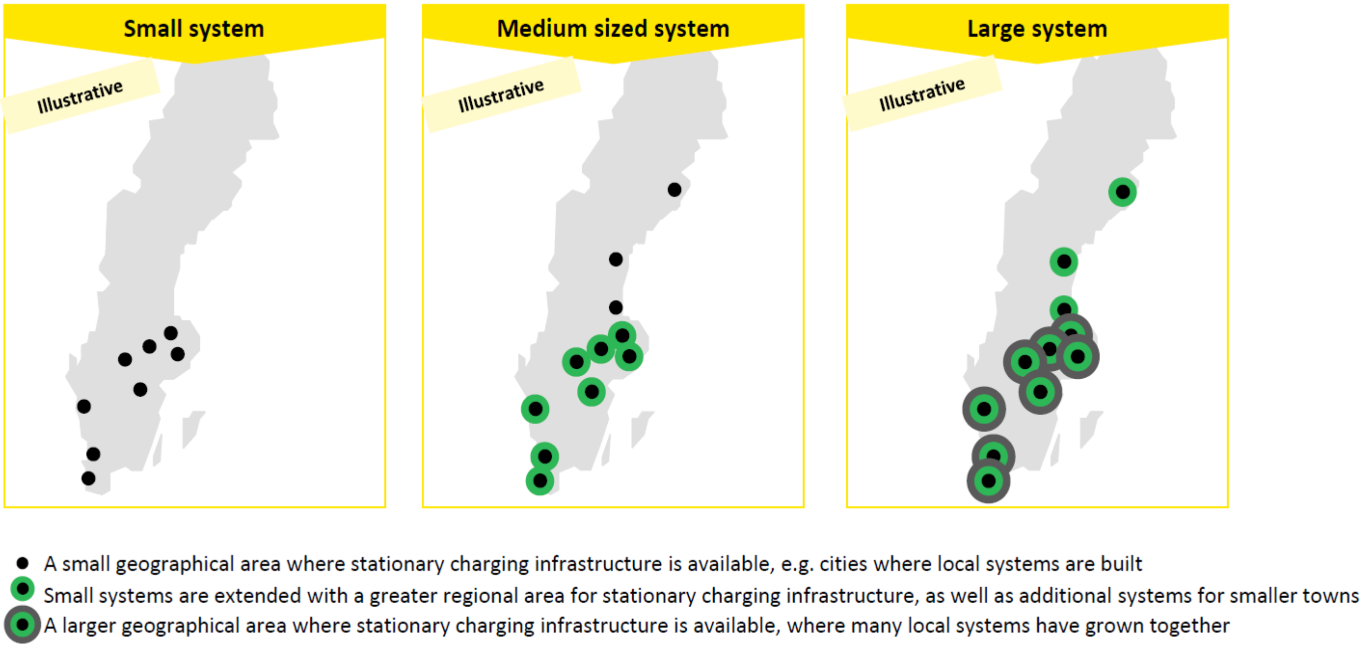



***Figure 12 Illustrative example of the gradual development of stationary charging infrastructure***

The factors that determine the size and scope of a system of stationary charging are firstly the number of battery-equipped heavy vehicles that use stationary charging and secondly the geographical spread of stationary charging infrastructure. It has been assumed that the number of battery-equipped heavy vehicles using stationary charging would increase over time in the three scenarios and this number has been distributed over the three markets of long-distance, regional and city transport.

For the *small system* scenario, it has been assumed that the system would only consist of regional and city transports. This is because the vehicles used in these markets and their driving patterns could perform their transports by mainly charging in depots, only using semi-public and public charging stations to a limited extent. It is also in these vehicle segments that vehicles are already available on the market. The same markets have been included in the *medium sized* and *large system* scenarios.

Many of the variables used as input data in the calculation model are summarised in Figure 13 below. Some of these variables are commented on below.

| | | Number of battery-equipped heavy vehicles (percentage of heavy vehicle fleet >3.5 tonnes) | Charging output | | |
|---|---|---|---|---|---|
| | | | Depot | Semi | Public |
| Small | F | | 22 kW | 150 kW | 350 kW |
| Small | R | 6,800 (15%) | | | |
| Small | C | 2,700 (15%) | | | |
| Medium sized | F | 3,000 (15%) | 35 kW | 350 kW | 600 kW |
| Medium sized | R | 13,600 (30%) | | | |
| Medium sized | C | 9,000 (50%) | | | |
| Large | F | 10,300 (50%) | 50 kW | 350 kW | 600 kW |
| Large | R | 34,000 (75%) | | | |
| Large | C | 13,600 (75%) | | | |

| | | Percentage vehicle km per charging type | | | Number of charging points per battery-equipped heavy vehicle | | |
|---|---|---|---|---|---|---|---|
| | | Depot | Semi | Public | Depot | Semi | Public |
| Small | F | | | | | | |
| Small | R | 80% | 15% | 5% | 1.00 | 0.30 | 0.10 |
| Small | C | 90% | 10% | - | 1.00 | 0.20 | - |
| Medium sized | F | 80% | 15% | 5% | 1.00 | 0.40 | 0.20 |
| Medium sized | R | 80% | 15% | 5% | 1.00 | 0.20 | 0.05 |
| Medium sized | C | 90% | 10% | - | 1.00 | 0.15 | - |
| Large | F | 60% | 30% | 10% | 1.00 | 0.30 | 0.15 |
| Large | R | 80% | 15% | 5% | 1.00 | 0.10 | 0.02 |
| Large | C | 80% | 15% | 5% | 1.00 | 0.10 | 0.02 |

F Long-distance transport
R Regional transport
C City transport

***Figure 13 Scenarios for initial analysis of systems for stationary charging infrastructure***

The percentages given in brackets in Figure 13 above correspond to the proportion of battery-equipped heavy vehicles in the total heavy vehicle fleet [13]. The capacity reduction that has been included in the analysis is compensated by assuming additional vehicles in the system; these additional vehicles are not reported in the figure above.

In order to calculate the number of charging points in the different scenarios, a factor stating the "number of charging points per battery-equipped heavy vehicle" has been used in the calculation model. This factor has been given different values for different types of charging points and for the different markets, based on assessments in various sources and in close dialogue with the actors in the industry [10] [14]. At this early stage, these figures must be regarded as hypothetical. The various input data has been used for the factor "number of charging points per battery-equipped heavy vehicle" presented in Figure 13.

Based on the number of battery-equipped heavy vehicles and the number of charging points for these, Figure 14 shows the total number of semi-public and public charging points, as well as the level of utilisation of these at system level for the three different scenarios (calculated in relation to total available charging time). It has been assumed for all scenarios that there is one depot charger for every battery-equipped heavy vehicle.

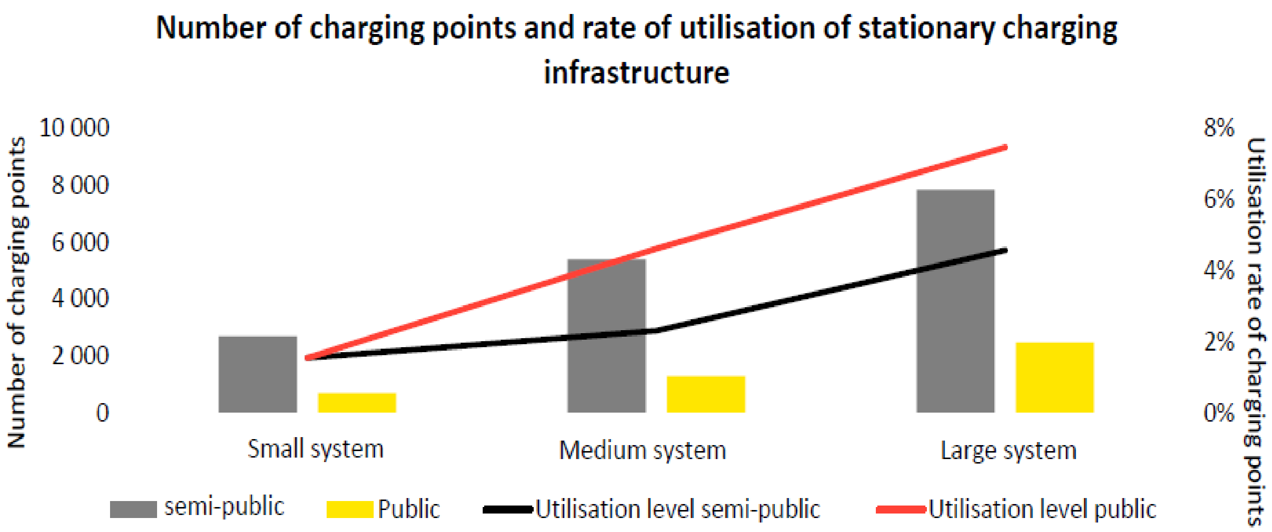



***Figure 14 Number of charging points and level of utilisation of stationary charging infrastructure for the three scenarios***

The number of charging points has increased somewhat more quickly than the number of vehicles in the three scenarios. This is based on the assumption that the charging infrastructure needs to be in place before battery-equipped vehicles are able to use it to a greater extent. This means that the utilisation rate will have a more or less linear increase, with semi-public charging something of an exception since it seems reasonable to assume a certain amount of "overdevelopment" so as to establish a sufficiently attractive system. The utilisation rate can also be used to give an indication of whether the number of charging stations should increase or decrease there. A low utilisation rate could lead to low profitability in the system, although such an optimisation of utilisation rate has not been included in this study.

The gradually increasing utilisation rate is illustrated in Figure 14, where the utilisation level for public charging infrastructure goes from about two per cent in a *small system* to about seven per cent in a *large system*. A factor stating the "number of vehicle kilometres per charging type" has also been given. This factor corresponds to the proportion of the energy needs of each of the markets that is met by the different types of charging, where the starting point has been that most of the energy needs are met via depot charging (about 60 - 80 per cent). Semi-public charging corresponds to about 15 - 30 per cent of energy needs and public charging about 5 - 10 per cent [14].

### 4.3.2 Financial consequences for actors in systems with stationary charging

Based on the financial calculation model, preliminary analyses have been performed for the financial consequences for actors in a system with battery-equipped vehicles and stationary charging.

Financial consequences in systems with stationary charging

The financial consequences for the three different scenarios for developing a system with stationary charging are illustrated in Figure 15. The graph indicates that there could be commercial sustainability in a system with stationary charging infrastructure for the *large system* scenario. The indication for the small and medium sized systems is that it would be problematical to achieve commercial sustainability.

Annual costs, income and results have been analysed in general terms at system level and are presented below. The costs, income and results that are presented in Figure 15 are a summary of balanced costs and income for all actors in the system.

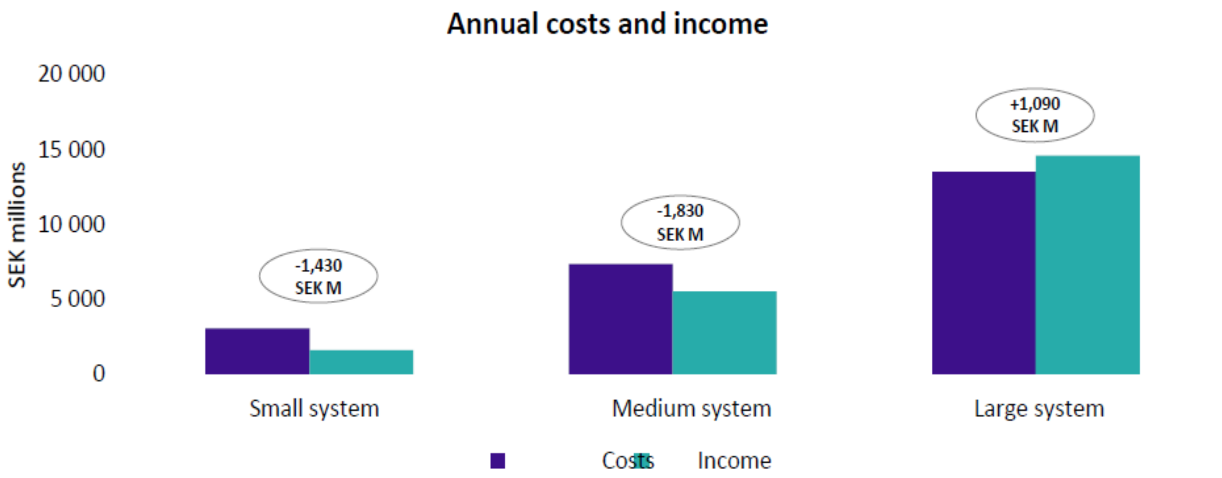



***Figure 15 Annual costs and income in the system for stationary charging infrastructure for three scenarios, as well as the combined annual financial results in the system (infrastructure and vehicles)***

On the basis of the input values that have been applied for the different scenarios, the calculation model gives an indication that it could be possible to achieve commercial profitability in a system of charging infrastructure and battery-equipped vehicles, in the longer term. Many of the variables used as input values have an influence on the results; there is also uncertainty in the value of these variables, which should be considered when interpreting the results. The variables that affect the results from the calculation model are the comparative costs of diesel and electrical operation, investment costs of charging infrastructure and battery-equipped vehicles and the level of utilisation of the stationary charging infrastructure. The preliminary results from Figure 15 should thus be viewed with caution and further analysis of investment levels should be performed in the next step.

Comparative costs of diesel and electrical operation have proved to have great significance for the results for the system as a whole, and especially for carriers as an actor group. The input values for both diesel and electricity consumption, as well as the price of diesel and electricity, have been shown to be variables that influence the result. Uncertainty about future price trends for these variables, as well as potential energy efficiency increases in the vehicles make a considerable contribution to the uncertainty in the results from the calculation. Values from ASEK 7 have been used in the scenario analyses. In accordance with ASEK, the analyses have also applied an estimate of diesel and electricity prices over time with a forecast that is intended to reflect the defined environmental goals [7]. For energy consumption, an increase in efficiency of 1.8 per cent per year has been assumed for both diesel and electricity consumption by vehicles. The analysis shows that if diesel is comparatively cheaper to use than electricity, the incentive to use electricity is weakened.

The levels of investment expenses for the different parts of the system (stationary charging infrastructure and additional cost of battery-equipped vehicles) vary between the three scenarios and have an influence on the results from the calculation model. It has been assumed here that in the longer term there will be economies of scale in the industrialisation and streamlining of production that will be reflected in lower costs for the different investment components in the system. However, there are uncertainties in the above scenarios in terms of what level of investment expenses should be used so as to give a fair picture of the investments that would be needed to build up a medium sized and a large system.

The analysis has shown that it is probable that a higher utilisation level of the stationary charging infrastructure for the large scenario would have a positive effect on the results. Volumes from foreign-registered vehicles are also included in the medium sized and large system scenarios and would give, as described previously, an increased income flow to the owners of the public and semi-public stationary charging infrastructure. The analysis shows that a sufficiently high level of utilisation is required to achieve profitability for the stationary charging infrastructure, although this level of utilisation is relatively low, seen from an annual perspective.

Calculated in this way, the higher utilisation level for charging points in the large system scenario is based to a certain extent on volumes from foreign-registered, battery-equipped heavy vehicles. As a next step in the analysis, it would be interesting to further investigate possible effects on results of a higher utilisation level of the charging infrastructure. The balance between how many additional charging points need to be built to ensure geographical coverage while ensuring a sufficiently high utilisation level is also important for further analysis.

Implications for owners of stationary charging infrastructure from the scenarios analysed

The scenario analyses have indicated that one of the decisive factors for profitability for the actor group of owners of charging stations is how great the mark-up on the electricity price is for semi-public and public charging. A higher mark-up is obviously beneficial for owners of stationary charging infrastructure, but would lead to a poorer financial calculation for carriers. It is of course difficult to assess a reasonable long-term level for the mark-up for semi-public and public charging that would provide the conditions for an effective market. It is reasonable to assume that a period would be needed in which different price strategies exist in the market before models that function in the long term can be established. The development of price models on the mobile phone market over time could be a source of inspiration for evaluating future pricing strategies in this context.

A further factor of great significance for profitability for owners of stationary charging infrastructure is the charging output that the charging infrastructure is to offer. In the analysis, the investment expenses have been based on the output that is offered and the investment increases with higher output [10]. There is also a connection here with the time that heavy vehicles must use for charging. With a higher charging output, battery-equipped heavy vehicles could be charged more quickly and a charging point could be used by several vehicles over the same time period. This increase in the number of charging sessions offered per unit of time must however be balanced against the significantly increased investment costs inevitably associated with the charging output offered. A higher charging output also means that the utilisation level would go down, since vehicles spend less time at the charging point. This may need to be compensated by having fewer charging points or a higher mark-up. The net effects of more charging sessions and higher investment expenses need further analysis in the future.

Implications for carriers from the scenarios analysed

For carriers as an actor group, a great deal of the investment consists of the additional costs of equipping heavy vehicles for battery operation instead of with diesel powertrains. The vehicle component that decides how great the additional expenses are for battery-equipped vehicles is battery capacity expressed in kWh. In the calculation model, different battery sizes have been assumed for long-distance, regional and city transports. For example long-distance transports, on the basis of the driving pattern that characterises their market, have been assumed to require larger batteries, while city transport, based on the driving pattern, is assumed to require smaller batteries, in terms of battery output.

A probable hypothesis for a future scenario is that the battery capacity needed for heavy battery-equipped vehicles could be reduced in the longer term. This could be made easier with a well-developed system with good access to public charging infrastructure, meaning that the vehicle could travel greater distances with smaller batteries. Another possibility is that battery capacity could be optimised over time based on how the battery-equipped heavy vehicle is used.

It has been assumed in the calculation model that carriers bear the investment costs of depot charging. This investment is however less than the additional cost of battery-equipped vehicles. Carriers also have expenses for electricity consumption. The mark-up with semi-public and public charging is paid by the carriers, and it has been assumed that the long-distance and regional transport markets will use public charging to a greater extent than city transports.

The analysis has shown that depot charging can be assumed to be the cheapest form of charging, in comparison with what carriers pay for electricity for public charging. However, the driving patterns of regional and long-distance transport in particular limit the total volume of energy that can be charged in depots. Public stationary charging complements the energy needs for these markets.

# 5 PROPOSALS FOR FURTHER INVESTIGATION AND RECOMMENDATIONS FOR THE NEXT STEP

Electric roads and stationary charging have been discussed in this report and are judged to be technologies that would probably affect each other and interact in a growing market for the electrification of heavy vehicles. These electrification technologies may also need to be seen in relation to other technical developments that are occurring, such as fuel cells. The recommendation for further work is thus to extend the analysis for electric roads, now with the addition of stationary charging, so as to perform comparisons between different electrification alternatives for heavy road transport. Analysis may also be needed so as to understand what role the Swedish Transport Administration might have and what degree of involvement is required.

Two main areas are suggested to be analysed in the next step:

1. **Deeper analysis of business models, interfaces and distribution of responsibilities between different actors with regard to different electrification technologies for heavy vehicles**
   With new electrification alternatives for heavy vehicles, such as electric roads, stationary charging etc., actors will need to interact in new markets. There may also be new actors, which may mean that a number of new, and in some cases complex, relationships may need to be formed. It will therefore be important to further analyse interfaces and distribution of responsibilities between different actors to create an understanding of how the different electrification alternatives can be formulated and influence each other.

   On the basis of interfaces and distribution of responsibilities that are developed between actors, it is also important to understand how business models for different electrification alternatives can arise. To create an understanding of what markets for different electrification alternatives may be like, deeper insights must be found into what driving forces and incentives the different actors have. Experience gained in the work on business models for electric roads can be taken into account in continuing analysis of business models for different electrification alternatives. Another aspect to bear in mind is how different electrification alternatives and their associated business models can interplay, as well as any need or opportunity to combine these business models. The recommendation for the next step is therefore to continue to analyse business models, interfaces and distribution of responsibilities to be able to identify the opportunities and challenges of the different electrification alternatives.

2. **Extend the analysis of cost structures and business opportunities between different electrification technologies so as to be able to weigh up different alternatives against each other.**
   Comparison and analysis should be performed of different electrification alternatives. As a first step, an analysis is proposed of the two calculation models that he been devised for electric roads and stationary charging respectively. The calculation models' cost and income calculations are an important support for this analysis work and can be supplemented with similar models for fuel cells, for example. Scenarios with different combinations of electric roads, stationary charging and fuel cells may need to be discussed to understand the differences between these and also how the development of the electrification of the national road network for heavy transport should occur. The recommendation for the next step is therefore to extend the analysis of cost structures and business opportunities to also include fuel cells and to compare different electrification technologies.

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