



Roles, actor relations and risks in the electric roads market

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Summary

Sweden's long term climate objective is to have no net emissions of greenhouse gases by 2045, and thereafter to achieve negative net emissions. For greenhouse gas emissions from domestic transport, except domestic aviation, the goal is for these to be reduced by 70 per cent by 2030, compared with emissions in 2010. One of several possibilities for reaching this goal is the electrification of heavy road transport, and in this connection the Swedish Transport Administration is running a major programme to develop and implement electric roads.

In May 2018 the Swedish government decided to commission a major electric road pilot project from the Swedish Transport Administration. The target is for an electrified pilot stretch to be operational in 2021, and this assumes government financing of a maximum of 50 per cent of the cost, with a ceiling at SEK 300 million. The pilot phase is intended to test parameters such as legal conditions, potential business models and planning.

In preparation for the pilot phase, EY was assigned to assist the Swedish Transport Administration in examining the conditions for business models in greater detail, on the basis of the government's decision to draw up a proposal for implementation. The focus has thus been on the pilot phase, but in the course of preparing this report it has become clear that the issues concerning the various phases of developing an electric road system are largely similar. The report therefore covers both time perspectives, i.e. the pilot phase and long term development. It supplements and expands on the report that was prepared in the spring and summer of 2018 concerning possible organisation and financing of the future development of electric roads [1].

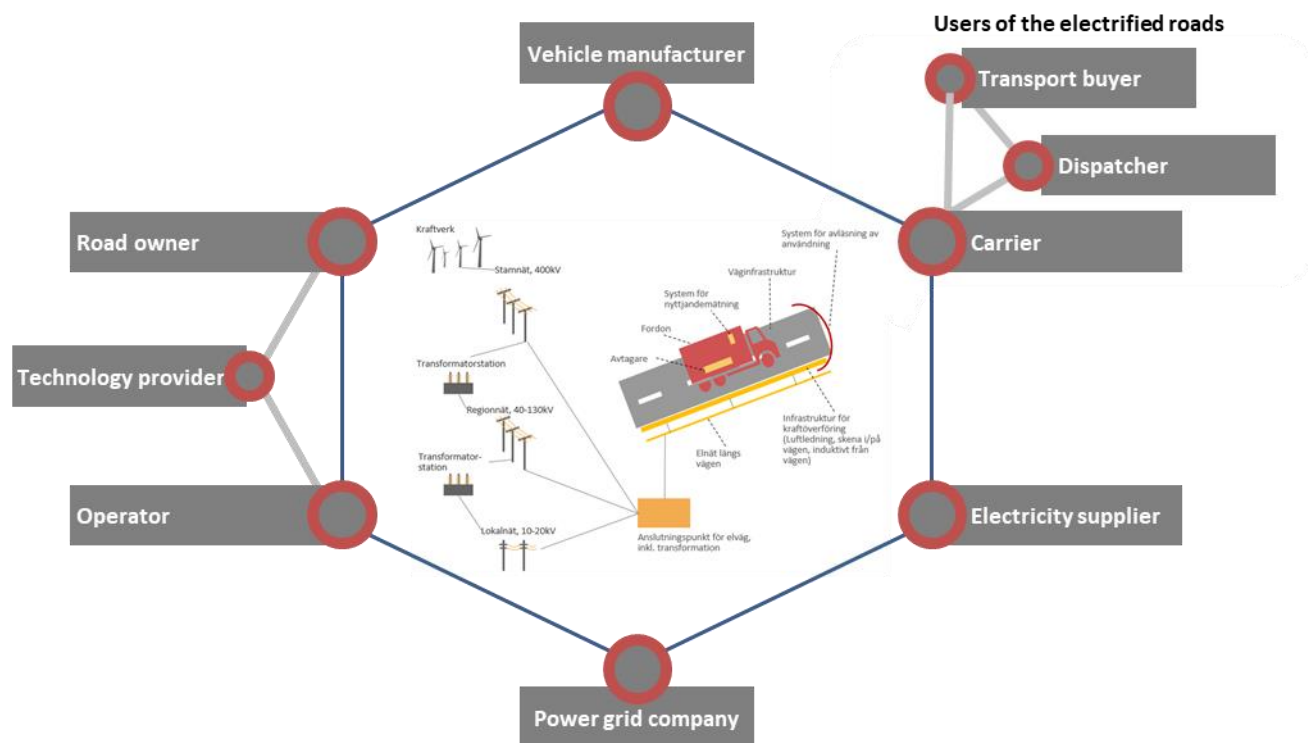
The assignment was carried out in close collaboration with the Swedish Transport Administration and in dialogue with actors in the electricity, telecoms, forwarding, transport and vehicle industries. Meetings were aimed at exploring what roles different actors might have in a future electric roads market, and what the conditions for their interest in participating are. In addition to the market dialogue, two information meetings, led by the Swedish Transport Administration, were held with a number of different market actors present.

Assumptions regarding the Swedish Transport Administration's role

The role of the Swedish Transport Administration in the development of electric roads can be described as setting the framework and creating the conditions for the market to develop. It is not the task of the Swedish Transport Administration to define every aspect of business relations in the emerging electric road system, but it does have a responsibility to drive development and, if possible, contribute to the forming of the market. Given the short amount of time left before a pilot installation has to be ready, the assessment is that the Swedish Transport Administration will need to take a more active role during the pilot phase than what will be feasible for the longer-term development. This applies e.g. to the Swedish Transport Administration possibly taking a more active financing and ownership role with respect to electric road infrastructure than what is judged to be necessary in the longer-term development phase.

Roles and actor relations in the electric road system

Below we describe a possible organisation of electric road development, both during a pilot phase and over the longer term, on the basis of an overall structure for the roles that are expected to be included in the electric road system. At the centre of the diagram is the schematic image of the structure of the electric roads market that was drawn up in the preceding report [1].



Road infrastructure manager

The Swedish Transport Administration has a statutory responsibility as infrastructure manager of public roads, and thus also of such roads as will be electrified. The road infrastructure manager is in direct contact mainly with two actors within the electric road system – operators (a future role that is described in this report) and electricity grid owners. The relation with operators follows from their activities in the road area¹, where the Swedish Transport Administration is responsible for operations and maintenance, and matters regarding e.g. accessibility. Core elements of the Swedish Transport Administration’s relations with electric road operators include operational reliability, monitoring and maintenance of the electric road system, since these roles can affect the Swedish Transport Administration’s areas of responsibility.

The road infrastructure manager is also likely to have a relation with electricity grid owners, as there will be a physical interface in the electric installation between the road area and the electricity grid infrastructure. EY’s assessment is that there is much to suggest that the Swedish Transport Administration will own the electric road infrastructure in the road area during the pilot phase. It is simply the case that the time until 2021 is too short to arrange for external owners to assume this role.

While the road infrastructure management responsibility is unlikely to change and the government, via the Swedish Transport Administration, will continue to be the formal manager of road infrastructure for electric roads as well, there are several different possibilities for how the roles in the electric road system for providing electricity grids, electric road infrastructure and metering/invoicing can be divided between public and private sector actors. In this report, EY has considered both public and private ownership and financing of these different parts of the system.

¹ The Roads Act (1971:948) defines the term road area (“vägområde”) as land that has been put to use for road fixtures, and the road fixture itself. Road fixtures comprise all fixtures permanently needed for the existence, operation or use of the road, and which have been installed or taken over by the road infrastructure manager. [27]

Operators

At a comprehensive level, the hypothetical operator role can be described as the connecting physical and/or operative link between road, electricity, vehicles and infrastructure. The obvious motivation for businesses to take on the role of operator is to partake of a completely new market with new business opportunities and revenues that did not previously exist. The incentives for participating in the pilot phase would then be to build knowledge about this emerging market at an early stage and take a market position. There may also be incentives for operators to own the electric road infrastructure, since that can lead to a long term, green investment, with stable cash flows over time. However, various different organisational and financial solutions are possible.

It has emerged in the market dialogue that the electricity grid companies, which are supply-driven companies and apply long depreciation periods, can be regarded as potential actors in the operator role and as owners of electricity road infrastructure. Telecoms companies, (fossil) fuel actors and electricity suppliers possess knowledge and experience that could be of use to an operator, it has emerged during the preparation of this report. Neither is it unthinkable that the state, via the Swedish Transport Administration, would take this role.

Electricity grid owners

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

Electricity suppliers

The role of electricity suppliers in the electric roads market will likely be similar to their traditional role in the electricity market, which includes the sale of electricity and invoicing. Their relation can be directly with users, or be channelled via the electric road operator. There is also an interface with the actor that will be in charge of measuring users' electricity consumption, either as a part of the operator role or as a separate service. In order to ensure the free choice of electricity suppliers under the general principles of the Electricity Act (1997:857), it is reasonable that users will be given the possibility of choosing their electricity supplier.

Road users

An electric road system has the potential of creating competitive advantages for users in the form of lower costs and the possibility of positioning themselves as green logistics actors with sustainable deliveries. Lower fuel and maintenance costs for electric vehicles compared with diesel vehicles are considered the main driving forces for getting users to actually use electric roads, during the pilot phase as well as in the longer term. It is also possible that users will utilise the electric road system even if the total cost is the same as for diesel vehicles, but unlikely that they will do so if the total cost exceeds that for diesel vehicles.

Vehicle manufacturers

Vehicle manufacturers' participation in the pilot phase would reasonably be motivated by obtaining early competitive advantages and eventually by gaining market share. In order to manufacture vehicles in time for the 2021 start of operations of the pilot installation, information about the section of road in question and the development of the electric road along it needs to be provided early, as these factors affect vehicle specifications. Vehicles need to be ordered with sufficient time margin, probably no later than by the end of 2019.

Defining roles and actor relations

There are several actors that could take on different roles and be part of shaping the future electric roads market. These roles have several interfaces with each other that imply various types of business relations, incentives and challenges. The role as electricity grid owner appears to be one of the most decisive for the structuring of the system, in terms of responsibility for electricity distribution as well as being a potential investor in and owner of the electric road infrastructure. The involvement of and business opportunities for electricity grid owners will be determined partly by whether electricity grids for electric roads are to be regarded as concessionary or not – an issue being studied by the government's Grid Concession Commission [2].

Organisation proposal for the pilot phase

Two main interfaces, or assignments, are proposed for the Swedish Transport Administration:

1. Acquire, build and manage the electric road infrastructure
2. Organise and procure the operator role.

The actors that are given these assignments will then, in turn, be free to engage any subcontractors and partners needed in order to fulfil the roles required in the system. The advantage of only having two assignments is that the risk of demands and dependences between parties is minimised – and in organisational terms it emulates a likely long term solution to the greatest extent possible.

Potential organisation in the longer term

There are a number of circumstances for longer-term development that differentiate it from the pilot phase. For the further development of electric roads, the following possibilities can be envisaged:

- Private actors can initiate, build, own and operate electric road infrastructure
- As an alternative, the Swedish Transport Administration can own the electric road infrastructure and then procure the operator function as a service concession for an extended period
- The electric road operator has the overall responsibility for running the electric road installation
- An electric road operator can operate several stretches of electric road
- Users have a free choice of electricity supplier and are charged based on actual consumption
- Technology and metering are standardised, and users can easily drive on different stretches
- New services, adapted to the electric road, are developed and provided by third party suppliers
- Further business opportunities are developed through peripheral services occasioned by the electric road

Uncertainties and risks for further study and management

There are several risks and uncertainties connected with the pilot phase, particularly regarding financing and profitability, but also regarding the Swedish Transport Administration's role. Since many issues, particularly legal and financial ones, remain to be addressed it appears uncertain whether the goal of putting a pilot phase of the desired scope into operation in 2021 will be possible to achieve.

Recommendations for the next step

As a next step, the Swedish Transport Administration is recommended to proceed with three procurement-like projects in preparation for the pilot phase:

- Selection of road section (ongoing)
- Construction of electric road infrastructure
- Continued analysis of the operator role, and procurement of an operator

In addition to the three projects above, we also recommend that the legal analysis be prioritised, as its outcome may be decisive in determining how the development of electric roads can be implemented.

The next step should also include making a business investment estimate – at least a general one – for electric road development as a whole, and also for each participating actor.

In order that these three projects can be run in parallel, while many complex issues still remain, it is crucial that all work be carried out efficiently and in a way that secures the market's continued trust.

TABLE OF CONTENTS

Summary	1
1 Introduction	7
1.1 Background.....	7
1.2 Aim.....	9
1.3 Method.....	9
1.4 Delimitations	10
2 Conditions for the implementation of the pilot phase.....	11
2.1 Assumptions and premises regarding the Swedish Transport Administration's role.....	11
3 Supplementary market dialogue about the development of electric roads in the short and long term.....	13
3.1 Electricity market actors	13
3.2 Vehicle manufacturers.....	14
3.3 Hauliers and freight forwarders.....	14
3.4 Telecoms	15
4 Roles and actor relations within the electric road system.....	17
4.1 Road infrastructure manager	17
4.2 Operator	18
4.3 Electricity grid owners.....	18
4.4 Electricity suppliers.....	19
4.5 Road users	20
4.6 Vehicle manufacturers.....	20
4.7 Summary of incentives and conditions for private actors' participation in the development of electric roads.....	21
5 Issues of decisive significance for the coming development.....	23
5.1 Financing, profitability and conditions in terms of calculations.....	23
5.2 The Swedish Transport Administration's responsibility and interfaces with private actors.....	26
5.3 Connection to the electricity grid.....	28
6 Conclusions on models for implementation.....	29
6.1 Shaping roles and actor relations	29
6.2 Proposal for organisation of the pilot phase.....	30
6.2.1 Acquisition and construction of electric road infrastructure.....	31
6.2.2 Organisation and procurement of the operator role.....	31
6.3 Potential organisation for the longer term	33
6.4 Uncertainties and risks for further analysis and management	34
7 Recommendations for the next step	35

1 Introduction

1.1 Background

Sweden's long term climate objective is to have no net emissions of greenhouse gases by 2045, and thereafter to achieve negative net emissions. For greenhouse gas emissions from domestic transport, except domestic aviation, the goal is for these to be reduced by 70 per cent by 2030, compared with emissions in 2010. One of several possibilities for reaching this goal is the electrification of heavy road transport, and in this connection the Swedish Transport Administration is running a major programme to develop and implement electric roads.

The Swedish Transport Administration's work on electric roads is carried out within the Electric Roads Programme [3] and includes testing different methods for electric roads with the aim of accumulating knowledge regarding construction, operation and use. The Electric Roads Programme encompasses all areas of activity in the Swedish Transport Administration. To date there are two demonstration stretches for electric roads in Sweden – one on the E16 outside Sandviken and one in Rosersberg, near Arlanda outside Stockholm [3]. The Swedish Transport Administration is currently working on the completion of three more demonstration projects for the development of different electric road technologies, and on a bigger pilot phase.

In May 2018 the Swedish government decided to commission at least one major electric road pilot project from the Swedish Transport Administration [4]. The target is for a pilot section of road to be operational in 2021, with co-financing by businesses, and for government financing to cover a maximum of 50 per cent of the cost, with a ceiling at SEK 300 million. While the demonstration projects test different electric road technologies, the pilot phase is intended to comprise legal conditions, organisation, financing, and spatial planning, see Figure 1 below.

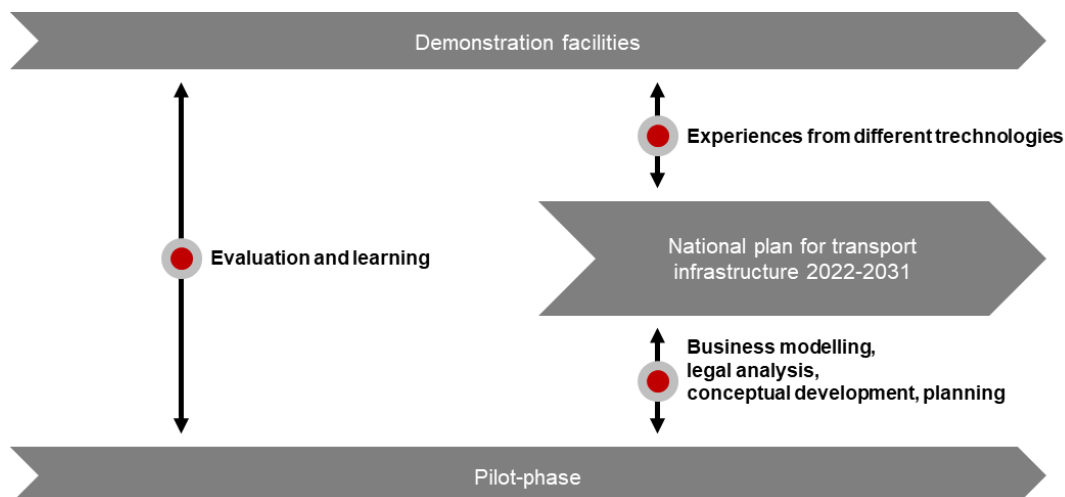


Figure 1. The Electric Roads Programme 2018–2022 [5]

The demonstration projects and the pilot phase shown in Figure 1 are run in parallel and are intended jointly to provide lessons and experiences for the 2022–2033 National plan for the transport system and the continued development of electric roads in Sweden [5].

In the spring and summer of 2018 the Swedish Transport Administration, supported by EY, analysed possible organisational and financing solutions for the future development of electric roads [1]. Results included an overview of the electric road system's components and services, see Figure 2.

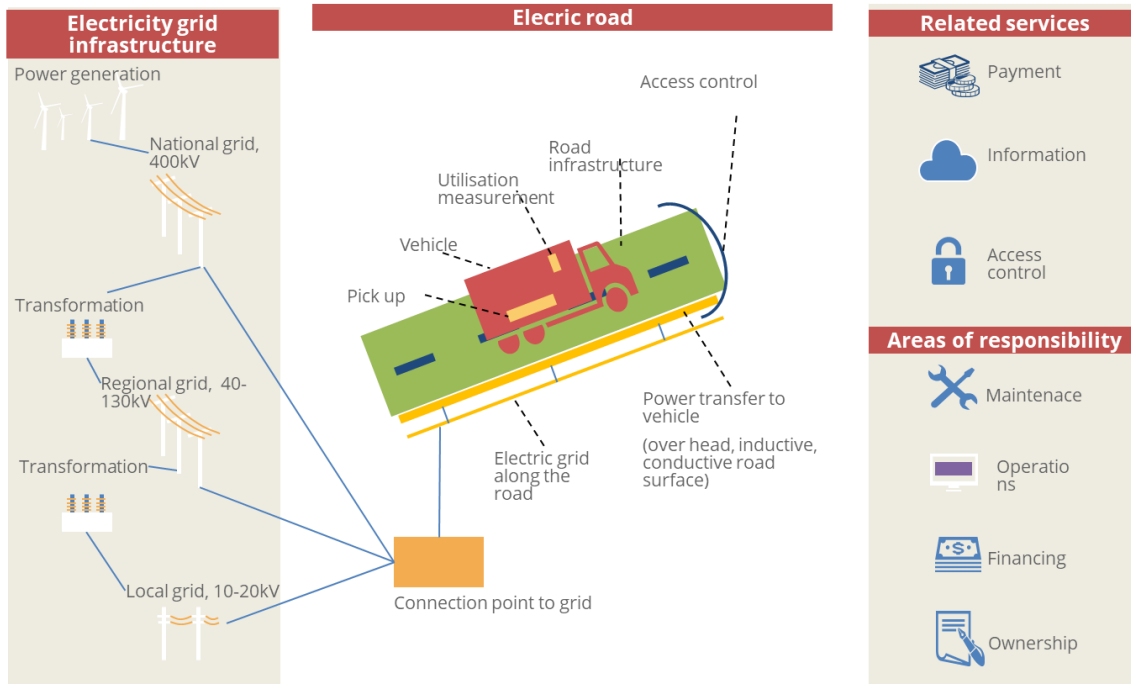


Figure 2. Components and services of the electric road system

The analysis also resulted in a proposal for a preliminary organisation into four different business packages, see Figure 3.

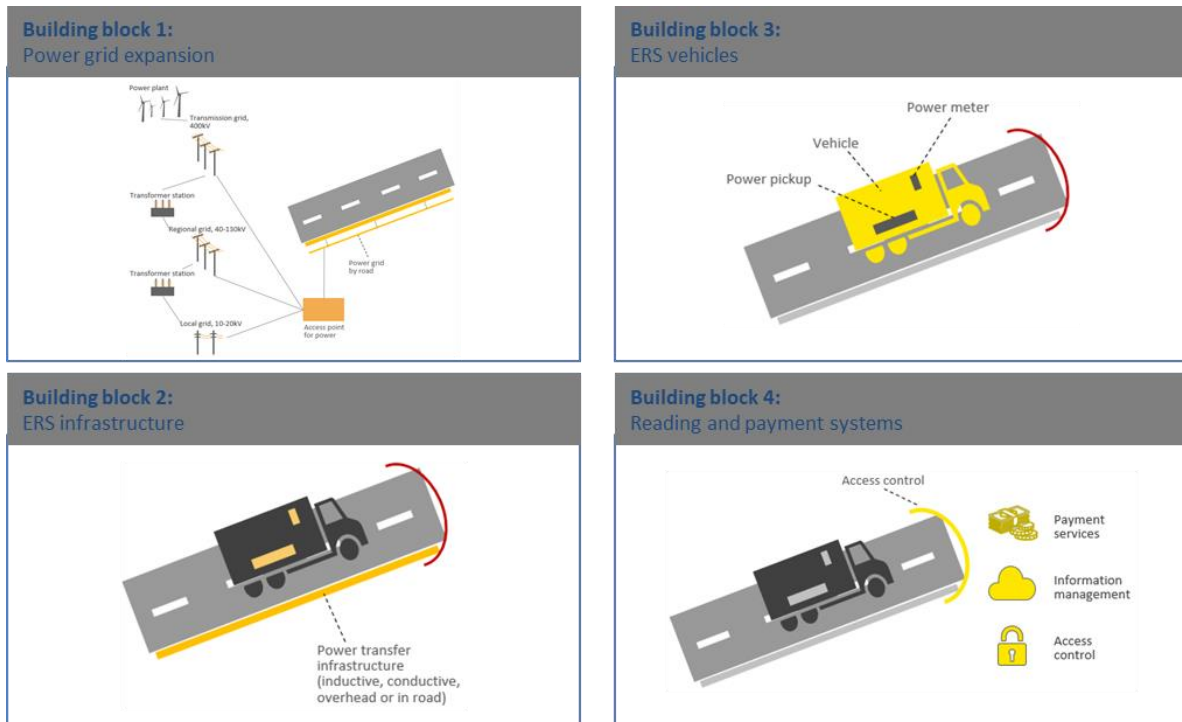


Figure 3. Organisation into four different business packages

In preparation for the actual development of electric roads and in particular for the realisation of the pilot phase, EY was assigned to assist the Swedish Transport Administration and the Electric Roads Programme with more specific analyses of conditions for business models, on the basis of the government's decision to draw up proposals for practical implementation. The part of this assignment that is presented in this report was carried out between October 2018 and January 2019, with the Swedish Transport Administration's Björn Hasselgren as the contact point.

1.2 Aim

The aim of this report is to draw up feasible models for how the development of electric roads in Sweden can initially be carried out in terms of organisation, roles and responsibilities.

The report adopts two perspectives: that of an initial development by means of the pilot phase commissioned by the government, and that of a longer-term development. Wherever possible, both perspectives are described and compared with each other, and proposals are made and conclusions drawn about the organisation of the pilot phase as well as of longer-term development.

1.3 Method

This report is the product of information gathered and analysed in five main steps between October 2018 and January 2019:

1. Project initiation
2. Mapping of conditions for implementing the pilot phase
3. Supplementary market dialogue
4. Analysis of the result of the market dialogue
5. Reporting of results

The report is intended to bring an increased understanding of the market as a whole. In step 3, the market dialogue, ten separate dialogue meetings were held with different actors. The object of the market dialogue at this stage is not to be comprehensive; instead it supplements and expands on the report produced in the spring of 2018 [1]. The actors that participated in individual meetings during the market dialogue were:

- E.ON Energidistribution
- Vattenfall Eldistribution
- Ellevio
- Fortum
- Volvo
- Tele2
- Nokia
- Sveriges Åkeriföretag (the Swedish Association for Road Transport Companies)
- Transportföretagen (the Swedish Confederation of Transport Enterprises)
- Telia

The meetings were aimed at exploring what roles different actors might have in a future electric roads market, and what the conditions for their interest in participating are. A number of headline issues were formulated as part of a guidance dossier for the dialogues, see annex.

In addition to the market dialogue, two information meetings and a bigger seminar on electric roads were held, and were attended by a broad spectrum of market actors. Besides private actors, principally from the industries mentioned above, representatives from various regions, municipalities, and academia, as well as other stakeholders such as RISE and Energimarknadsinspektionen (the Swedish Energy Markets Inspectorate), took part in the information meetings. In the course of the meetings the Swedish Transport Administration informed about the ongoing work, and a discussion was held about different proposals and ideas regarding implementation. The information meetings also helped develop and deepen the relation between the Swedish Transport Administration and the market.

This report presents the results in seven chapters: Chapter 2 describes conditions and assumptions, Chapter 3 presents the results of the market dialogues, and Chapters 4–7 present EY's analyses, assessments and recommendations.

Weekly working meetings were held by the project group (the Swedish Transport Administration and EY), where results from dialogue meetings, analyses and other work were reviewed and processed in order to produce and evaluate proposals for implementation models. Analyses were carried out in close collaboration between the Swedish Transport Administration and EY, and the project's status was reported on a continuous basis to the Electric Roads Programme.

This report was prepared between October 2018 and January 2019. Information that has come to the project group's attention after 15 January has not been taken into consideration.

1.4 Delimitations

The report focuses mainly on the pilot phase, but also touches on long term development to the extent that this has been possible. The pilot stretch had not yet been chosen when this report was prepared; this is the subject of a parallel analysis in the Electric Roads Programme. This means that the proposals and models produced do not take specific conditions such as traffic volume, the proportion of electric road on the section, or investment volumes into consideration. The results and conclusions are therefore formulated in more general terms than what will be required for an actual pilot development. However, the fact that the analysis has not been limited to a specific stretch may facilitate the drawing of more general conclusions about electric road development over the longer term as well.

As mentioned earlier, the work of the Electric Roads Programme follows several parallel tracks that will have a direct influence on how the development can be organised, both in the pilot phase and over the longer term. Of the parallel analyses being carried out within the programme, the following have had points in common with this report:

- The choice of pilot stretch
- Legal analysis
- Financial analysis

There are probably a considerable number of other analyses with a bearing on the practical conditions of the development, but the ones listed above are those that have emerged specifically and been identified during the preparation of the report. Where this has been possible, experiences from the ongoing projects have been obtained. However, as this report was prepared slightly earlier than the others it has been difficult to absorb into it any real conclusions from the other analyses.

2 Conditions for the implementation of the pilot phase

In order to initiate the development of electric roads in Sweden, the Swedish Transport Administration has been commissioned by the government to build a pilot stretch and put it into operation [4]. This stretch will briefly describe what prerequisites and conditions govern implementation of primarily the pilot phase, and also a couple of assumptions regarding organisation for the pilot phase and over the longer term.

The government's decision specifies three conditions for the implementation of the pilot phase [4]:

- The pilot section must be put into operation in 2021
- The government's share of financing must not exceed SEK 300 million
 - These funds must be distributed between the Swedish Transport Administration's appropriation for research and innovation (20 per cent) and for trimming (minor) investment measures (80 per cent)
- Government financing must not exceed 50 per cent of the total cost; the remaining half must be financed by the private sector.

In addition to the stringent conditions above, there are a number of further working assumptions for the pilot phase that the Swedish Transport Administration is applying for this part of the Electric Roads Programme [5, 6]:

- The road technology must correspond to at least TRL² 8
- Pilot installations must be regarded as permanent³
- Commercial aspects such as payment streams and actor relations must be included in order to allow for evaluation of possible business models over the longer term
- Operation and maintenance must be included and be analysed as part of the pilot phase

Further, implementation of the pilot phase should promote continued technology development, ensure good competition at all stages, and ensure that the installation is safe for citizens and users. Analysis of legal aspects will need to continue during the pilot phase as well. Any lock-in effects should be minimised, i.e. no actor must be given unreasonable advantages to participate in the pilot phase prior to an extended development. The possibility of eventually replacing electric road technology should be guaranteed, based on which technology will constitute the future standard for electric roads.

Lessons and experiences from the pilot phase will be used as documentation in efforts to introduce electric road systems into the 2022–2033 National plan for the transport system.

2.1 Assumptions and premises regarding the Swedish Transport Administration's role

The Swedish Transport Administration's role in the development of electric roads can be described as setting the framework and creating the conditions for the market to develop. It is not the Swedish Transport Administration's task to define the business relations of the entire system, but the Administration has a responsibility for driving development and contributing to the formation of the market. The Swedish Transport Administration can also, within certain limits, define what risks it wishes to bear in its role as government agency.

² Technology Readiness Level, where level 8 corresponds to a technology ready to be launched and industrialised [26].

³ As opposed to the demonstration installations, which are set to be dismantled after a certain period of time.

The general premise of this report is that the Swedish Transport Administration will not be singly responsible for building and providing electric roads. Today the market for the provision of fuel is within the private sector and is expected to remain there, regardless of whether the actual energy source is diesel or electricity. The railway system, where the state provides the infrastructure and the electricity supply, is here not an obviously appropriate parallel and reference point for electric roads; its justification is based primarily on historical circumstances. The requirement that government financing of the pilot phase cannot exceed 50 per cent signals a will to achieve significant private involvement in a future electric roads market.

Given the short period of time remaining before a pilot installation has to be ready, the assessment is that the Swedish Transport Administration will need to take a more active role during the pilot phase than will be possible in development over the longer term. The Administration may, for example, need to take a more active financing and ownership role of the electric road infrastructure in the road area than what is deemed necessary in a longer-term development phase. As the Swedish Transport Administration is road infrastructure manager under the Roads Act (1971:948), it is assumed that it needs to have a significant influence over infrastructure in the road area, at least during the pilot phase. Based on currently applicable legislation, therefore, it is a premise of this report that during the pilot phase the Swedish Transport Administration will control installation components within the road area, either through direct ownership or through some other regulation, e.g. in an agreement.

On the basis of the conditions for the state's financing of the pilot phase as specified by the government, the Swedish Transport Administration can use its funds primarily for the procurement of fixed assets, and primarily within the road area. Funds allocated to R&D may, however, be used for other things than physical assets.

3 Supplementary market dialogue about the development of electric roads in the short and long term

This chapter covers the market dialogues that were carried out. The participating actors have been grouped by industry. The intention is not to provide a comprehensive picture of each segment, but to highlight viewpoints from actors that could potentially become part of the future electric roads market.

3.1 Electricity market actors

The following section is based on dialogues with E.ON [7], Vattenfall [8], Ellevio [9] and Fortum [10].

During the dialogues it emerged that several of the large companies are in the process of making internal analyses of a financial and strategic nature in order to investigate how attractive the electric roads market would be, in the pilot phase as well as over the longer term. The actors' own estimates indicate a need for fairly significant investment in electricity grid infrastructure. Transformer substations are highlighted as a clear cost driver in the electricity grid required along the road. According to the electricity grid owners, their role in the electric roads market can be likened to their present role in the rest of the electricity market. There are further business opportunities for the electricity grid companies in the role of an operator, for which reason this role is attractive to them. Electricity suppliers, who cannot take on the role of electricity grid owners, also expressed an interest in the operator role over the longer term.

The electricity grid companies made it clear that their traditional business concept is to build, own, operate and maintain different types of systems for their customers. Since the role as operator in the electric road system would also include providing a service, the view of the electricity grid companies is that it would amount to stepping away from their core activities, while still being within their field of competence. The market dialogue also indicated that electricity grid companies can envisage owning the infrastructure within the road area, and not just that leading to the road area. Some of the companies expressed that the operator role is not interesting for them if it does not imply ownership of the electric road infrastructure. This is because a long-term investment with a stable return is considered a lower risk than establishment as operator in a new industry.

The electricity grid owners raised a number of issues that influence their will to participate in the pilot phase. One of these is whether the electric road's connection to the electricity grid will be via a local area concession or as a non-concessionary grid. In the event of a connection in accordance with existing area concessions, electricity is distributed by the local electricity grid owner, who also has a duty of connection. It emerged from the market dialogue that incentives to take on the role as operator are weaker if the electricity grid companies do not own the electricity grid that the electric road is connected to. Electricity grid owners underlined that this question is decisive for their role in the pilot phase and over the longer term.

Another question that was discussed was whether the installation would be profitable or not during the pilot phase. Early rough estimates by the electricity grid owners indicate that the cost of investing in electricity grid infrastructure along the road and in electric road infrastructure is relatively high, and that an extension of the existing electricity grid may also be required. Several electricity grid companies pointed out that they need more information in order to be able to complete their estimates and thus be able to weigh profitability against risk.

The electricity grid companies also emphasised that the Swedish Transport Administration's potential role as owner of the electricity grid infrastructure in the pilot phase is not the long-term solution that they would want. If the idea is for electricity grid companies to own and operate the electric road

system in the future, they see advantages to being its owners initially as well. It was pointed out in the dialogue that for a solution along those lines they would have found it better if the government's share of funding could have been used more freely than the current wording of the government decision allows for. Several actors also called for a long-term plan from the government for the establishment of an electric road system.

3.2 Vehicle manufacturers

The following section is based on a dialogue with Volvo [11] and comments made by Scania during information meetings [5, 6].

It emerged during the market dialogue that it is important for vehicle manufacturers to understand how their customers are going to achieve profitability on electric roads, particularly during the pilot phase. It is considered desirable that the pilot phase include several hauliers with several vehicles, so that business conditions can be tested as realistically as possible. Vehicles need to be used a lot in order to become profitable, which may be a challenge for hauliers initially as electric powering will only be possible in connection with the limited electric road section. It was pointed out during the dialogue that the residual value risk is likely to be high during the market development period, and that it will be difficult for hauliers to bear it. Leasing was presented as an alternative in which the residual value risk can be managed differently than in a normal purchase.

It also emerged during the dialogue that the design of the electric road affects the vehicles' technical specifications. According to the actors, the distance between different segments of electrified road affects the capacity that batteries, or other power sources, need to have in order to guarantee passage between them. The vehicles' desired range beyond the electric road will also affect the capacity of the alternative power source.

Vehicle manufacturers maintain that considerable advance planning is needed for ordering vehicles for the pilot phase, since production of them will be separate from normal production. Trucks to be taken into operation in 2021 probably need to be ordered by the end of 2019 at the latest. It was also pointed out that in the event that the subsequent development of electric roads uses a different technology than what was used in the pilot phase, this will mean a complex adaptation for manufacturers.

During the dialogue the prospect was raised of vehicle manufacturers delivering value-added services in the area of prepayment on electric roads in the future. Examples include analysis services for price segmentation and control of battery charging. It was pointed out that services of this kind are also offered by third party suppliers.

3.3 Hauliers and freight forwarders

The following section is based on dialogues with the Swedish Association for Road Transport Companies [12] and the Swedish Confederation of Transport Enterprises [13].

During the dialogue it emerged that smaller transport companies (hauliers) often organise themselves in what are known as 'lastbilscentraler', or truck centres, in order to facilitate the administration of transports. Shippers purchase transport services from the truck centre, which manages its members' shared planning and finances. Hauliers also sell transport services to freight forwarders. The large freight forwarders represent the majority of transports on the large international "E-marked" roads, according to the actors in the dialogues, and often have fairly long term relations with hauliers. The smaller freight forwarders often purchase transport services in the transportation spot market. In those cases where hauliers work for the larger freight forwarders they are rarely in direct contact with the shippers.

In the current market hauliers buy their vehicles and write them off in about 5–8 years. It emerged that leasing has become more common, just like in the private car market, but it still represents a small share

of total acquisitions. It was emphasised that hauliers, due to intense competition and low profit margins, want a predictable investment. In order for hauliers to buy a vehicle adapted to electric roads, therefore, it is important to reduce uncertainties around e.g. technology. A fragmented system, with different technologies on different segments of road, was described as negative from the hauliers' perspective, while a uniform system would mean greater flexibility for hauliers.

It was emphasised during the dialogues that the selection of a stretch or stretches for the pilot phase will determine which hauliers can potentially use the electric road, since this should be based on already existing flows. It was also pointed out that the total additional cost that is assumed to arise compared with acquisition of a diesel truck makes it more difficult for hauliers to justify a transition to electricity, particularly during the pilot phase when the road section is very limited. In order to evaluate an investment in a truck compatible with electric roads, hauliers need to know how much their operating costs will be reduced by, and how big a proportion of the driving distance needs to be on electric roads in order to reach profitability. Financial incentives such as government subsidies for purchases were also mentioned during the dialogues as a way of creating incentives for hauliers to take on the risk inherent in a transition to electric road vehicles.

The actors also point out that because of the pressured financial situation of hauliers, it is important to find shippers that are willing to buy transport services specifically connected with the electric road. If shippers were willing to pay a higher price for electric road transports, e.g. as part of an environmental initiative, this would change the hauliers' incentive to provide them. Clearer conditions were called for in order for actors to make a financial calculation and agree on a price with shippers. In general, hauliers' contracts with freight forwarders are over 2–3 years, i.e. considerably shorter than the vehicle's depreciation period. This reduces their will to limit a vehicle to a specific road section over an extended period of time, which an investment for the pilot phase would entail.

It should be pointed out that for the pilot phase the most interesting road stretches are ones with shuttle traffic, in order to maximise the number of vehicles and deliveries on the electric road and also to ensure that the share of electric operation for individual vehicles is maximised. This means that the relation to shippers and freight forwarders may prove to be of a different nature than in the above description.

3.4 Telecoms

The following section is based on dialogues with Tele2 [14], Nokia [15] and Telia [16].

Several of the telecoms companies mention that they are working on finding new business opportunities beyond their traditional core business. Connectivity and the internet of things (IoT) were central themes in the market dialogues, and all the actors are focused on expanding their connectivity business. Among the sectors that are prioritised by the telecoms companies are buildings, the transport sector and the energy sector. However, the actors' strategy appears to be to maintain a relatively superficial involvement in the various sectors, and instead offer generic solutions that can be developed further based on the customer and context. Several of the actors point out that they do not themselves develop hardware for their customers, instead relying on a network of partners with which they create bespoke solutions.

The dialogues with the telecoms companies showed that this type of actor may come to play an important role in the electric road system. The need for a structured flow of information between the system's units was highlighted, and may become crucial for activities such as invoicing, metering of consumption, and registration of vehicles using the road. The actors pointed out that this could be realised by means of various connectivity services. The telecoms companies would also be able to build various solutions in the electric road system that facilitate operations and maintenance by means of sensors in the roadway. Solutions were also presented in the dialogues by which sensors and cameras

would e.g. be able to identify and classify the type of vehicle using the road, and its weight. The operator could then use this information to build a pricing system.

None of the telecom companies expressed any greater interest in taking on the role of operator on their own. The reason given for this was that telecom companies see this role as being too far from their core business to regard it as reasonable to operate as well as to invest in the infrastructure. Several companies maintain that the fundamental role would be to provide services that allow the other actors in the system to carry out their roles. Considerable interest was manifested in driving the market forward and being part of the development at an early stage. There is an ambition to be involved in creating the information flows in the market and to lay out the framework for which units will be connected to each other.

4 Roles and actor relations within the electric road system

The following chapter describes a possible organisation of the electric roads development, in a pilot phase as well as for further expansion of electric roads. An overall structure for roles included in an electric road system has been drawn up in order to better understand potential organisation options, and what actors can take on what roles, see Figure 4. In the middle of the diagram is the schematic picture of the electric road system that was produced for the previous report [1].

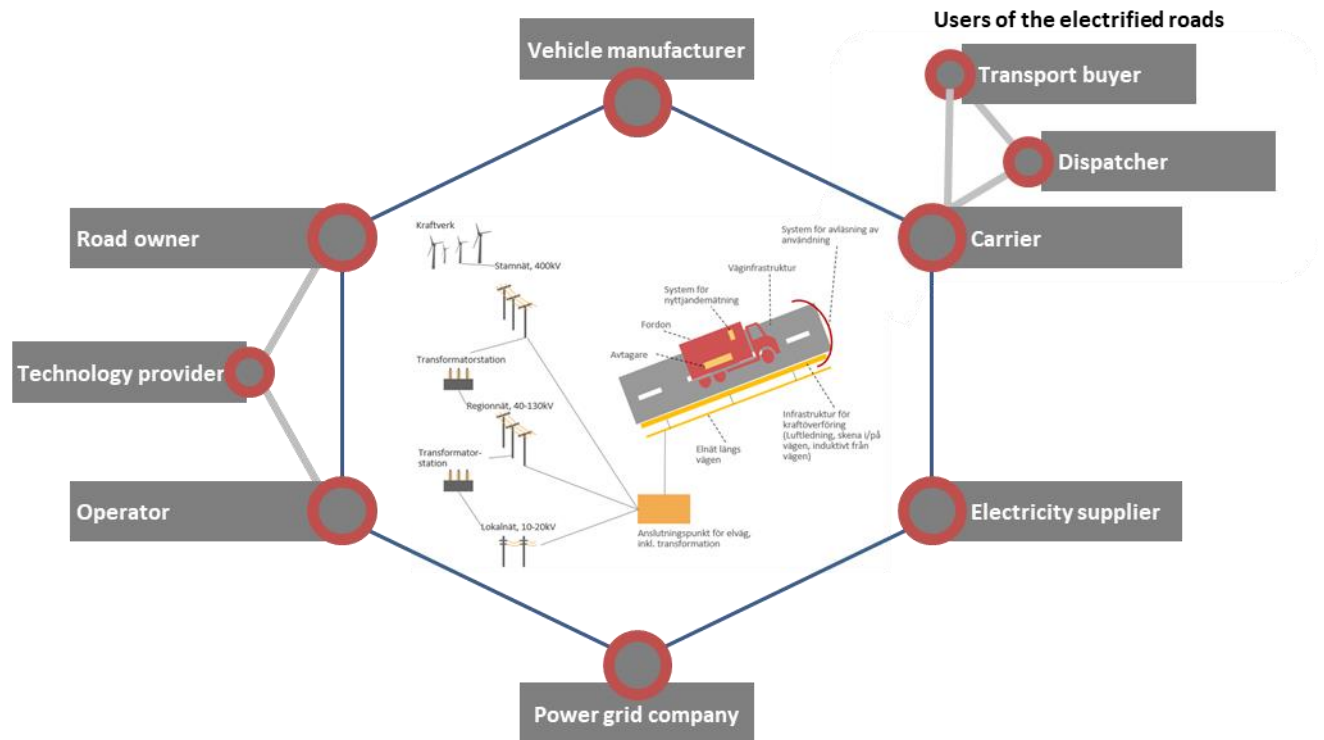


Figure 4. Overall structure of roles in an electric road system

4.1 Road infrastructure manager

As mentioned in section 2.1, the Swedish Transport Administration has road infrastructure management responsibility for public roads, which may be assumed to include the roads that are going to be electrified.

The road infrastructure manager is in direct contact mainly with two actors within the electric road system – operators (described in section 4.2) and electricity grid owners. The relation with operators follows from their activities in the road area, where the Swedish Transport Administration is responsible for matters regarding e.g. accessibility. Core elements of the Swedish Transport Administration's relations with electric road operators include operational reliability as well as monitoring and maintenance of the electric road system, since these roles can affect the Swedish Transport Administration's areas of responsibility. It is difficult to determine precisely what the division of responsibilities will be here, and it is moreover likely to vary depending on who takes on the operator role.

The road infrastructure manager is also likely to have a close relation with electricity grid owner, as there will be a physical interface in the electric installation. This interface may come to govern how

responsibilities for operation and maintenance are divided, depending on who owns the electric road infrastructure, which is described in greater detail in section 4.3 and Figure 5.

How responsibility for operations and maintenance can be organised within the road area also needs to be analysed on the basis of the road infrastructure management responsibility, which is described in greater detail in section 5.2. Furthermore, a direct relation will arise between the road infrastructure manager and the technology provider if the road infrastructure manager owns or is responsible for electric road infrastructure – which, as described in section 2.1, is a likely scenario in the pilot phase.

4.2 Operator

The role of operator is a difficult one to define in the electric road system, as it does not exist in the market today. At a general level, the future possible operator role can be described as the connecting link between road, vehicle and infrastructure. This works through a number of business relations with other actors in the electric road system. One central such relation is with the users of the electric roads, as it is this relation that generates revenue. Here the operator manages registration and connection of vehicles using the electric road, as well as charging and invoicing for electricity consumed, distance driven, or some other basis for charging. The operator also has a relation with the road infrastructure manager, as the conditions for operations and maintenance will likely be governed by the road infrastructure management responsibility. The nature of this relation will depend on who is responsible for operation and maintenance of the electric road system. It is further the operator's responsibility to provide hauliers with electricity, and thus the operator will probably be paying an electricity grid charge to the electricity grid owner.

The obvious motivation for companies to take on the role of operator is the access it gives to a completely new market, with new business opportunities and potential revenue. The main incentive for participating in the pilot phase is probably that it provides an early start for building knowledge about this emerging market. As mentioned in section 2.1, it is possible that the operator will not own the electric road infrastructure in the pilot phase. In the longer term there should be an openness for potential interest from the operator in also owning the electric road infrastructure. It emerged in the market dialogue that the electricity grid companies, which are supply-driven businesses that apply long depreciation periods, may be seen as potential actors in the operator role.

The telecom companies do not regard themselves as natural candidates for the operator role, either in the pilot phase or over the longer term. Instead the market dialogue indicated that the telecom companies would be happy to assist the operator with various types of connectivity services for sharing information. Electricity suppliers as well, and possibly today's fuel market actors, possess knowledge and experience that could prove useful in the operator role.

4.3 Electricity grid owners

The electricity grid companies that are responsible for connecting electric roads to the electricity grid will play an important role in the development of electric roads, both in the pilot phase and in a more extensive development of electric roads. First and foremost, the electricity grid owner will interface with the owner of the electric road infrastructure, since their respective components in the overall electricity installation will be physically connected to each other. One possibility would be for the electricity grid owner also to own the electric road infrastructure, since the electricity grid owner's business, as described in section 3.1, consists to a large extent of owning, operating and maintaining different systems. Figure 5 illustrates the uncertainty as to where the interface between the different types of infrastructure should be, which affects the investment volume for the various actors. It would be possible to increase the electricity grid owners' investment propensity by working over the long term to also allow them to own the electric road infrastructure.

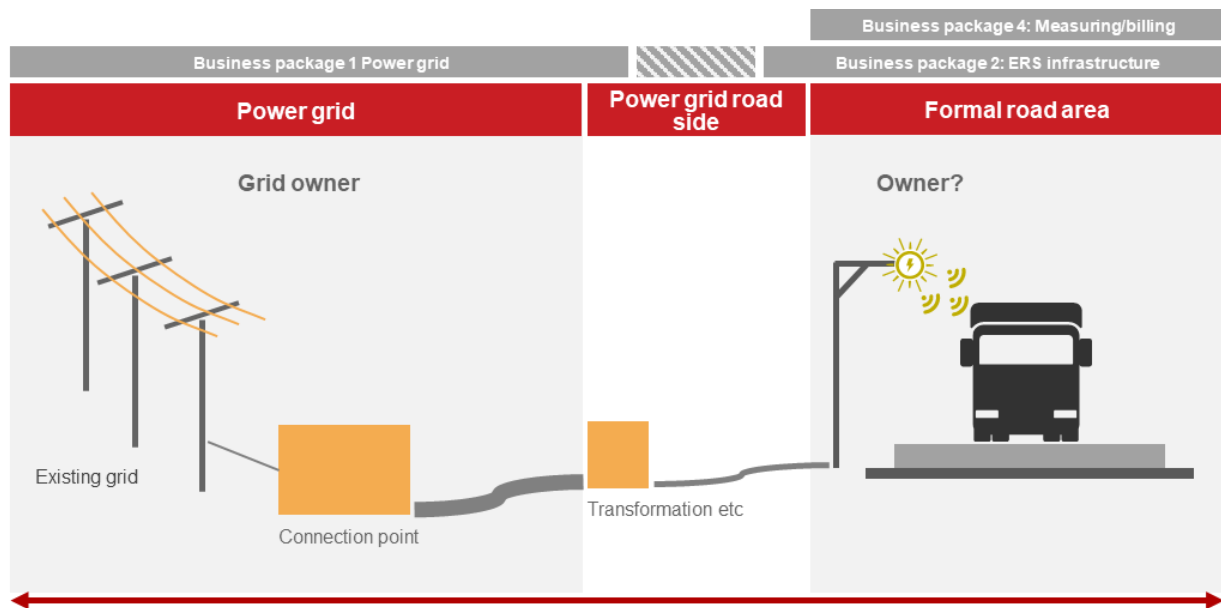


Figure 5. Interface between electricity grid infrastructure and electric road infrastructure

The electricity grid owner will also have an interface with the electric road operator. The electric road operator pays an electricity grid charge and the electricity grid owner distributes electricity to the electric road. As mentioned earlier there is also the possibility that the electricity grid owner takes on the role of electric road operator, making the electricity grid owner responsible for the customer interface as well. One positive effect of such an arrangement would be that electricity grid owners, with their experience of metering the end customer's energy use, would have that responsibility in the electric road system as well.

For electricity grid owners, an important parameter of investments is the long view; depreciation periods of about 40 years are common. In order for these actors to be interested in participating in the electric roads market, therefore, it is important that there is long term demand. At the same time, the electricity grid installed along the electric road should be possible to use for other purposes if the electric road were to be taken out of operation in the future.

Another important question is whether the development of electricity grids for the roads should be done under the current concession model or as a non-concessionary grid, which is described in greater detail in section 5.3.

4.4 Electricity suppliers

The role of electricity suppliers in the electric roads market will probably be similar to their traditional role in the electricity market, which includes the sale of electricity and invoicing. Their relation can be with users directly or be channelled via the electric road operator [1]. There is also an interface with whatever actor will be in charge of metering users' electricity consumption, either as a part of the operator role or as a separate service. The actor who meters consumption needs to make this information available to electricity suppliers in order to allow for charging. In order to guarantee a free choice of electricity supplier under the general principles of the Electricity Act (1997:857), it would be reasonable to give users the possibility of choosing their electricity supplier. In addition to the traditional tasks of the electricity trading role, the electrification of road vehicles also creates new business opportunities. One example which came up during the market dialogue is the potential aftermarket for batteries once they reach the end of their useful life in vehicles, when they can still retain enough charge to be used e.g. in data centres, or to balance capacity in the overall power supply system. Another possibility that has been mooted is the provision of battery packs to the vehicles.

4.5 Road users

The users, i.e. the hauliers, are decisive for the success of the electric road system as their use of it generates the revenue. The users have direct contact with several other actors in the electric road system. The truck need to be purchased or optionally leased from the truck manufacturers. Users also have a direct relation with the electric road operator providing the vehicle with electricity and charging for use of the infrastructure. Whether charging for the electricity consumed will be done by the operator or the electricity supplier is an open question, and will depend on what the payment model looks like.

If the total operating cost for users is lower when they use electric roads than when they use other roads, clear incentives will be created for investing in vehicles compatible with electric roads. If the electric road incurs costs for hauliers that are equal to or higher than those for other roads, the shipper probably needs to be willing to pay a higher price for this type of transport, e.g. for environmental reasons. Getting hauliers on board may also require adding other assurances, such as subsidies for buying vehicles or similar, which is discussed in section 3.3.

Even if participation in the pilot phase were to mean lower costs for users, the threshold of investing in trucks technically able to use the electric road remains. In this connection, the residual value of the truck has been identified as an impending risk for users.

In summary, electric road systems could contribute competitive advantages in the form of lower costs and the possibility for companies to position themselves as green logistics actors with sustainable delivery services. Lower fuel and maintenance costs for electric vehicles than for diesel vehicles are judged to be the primary motivators for getting users to actually use the electric road, both during the pilot phase and over the longer term. It is also possible that users adopt electric road technology even if the total cost is the same as for diesel vehicles. However, the degree of adoption of the system would likely be higher if the electric road option were to reduce costs for users. Given that the profitability of the whole electric road system is directly dependent on the number of vehicles using electric roads, and on the share of users' total driving distance that is done on electric roads, a reasonable goal ought to be to keep the price level such that the total cost estimate is lower than for vehicles that run on other fuels.

4.6 Vehicle manufacturers

The introduction of electric roads will probably not greatly affect the role of vehicle manufacturers in the market. Still, the transition from fossil fuel powered vehicles to electric vehicles is a change that is likely eventually to alter the entire industry. For the pilot phase, however, it is reasonable to expect a traditional interface between vehicle manufacturers and hauliers, where vehicles are either purchased or leased.

Technology standardisation is important in order to facilitate vehicle manufacturers' participation. An industrial production process can only be created if certain physical interfaces, such as between vehicles and pick-ups, have been standardised.

It is reasonable to assume that vehicle manufacturers' participation in the pilot phase will be motivated by the opportunity of opening up a new market and new revenue streams, and of building competitive advantage in this market at an early stage. Demand, both in the pilot phase and subsequently, is nevertheless difficult to predict. In order to reduce uncertainty about demand, economic instruments such as subsidies for purchasing electric road vehicles could be an option during the pilot phase as well as over time in an accelerated development.

As mentioned in section 3.2, vehicle specifications are affected by what stretch or stretches become electrified. If the road contains many downhill inclines, for instance, the truck does not need as large a battery as for a more level road. To allow for the production of suitable vehicles by the start of the pilot

phase in 2021, it is therefore important that information about the road section and the development of the electric road along that section be specified soon.

4.7 Summary of incentives and conditions for private actors' participation in the development of electric roads

As described above, there are several roles in an electric road system that can be taken on by different actors from different industries. In order to generate interest from private market actors for participating in the pilot phase, a number of incentives and aspects have been identified based on the market dialogue:

- **Business opportunities for private actors should be made clear** in the form of conditions and opportunities. In particular, more information is called for about the operator's role and what role the Swedish Transport Administration will adopt.
- **Long-term development plans are called for** in order for market actors to have something to base their estimates and assessments of business opportunities on. The development of the electric grid appears particularly extensive by nature, and examples of requested parameters include how large a share of Sweden's road network is intended to be electrified, and if development is planned along the major roads or over a wider area.
- **Financial incentives may need to be strengthened**; subsidies, guarantees and possibilities of repurchasing the installation after the end of the contract period have been suggested in the situation where the installation is owned by a private actor.
- **Added value beyond the financial is called for**; in particular, advantages in the further development of electric roads as a result of participation in the pilot phase, e.g. by means of options for future phases, was mooted. The chance to influence the choice of technology is another added value of participating in the pilot phase that was mentioned. As pointed out earlier, however, the Swedish Transport Administration should not offer any unreasonable advantages.

In addition to these aspects, there are a number of risks connected with the pilot phase that were raised during the market dialogue and in other meetings. These risks can be distributed between different actors, including the Swedish Transport Administration, in a way that creates incentives for efficiency, business generation, and profitability.

The main risks raised and proposals for dividing responsibility are briefly summarised below.

- **Volume risk**
Traffic volume, i.e. the extent to which the electric road is used, has a considerable influence on future profitability and potential revenue for several of the actors – and thus for their interest in participating. In order to ensure the right incentives for the operation of the electric road, and for it to attract customers, it would seem to be important that at least part of the volume risk is borne by the operator.
- **Operational reliability risk**
The operator should have a high degree of responsibility for operational reliability as this has a direct effect on the business and revenue streams. If operational reliability is affected by other actors, e.g. the Swedish Transport Administration, they could potentially become liable to compensate for loss of revenue, depending on how the agreements between them are formulated.
- **Technology risk**
The operator and the technology manufacturer should bear the technology risk, i.e. be responsible for the adequacy of the technology. This in order to give the operator the incentive

to ensure that the technology is managed in the correct way from an operational and safety perspective, and the technology manufacturer the incentive to ensure that its technology works.

- **Risk that the technology becomes obsolete**

Since there is no established standard for electric road technology at the present time, there is a risk that the technology used during the pilot phase becomes obsolete at a later stage. This risk can also exist in an expanded development over the longer term, which would affect any contracts such as the operator's service concession. It is difficult to allocate this risk to an individual actor, but it could be managed to some extent by means of e.g. contract clauses about the possibility of a renegotiation or early termination by either party.

5 Issues of decisive significance for the coming development

There are a number of issues regarding the development of electric roads, both in the pilot phase and over the longer term, that have emerged in the course of preparing this report. Several of these are already being addressed within the framework of the Electric Roads Programme, while others may lie in the future. Overall these issues are deemed to lead to uncertainties, in which the probability of a specific outcome is not calculable, and to risks, where the probability can be calculated. It is important to emphasise that a risk need not be negative for implementation, as long as it can be assessed and allocated, and thus managed so that it is not realised.

Some of the identified issues will likely require considerable time and resources to analyse, and some, primarily of a legal nature, will have a direct effect on the timetable for the pilot phase. Certain other issues have more of an impact on financial planning, as a lack of clarity can lead to a more expensive solution than would otherwise be necessary.

As electric roads do not yet exist in Sweden, other than on test stretches, there are likely to be many more uncertainties and risks than what has been possible to identify and analyse within the framework of this report. The assessment is also that there are currently more uncertainties regarding the pilot phase than what will likely be the case regarding a longer-term development. Many of the issues highlighted in this chapter will need to be analysed thoroughly before they can serve to underpin further development of electric roads. The issues are presented according to what uncertainties and risks they imply, conditions at the present time, and recommendations for further analysis.

The issues have been grouped into three broad areas:

- Financing, profitability and conditions in terms of calculations
- The Swedish Transport Administration's responsibility and interfaces with private actors
- Connection to the electricity grid

5.1 Financing, profitability and conditions in terms of calculations

Issue	Uncertainty or risk	Recommendation
What will the investment funds allocated to the Swedish Transport Administration cover?	The allocated funds are insufficient. (max 50 per cent and SEK 300 million)	An investment estimate for the pilot phase as a whole needs to be made.
How profitable or unprofitable will the pilot phase be?	Unclear conditions will lead to a low interest among private actors in investing in the pilot phase.	An investment estimate for the pilot phase as a whole, and individually for each actor, needs to be made.
What fundamental conditions exist for making a business estimate?	A high degree of uncertainty in estimates risks: <ul style="list-style-type: none">• Reducing interest among private actors• Leading to high risk premiums and thus high costs for the Swedish Transport Administration as well as for other actors• Leading at a later stage to financial difficulties and/or early termination of contracts	Create a shared view regarding certain calculation parameters such as technical specifications and depreciation periods.

What will demand be like in the pilot phase?	Lack of interest by hauliers in investing in electric road vehicles Causing a shortage of manufactured electric road vehicles when the electric road becomes operational	Reduce users' risks e.g. by using purchasing subsidies. This will also strengthen incentives for vehicle manufacturers.
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What will the investment funds allocated to the Swedish Transport Administration cover?

Since the requirements for implementing the pilot phase are that the state's financing must not exceed 50 per cent of the total investment expenditure, nor exceed SEK 300 million, it is important to understand how big the total investment volume is, and the Swedish Transport Administration's share of this.

In order to clarify this, an estimate for the entire project needs to be made to assess the approximate size of the investments needed for the development during the pilot phase, regardless of what actors take on what roles. Several of the actors that participated in the market dialogue are making their own calculations and estimates, but at the present time there is no overall picture of investment expenditure. The Swedish Transport Administration is currently making a socioeconomic estimate, but would likely be well served by a business estimate as well. The purpose of such an estimate would be to assess whether the investment requirements would be covered by government-allocated funds, and to consider whether co-financing of at least 50 per cent by private actors is reasonable to expect.

In order for a business estimate for the development to be made, the geographic location of the road section needs to be determined. Only then will it be possible to make reasonable assumptions regarding e.g. traffic volume and the share of electrification of the road section.

How profitable or unprofitable will the pilot phase be?

As described earlier, several of the actors that were part of the market dialogue have made their own estimates in order to decide whether to get involved. Several of these state that they see scant profitability in the pilot phase on the basis of their cost estimates, earnings requirements, time frames, and assessments of depreciation periods. This is another reason why the Swedish Transport Administration needs to produce a business estimate for the project as a whole, to assess whether the pilot phase will be profitable in business terms (as well as socioeconomic terms). Estimates should also be made for each actor involved, to assess how what their specific profitability might look like.

The fact that the profitability of the pilot phase for involved private actors is uncertain will influence development plans to a great extent, as well as the possibilities of attracting 50 per cent private funding, as instructed by the government. There are probably few companies willing to invest the sums required in the pilot phase if it is judged to be unprofitable from the outset. The possibility of offering financial incentives and risk management methods, and of indicating other added value, will in this case be of considerable importance for attracting private actors.

What fundamental conditions exist for making an estimate?

Since many parameters for the pilot phase remain open it is difficult for private actors to produce reliable business estimates. Several actors have requested various estimative parameters that will have a considerable effect on the investment assessment.

Principal among these requested parameters are:

- Depreciation periods and service life of various components
- Technical specifications such as:
 - Voltage level of feeder power
 - Degree of hybridisation
- How much of the road section is going to be electrified
- Interfaces and division of responsibilities

Some actors take the view that the Swedish Transport Administration should determine parameters such as the above ones. Others prefer a greater degree of freedom in designing their own solutions, even if this may take longer. Even if individual companies need to make their own investment assessments and assumptions, a shared view is needed regarding what parameters it is appropriate to fix without limiting the market's creativity and capacity for innovation. If uncertainties are too many and too great, this risks leading to deficient estimates, high risk premiums and, at a later stage, private actors choosing to withdraw from the pilot phase.

What will demand be like in the pilot phase?

Decisive factors for the profitability of the pilot phase include traffic volume and the number of electric road users. It is important, therefore, that hauliers invest in electric road vehicles. However, several circumstances make this harder to achieve:

- Delivery times for the vehicles are 1.5–2 years, which means that the order needs to be placed long before the electric road system is operational
- Hauliers have low profit margins, and their investment needs to pay off in the short term
- Hauliers often have customer contracts that are shorter than the depreciation period of the vehicles
- Hauliers have existing fleets of vehicles that need to depreciate fully before they can invest in new vehicles adapted for electric roads
- There is as yet no market for used electric road vehicles

Traffic volume depends in part on the total volume of heavy vehicles, and in part on how many benefit from shifting to electric road vehicles. Facilitating hauliers' investments in electric road vehicles will be of great significance for the success of the pilot phase, and some type of subsidy therefore appears necessary. At the time of preparing this report, Transport Analysis (Trafikanalys) was carrying out an analysis of how economic instruments might be designed [17]. Once a pilot stretch has been chosen, the number of vehicles in an initial phase, e.g. year 0–2, should be estimated in order to indicate volumes for vehicle manufacturers, but also to calculate payment streams and revenue for the investment estimate.

5.2 The Swedish Transport Administration's responsibility and interfaces with private actors

Issue	Uncertainty or risk	Recommendation
Can some other party than the Swedish Transport Administration own installations in the road area, and what does that imply for the Swedish Transport Administration's road infrastructure management responsibility?	The Swedish Transport Administration cannot guarantee that road infrastructure management responsibilities regarding e.g. road safety, environmental protection, operational reliability and accessibility are met.	Analyse the legal conditions for other parties' ownership of electric road infrastructure over the longer term. A potential short term solution might be for the Swedish Transport Administration to own the electric road infrastructure.
Can some other party than the Swedish Transport Administration be responsible for operation and maintenance of the electric road infrastructure in the road area?	An interface between the party responsible for operation and maintenance of electric road infrastructure and the electric road operator can have a negative effect on operational reliability.	Limit the number of interfaces in order to guarantee good operational reliability Analyse the legal conditions for transferring responsibility for operation and maintenance of electric road infrastructure to the electric road operator
Where is the interface between electricity grid and electric road infrastructure?	Imbalance in the financing of the installation	Analyse the legal conditions for where the interface between electricity grid and electric road infrastructure should be.
How does legislation affect any obligations the Swedish Transport Administration might have as owner of electric road infrastructure in the pilot phase?	The Swedish Transport Administration acting in breach of the Electricity Act The Swedish Transport Administration acting in breach of its instructions	Analyse the legal conditions of the implications for the Swedish Transport Administration of owning electric road

Can some other party than the Swedish Transport Administration own installations in the road area, and what does that imply for the Swedish Transport Administration's road infrastructure management responsibility?

The conditions for whether another party than the Swedish Transport Administration can own installations in the road area are regulated in the Roads Act. An assessment needs to be made of what is permitted in this respect, in order to clarify where the boundaries are for the possible roles for the state and private actors respectively. Should it be deemed permissible from a legal standpoint, the appropriateness of another party owning installations in the road area also needs to be examined. The role as owner of electric road infrastructure may be a good business opportunity for private actors, while at the same time the Swedish Transport Administration can focus on its more traditional role as road infrastructure manager. In the event that a private actor is given the role of owning parts of the electric road infrastructure, the interface with the Swedish Transport Administration will be very important to define in order to guarantee good operational reliability. Any damage to the electric road

or the road, for example, could affect the passage of all types of vehicles, for which reason a clear division of responsibilities and agreed action plans are necessary.

As analysis of the aspects described above will require time, it is not deemed unreasonable for the Swedish Transport Administration to own the electric road infrastructure during the pilot phase, with the aim of fulfilling the requirement for an operational electric road by 2021.

Can some other party than the Swedish Transport Administration be responsible for operation and maintenance of electric road infrastructure in the road area?

This issue needs to be assessed initially from a legal standpoint, in order to establish whether it is possible for any other party than the Swedish Transport Administration to be responsible for operations and maintenance in the road area. If this is possible, then a single actor could hypothetically take on the overall responsibility for operational reliability and the interface with users of the electric road system. In this way a structure of incentives could be created in which operations and maintenance of the electric road installation could be planned on the basis of demand. Such a solution would also give the Swedish Transport Administration the possibility of focusing on its more traditional role as road infrastructure manager.

In the event that another party than the Swedish Transport Administration is responsible for operation and maintenance of the electric road infrastructure, a clear interface is required with operation and maintenance of the electric road infrastructure. Response times and service levels need to be harmonised in order to minimise any negative effects on the electric road operator's activities of e.g. damage to the road. In the same way, the electric road operator's operations and maintenance may affect the Swedish Transport Administration's road infrastructure management responsibilities regarding e.g. road safety and accessibility.

In general, it is regarded as reasonable that the number of interfaces that affect the safety of operations and maintenance be minimised, which could be an argument in favour of making responsibility for operations and maintenance part of the operator's role in future. This assumes that responsibility for operations and maintenance is seen as an important element of a potential electric road operator's tasks. The operator's role needs to be more clearly defined in a future analysis phase.

Where is the interface between electricity grid and electric road infrastructure?

Defining the boundary between electricity grid and electric road infrastructure is an issue that was discussed with several electricity market actors during the preparation of this report. It is not entirely clear what the legal conditions are for where the boundary between various parties' ownership of installations can be drawn. It is important to clarify this boundary as it will affect the size of the investments each actor will need to make.

How does electricity legislation affect any obligations the Swedish Transport Administration might have as potential owner of electric road infrastructure during the pilot phase?

If the outcome is that the Swedish Transport Administration owns the electric road infrastructure during the pilot phase, there is some uncertainty as to how the activity will be affected by current legislation. An assessment of the legal conditions is important in order to reduce the risk that the Swedish Transport Administration in some way acts in breach of the Electricity Act or of its general instructions.

5.3 Connection to the electricity grid

Issue	Uncertainty or risk	Recommendation
Can electricity grids along the road be built under the concession model, with an area concession, or as a non-concessionary grid?	Reduced interest from electricity grid companies that cannot assess business opportunities The pilot phase is delayed and the development does not meet the requirement of being operational by 2021	Further analysis of the issue The pilot phase section needs to be chosen

Can electricity grids along the road be built under the concession model, with an area concession, or as a non-concessionary grid?

It is important to determine whether the electricity grid that is needed along the road should be built under the concession model or as a non-concessionary grid. If the concession model is to be followed, the local electricity grid company's duty of connection will apply, and the electric road will be regarded as another connection to the grid. The roadside electricity grid will then be built as a part of the local grid. If the connection is deemed non-concessionary, the roadside electricity grid will be regarded as an internal grid solely for the electric road. In this case the electric road will not need to be connected to the local grid, but can instead be connected to the regional grid if that is judged to be a better solution.

The grid Concession commission (Nätkoncessionsutredningen) was appointed to assess the need for changes to the rules on obligatory concessions for heavy duty power lines [2]. The Commission's report is due to be presented on 15 June 2019 and may have considerable significance for the development of electric roads, both in the pilot phase and over the longer term. Should the Commission's report not provide any clear conclusions, the matter may also be examined by the Swedish Energy Markets Inspectorate on the basis of current legislation.

Since the concession issue determines which actor can connect the electric road to the electricity grid, it greatly influences which actors will have the possibility of participating in the pilot phase and taking responsibility for the electricity grid infrastructure. This also affects the investment estimate and how much the development of the electricity grid infrastructure is going to cost. The local grid has a voltage limit, which may mean a higher installation cost compared with an electric road installation connected to the regional grid, which has a higher voltage capacity.

If the concession issue is not resolved on time, this could delay the pilot phase as potential actors will then risk not being given enough time to prepare. If the decision is to build the pilot phase under the concession model, it is of considerable importance that the section be chosen, so that the local electricity grid company or companies can become involved as soon as possible.

6 Conclusions on models for implementation

This report, which expands on the 2018 report on business models for the development of electric roads [1], primarily examines the market conditions for the pilot phase, and to some extent those for phases further ahead. This section has two main threads, where one focuses on the pilot phase and the other on the longer-term development of electric roads. In summary it can be noted that many issues remain to resolve, particularly issues of a legal or financial nature, which makes it uncertain whether the goal of an operational pilot phase in 2021 that includes all the elements of an electric road installation will be possible to achieve.

6.1 Shaping roles and actor relations

It can be noted from the outset that there are several actors from different industries that could become involved in creating the future electric roads market. Compared with the preceding report, even more potential electric roads actors have been identified – specifically telecom companies. Additional business opportunities, beyond the electric road function itself, have also been discussed. Many actors are themselves seeking to explore and develop their role in a future electric road system. Their progress in this regard is varied, with some showing a cautious optimism in their existing solutions and others appearing to be developing new offerings linked to electric roads.

A majority of the market actors are calling for a long term view, and want to partake of plans for a future development – and there is an expectation that the Swedish Transport Administration will provide such plans. Since many aspects of the electric road system are in a design phase, the Swedish Transport Administration is not always able to give clear information about future developments, which in turn creates some uncertainty among the market actors. As an example, concrete information is requested about how large a proportion of the road network is planned for electrification over the longer term, and if the development will be mainly along the major roads or be based more on local needs or demand.

A number of roles in a future electric roads market have been identified:

- Road infrastructure manager
- Operator
- Electricity grid owner
- Electricity suppliers
- Users
- Vehicle manufacturers

These different roles interface with each other, which implies different types of business relations, incentives and challenges. Some roles seem to be clearer than others – the businesses of road infrastructure manager, electricity supplier and vehicle manufacturer, for example, appear to be largely similar to what they are today, at least for the pilot phase.

Even with the results presented in this report, some of the other roles remain difficult to define, with the operator role standing out as particularly unclear. It will be affected by a number of things, including what type of actor takes it on and how its interfaces with other actors are defined. The role of user also needs to be analysed further, as underlying relations with shippers and freight forwarders greatly influence their interest and purchasing power. It will be important to understand the motivations of these actors ahead of the pilot phase.

The role as electricity grid owner stands out as the most decisive for the structuring of the system, both in terms of its responsibility for electricity distribution and as a potential investor in and owner of electric road infrastructure. However, the electricity grid owner's involvement and business opportunities are determined in part by whether the electricity grid for electric roads is to be regarded as concessionary or not – an issue currently being analysed by the grid Concession commission [2]. The electricity grid element of the business can either be seen as a part of the concession-regulated electricity market or as a non-concessionary activity. In either case, some form of regulation is needed regarding consumer protection, competitive neutrality and transparency. It may fall to the Swedish Transport Administration to provide parts of such regulation, but it could also become a task for the Swedish Energy Markets Inspectorate.

It seems likely that the structure of different roles in the electric road system in the pilot phase will be similar to that for the longer term, even if the scope and responsibilities of each role may change over time. Since it is difficult to predict in advance precisely what configurations and businesses will be created, it is important that the system, as far as possible, is developed in a way that allows for and promotes further business opportunities, evolution and innovation.

6.2 Proposal for organisation of the pilot phase

Based on the conditions described in greater detail in Chapter 2, a number of conclusions have been drawn about how the pilot phase can most appropriately be organised. These conclusions are founded on the analysis in this report as well as on current legislation, the timetable for the pilot phase, and the government decision on how the Swedish Transport Administration may use its allocation for this purpose. However, they need to be further validated, tested and analysed for impact before formal decisions are made, primarily regarding financial and legal aspects, as described later in this section.

Following this report, it appears feasible to organise the pilot phase into four parts: electricity grid, electric road infrastructure, operator activity, and vehicles. The difference compared with the assessment in the previous report is primarily that a system for metering and payment is assumed to be part of the operator's activity, and that the operator's activity can be a separate business from the electric road infrastructure.

In summary, two main interfaces or assignments are proposed for the Swedish Transport Administration in the pilot phase:

1. Acquire, build and manage the electric road infrastructure
2. Organise and procure the operator role

The actors that are given these assignments will then, in turn, be free to engage any subcontractors and partners needed in order to fulfil the roles required in the system.

The advantages of only two assignments are:

- It minimises the number of interfaces with the Swedish Transport Administration, which in turn minimises the risk that requirements and dependences between parties are not met, and in the worst case that the Swedish Transport Administration becomes an intermediary in such disputes and thus ends up bearing more risk than intended.
- It emulates a likely long term solution. It is possible that in the long term there will only be one contractual relation for the Swedish Transport Administration, as the electric road operator also owns and operates the electric road infrastructure. On the basis of legal conditions and decisions taken on how the Swedish Transport Administration's SEK 300 million may be used, this is probably as close to a long term realistic solution as it is possible to get in the pilot phase.

It is important for both interfaces that agreements are carefully formulated to create incentives so that the pilot phase has every chance of being a success, e.g. ensuring that the technology functions well and that the electric road has high operational reliability. The risk of establishing incentives that increase suppliers' profitability through parameters that hinder the success of the pilot phase, must be avoided.

Below are more detailed descriptions of the two interfaces.

6.2.1 Acquisition and construction of electric road infrastructure

In the pilot phase it appears reasonable for the Swedish Transport Administration to procure and manage construction of the electric road infrastructure, and to be the owner of it. In the longer term, however, there are expected to be several other possible organisation and ownership models. It may e.g. become advantageous for the operator to be able to own the infrastructure in order to be given sufficient responsibility for and control of guaranteeing good operational reliability and function for users. Depending on what is possible in legal terms, this could be done by giving a private actor the right to build and own electric road infrastructure, e.g. by means of a building concession, or by maintaining the Swedish Transport Administration as owner but having it procure operator services for extended periods of time, e.g. through a concession.

The procurement of electric road infrastructure should include some form of responsibility on the part of the actor supplying the electric road technology, see Technology provider in Figure 4, that the technology works and that it is possible for the operator to meter consumption and charging. If metering is not done through the electric road infrastructure it needs to be possible for the operator to add such functionality.

The procurement should be technology neutral on the basis of the requirement for TRL 8 to allow for competition between different technologies. If the choice of electric road technology turns out to have a considerable influence over other investments and areas of development, e.g. the design of the electricity grid and vehicle development, the possibility should be explored of relinquishing technology neutrality in the procurement while still achieving sufficient competition.

If the electric road infrastructure for any reason needs to be maintained by a specific actor, or in some other way requires special prior knowledge, maintenance may need to be procured together with the technology. That could mean that maintenance cannot be procured separately in competition. The precise details of how the technology should be purchased need to be agreed between the operator and the technology supplier.

Boundaries with the electricity grid, e.g. if transformer substations and rectifiers should be included in the procurement of electric road infrastructure, need to be determined on the basis of what is legally possible (see section 5.2). If, for example, transformer substations are deemed possible to include in the Swedish Transport Administration's allocation of SEK 300 million, and this furthermore creates suitable economic conditions for the operator, it should be possible to include them in the Swedish Transport Administration's responsibility. This interface will be affected even if the roadside electricity grid is to be built within the local grid concession or as a non-concessionary grid.

If the electric road infrastructure is procured as a package with the operator role, competition may be stifled because the operator able to offer electric road technology at TRL 8 is the only option. Competition in other parts can thus be safeguarded by procuring the infrastructure part separately.

6.2.2 Organisation and procurement of the operator role

One of the ambitions for the pilot phase as well as for stretches developed over the longer term is to give private actors the opportunity of running the operator's business. The role as operator could arise spontaneously in the market if new business opportunities were assessed to require more support and

formalisation, particularly in the pilot phase. Over the longer term it is possible that there is a market with interested actors that take the initiative for new electric road stretches.

In order to tie a private operator to the pilot phase, procurement may be appropriate where requirements can be specified on the basis of the government's decision and the Swedish Transport Administration's circumstances, e.g. starting operations by 2021 and that it must be possible for all existing and recently established hauliers to connect to the electric road. What type of procurement is most suitable remains to be analysed – possibly procurement of a service concession would be appropriate.

Another solution is for the operator role to be run for a period of time by the Swedish Transport Administration, if this is deemed necessary. However, such a solution poses problems in terms of what the Swedish Transport Administration is legally allowed to do, e.g. regarding charges. Regardless of which actor takes on the role of operator, it needs to be shaped and defined further. Examples of what may come to be part of the operator role include:

- **Connection and continuous provision of electricity to the electric road** – Depending on how the operator role is organised, this may require the operator to make investments in the development of the electricity grid. This seems unlikely in the pilot phase but may occur in the longer term. How the electric road can be connected to the electricity grid depends, as described, on whether the electricity grid is to be regarded as concessionary or not. As this will have a significant impact on the operator's investment and profitability estimates, it needs to be clarified as soon as possible.
- **Metering of vehicle traffic and consumption** – How identification of vehicles and metering of consumption are to be done remains to be defined. What is appropriate in the pilot phase need not necessarily be the same as what is suitable for a more developed system that makes other demands. In the longer term there should be a standardised solution in order to make it easier for users to drive on different stretches of electric road. If the Swedish Transport Administration wants to extract more experiences of such systems from the pilot phase, requirements can be specified that make the system more like a long term one, e.g. with possibilities of identifying any vehicles that use the system fraudulently and avoid paying the intended charge.
- **Debiting of user charges** – The operator needs to be given the power to cover its expenses and set prices in a way that makes the business profitable. Whether pricing should be regulated in any way, e.g. with an upper limit, remains to be analysed and is an important issue for the future business model. The report on business models for electric roads [1] assumes that it is reasonable that the price for use of the electric road, including electricity consumption, approaches but does not exceed the effective price per kilometre of the alternative fuel. The charge will likely be based on actual electricity consumption, and it will probably become a requirement that users are given the possibility of choosing the electricity supplier – but it is uncertain whether this requirement needs to be met already in the pilot phase. If not, the operator can choose the electricity supplier, which should not jeopardise the principal lessons that the pilot phase is intended to provide.
- **Operation and maintenance of electric road infrastructure** – In the event that the operator is given an overall responsibility for operation and maintenance, risk and control over operational reliability will be allocated to a single party. With such a solution, the Swedish Transport Administration is not at risk of only getting the role of intermediary when the operator and maintenance provider disagree. As described earlier, an analysis needs to be made of whether another party than the Swedish Transport Administration can be responsible for operation and maintenance of the electric road infrastructure in the road area.

It is important that the Swedish Transport Administration understands and can assess, to the greatest extent possible, the costs in order to be able to evaluate a suitable tender submitted in a procurement

of an operator. The evaluation needs to leave a margin for a reasonable level of profitability for the operator.

In order to limit the risk for the operator and maintain freedom of action in the event that the Swedish Transport Administration or the government want to be able to change a decision in the future, the contract entered into should be limited in time but should have a sufficiently long contract period. It should also include clauses concerning any renegotiation or early termination by either party in order to be able to change the contract in particular circumstances, e.g. concerning choice of technology.

Since the drawing up of tender documents for procurement of an operator is dependent on parameters that are determined by the electric road infrastructure, e.g. choice of technology, timetables, and conditions regarding service and maintenance, it is important that these are identified as early as possible in the process. If procurement of the electric road infrastructure cannot be completed before the process of appointing an electric road operator has begun, or progressed sufficiently far, additional negotiations will probably be required to deal with these parameters. The risk is that such additional negotiations become expensive for the Swedish Transport Administration as an operator has already been appointed, and this should be avoided. It will furthermore be necessary to clarify several of these parameters in order for the development and production of adapted vehicles to be possible.

6.3 Potential organisation for the longer term

There are a number of assumptions for a longer term development that differ from those for the pilot phase described above, and these are described as and when they occur in the report. Below is a summary and a listing of a number of possibilities for how a long term electric road development might be organised and implemented.

- Private actors can initiate, build, own and operate electric road infrastructure, e.g. electricity grid companies or electric road operators
- As an alternative, the Swedish Transport Administration can own the electric road infrastructure and then procure the operator function as a service concession for an extended period
- The electric road operator has the overall responsibility for running the electric road installation, including operation and maintenance
- An electric road operator can operate several stretches of electric road
- Users have a free choice of electricity supplier and are billed based on actual consumption
- Technology and metering are standardised, and users can easily drive on different stretches of electric road
- New services, adapted to the electric road, are developed and provided by third-party suppliers, e.g.:
 - Systems for connectivity and management of data for registration, metering and invoicing
 - Systems for control and identification of vehicles to ensure that no actor uses the system fraudulently or does not pay the intended charge
 - Systems and sensors intended to predict maintenance needs and plan maintenance measures
- Further business opportunities are developed through peripheral services occasioned by the electric road, e.g. separate pick-ups, management of batteries in the vehicles, or leasing services

The above should only be seen as potential possibilities. The development of the market and of circumstances will depend to a great extent on the results of the legal analysis and the experiences from the pilot phase.

6.4 Uncertainties and risks for further analysis and management

There are a number of uncertainties and risks connected with the pilot phase, in particular with respect to financing and profitability, but also regarding the role of the Swedish Transport Administration. The estimative parameters need to be clarified, e.g. by analysing whether the Swedish Transport Administration's allocation ceiling of SEK 300 million is sufficient, and how profitable or unprofitable the pilot phase is estimated to be. These issues are decisive for maintaining the interest of private actors. If the pilot phase is predicted to be unprofitable, the possibility of subsidies in various parts of the system or the creation of other added value should be considered.

Since many issues, particularly of a legal and financial nature, remain to be analysed, it is judged to be uncertain whether the goal of putting an installation into operation by 2021 is possible to achieve. Priorities will probably have to be defined as to which components and functions have to be in place from the start, and which ones could be added subsequently. Since the pilot phase will probably be limited in scope and only become operational in late 2021, and given that a lot of work remains to be done (e.g. planning, project design, procurement), experiences gained that can be applied in the 2022-2033 national plan for the transport system will probably be limited to building and contract writing. Feedback and experiences from operation of the installation will likely only be forthcoming in 2022 and beyond.

7 Recommendations for the next step

As a next step, the Swedish Transport Administration is recommended to proceed with three procurement-like projects in preparation for the pilot phase:

- Selection of road stretch (ongoing)
- Construction of electric road infrastructure
- Continued analysis of the operator role, and procurement of an operator

Given the tight timetable specified in the government decision it will not be possible to implement the projects sequentially, and they therefore need to be implemented in parallel. There are strong dependences between them, and direct interaction in several areas, e.g. technical prerequisites and the division of responsibilities in operations and maintenance. The projects therefore need to be run in close collaboration in order to quickly be able to adapt as new conditions, knowledge and decisions emerge. Information and experiences need to be shared between projects on a continuous basis, which will require a flexible and effective organisation.

In addition to the three projects above, we also recommend that the legal analysis be prioritised, as its outcome may be decisive in determining how the development of electric roads can be implemented. Drawing up a business investment estimate for electric road development as a whole, as well as for each participating actor, is also recommended in the next step.

In order that these three projects can be run in parallel, while many complex issues still remain, it is crucial that all work be carried out efficiently and in a way that secures the market's continued trust. The complexity of the Electric Roads Programme's different streams and analyses, as well as dependences between them, have led to a certain overlap, and it does not appear quite clear to the market what conditions apply [5]. A certain frustration on the part of the market has been noted during the preparation of this report. In order not to risk causing discontent and a reduction in interest from the market, there may be reason to review how collaboration with market actors is carried out, and to ensure future good and coordinated progress within the Electric Roads Programme.

In conclusion we recommend ensuring that there is a clear mandate for a decision, and sufficient decision making capacity, as these will be required in order to be able to make strategically important decisions in time to meet the 2021 deadline.