

## REPORT

# Electric buses for Swedish public transport services

A survey of Trafikförvaltningen Stockholm, Skånetrafiken and Västtrafik based on four perspectives

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Photo: Kerstin Ericsson

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# Summary

Electric buses represent a new concept on the market, and their technical development has progressed at a rapid pace over the last few years. The number of electric buses used for public transport has increased, both globally and in Sweden. To examine this development in greater detail, the Swedish Transport Administration (Trafikverket) has performed a survey of the three largest regions in Sweden which are implementing electric buses.

The purpose of this study has been to survey how Sweden's buses used for public transport services are being electrified. Four perspectives are used in this survey: 'Technology', 'Organisation and funding', 'A broader social perspective' and 'Digitisation'. This study has been limited to the three larger regions and their regional public transport authorities (abbreviated RPTAs); namely Trafikförvaltningen in the county of Stockholm, Skånetrafiken in the county of Skåne and Västtrafik in the county of Västra Götaland. This survey provides a snapshot in the summer of 2019 regarding plans and initiatives involving electric buses, primarily buses used for urban services.

The study is based on interviews; primarily with each of the RPTAs, but also with electric utility companies, bus operators and relevant experts. The study defines an electric bus as a bus with a drivetrain and that runs solely on electricity, as well as having a battery for energy storage.

The study found that there was a great deal of interest in electric buses among the RPTAs interviewed. They have introduced electric buses to their public transport services and will be continuing to do so. Trafikförvaltningen has expressed a preference for charging at depots, while Västtrafik allows its bus operators to make a decision with regard to the choice of technology. Skånetrafiken is assessing appropriate technology on the basis of conditions in the specific traffic region, which vary across the county of Skåne.

None of the stakeholders interviewed stated that a shortage of capacity in the electric grid or electric power is currently a limiting factor regarding the introduction of electric buses. However, it is important that the issue should continue to be monitored. The RPTAs have planned their introduction of electric buses to suit current plans for development of the electric grid and production, and hence the risk of capacity and electric power shortages was considered low.

In regard to batteries, all the RPTAs state that managing social sustainability in production and recycling presents a challenge.

Less noise, better local air quality, fewer greenhouse gas emissions, the increased energy efficiency of electric motors and the fact that electric buses can provide more attractive public transport for both passengers and drivers are cited as common driving forces behind the introduction of electric buses. Västtrafik and Trafikförvaltningen point out that the advantages stated create synergy effects in respect of a number of objectives, such as improved health.

Västtrafik has formulated a target; 30 per cent of its fleet of buses is to be made up of electric buses by 2025. Trafikförvaltningen and Skånetrafiken indicate potential, but as things stand at present they have not established official targets for percentages of electric

buses by a certain year. Furthermore, the study established that the Elbusspremien, Stadsmiljöavtal and Klimatkivet incentive schemes established by the government, which offer subsidies for electrification initiatives, have not been sufficiently pivotal in the initiatives implemented, although they are viewed as positive contributions when electric buses are implemented.

The scale of implementation varies between the three regions: Trafikförvaltningen is working gradually and in stages, Västtrafik is driving progress forwards and Skånetrafiken is varying the introduction of electric buses among municipalities. In a comparison with other Nordic countries, it can be noted that Copenhagen has set a target for 100 per cent of its buses to run on electricity by 2031, Oslo is aiming for 60 per cent by 2025, and Helsinki is aiming for 30 per cent by 2025. Hence the three Swedish RPTAs have relatively restricted targets by comparison, although they are working intensively on extensive introductory efforts. Implicitly, this may indicate that the RPTAs have loftier ambitions than their respective official targets would indicate.

Procurement procedures for electric buses remain largely unchanged compared with those for conventional buses with internal combustion engines, except for the fact that they frequent involve earlier discussions with various parties affected by the procurement procedures. Trafikförvaltningen and Skånetrafiken define detailed requirements for electric buses, while Västtrafik only uses functional specifications. Electric buses will be introduced in two ways; by means of regular procurement procedures at the end of a current contractual period, and within the scope of existing contracts.

The introduction of electric buses means that new skills will be needed and that all parties involved will face new tasks. The stakeholders involved are the traditional public transport parties such as RPTAs, bus operators and municipalities; but a number of new stakeholders such as electric utility companies have also been given more prominent roles in public transport. New stakeholders, along with the fact that electric buses are a new technology, means that it is important to define interfaces and responsibilities among stakeholders. The new stakeholders and responsibilities mean that cooperation is of obvious importance. All RPTAs have worked with discussions at an earlier stage of the procurement process, emphasising creation of an understanding of one another's conditions and creating clearly defined demands.

The ownership of vehicles and charging infrastructure has varied in the case of introduction within the scope of existing contracts. When a standard procurement procedure takes place, the bus operator normally owns the vehicle and the charging infrastructure; except in the case of a number of municipalities working with Skånetrafiken, owner of the charging infrastructure.

It costs more to purchase an electric bus than it does to purchase a comparable conventional bus, but several of the parties interviewed estimate the operating costs of electric buses to be lower. The charging infrastructure, power supply and training of mechanics and drivers are examples of additional initial costs. The increased initial costs mean that discussions are ongoing between stakeholders concerning whether the depreciation periods for electric

buses could be extended compared with other buses. Monitoring of the development of costs for overall electric bus technology is imperative.

Both Trafikförvaltningen and Västtrafik perceive some potential in coordinating electric buses with other electrification processes in the transport sector. However, this is not happening at present for technical and legal reasons. Furthermore, both Trafikförvaltningen and Västtrafik perceive a link between coordination of urban planning and electric buses, such as indoor bus stops. However, this is not something that will take place during the regular introduction of electric buses. To date, it has only been included as part of a demonstration project in Gothenburg.

The RPTAs, bus operators and bus manufacturers studied are using digitisation in public transport, and the common ITxPT standard is being introduced on digital platforms and for digital functions, for example. Bus operators perceive a greater need for digitisation in connection with electric buses, mainly to identify vehicle battery range and indicate when charging is needed.

There is no definite link between digitisation and electrification, and the study indicates that digitisation would have been introduced regardless of the vehicle drivetrain. Although there is a clear link between electrification and automation, which is a subset of digitisation. Electrification may facilitate the introduction of autonomous vehicles, mainly due to the fact that charging will be able to take place more easily without human intervention, compared with fuelling vehicles with fossil fuels, biodiesel or biogas.

The study identified a number of potential lock-in effects linked with the introduction of electric buses; namely increased capital expenditure and longer contracts, choice of technology, earlier investments and ingrained approaches and behaviours. None of the lock-in effects appears to be isolated: they influence and are influenced by one another.

Previous approaches may also have an impact with regard to what technology is selected, as there may be ingrained – both conscious and unconscious – behavioural patterns and norms that may promote choices of certain technologies. Existing directives and policies may also create a kind of inertia, as they can both counteract and facilitate changes in approaches and the introduction of electric buses. All stakeholders face a challenge in this regard, and transparency is required with regard to the lessons that electric buses will allow us to learn.

Further studies should return to the regions studied in a few years in order to follow up on the introduction of electric buses. Other regions in Sweden should also be surveyed, as the three considered here operate in relatively similar ways from a national perspective. Further comparisons may also be drawn with international initiatives.



# Glossary

Bus operator	Provider of public bus services. Other terms included are traffic operator, traffic company, bus company and traffic provider
Charging concept	The turnkey solution including both charging strategy and charging technology
Charging strategy	How electric buses are charged, primarily charging at the depot, supplementary charging or electric road systems
Charging technology	The technology used for charging electric buses, such as plug-in, inductive charging or conductive pantograph
Electric bus	The study defines the electric bus as an all-electric vehicle, i.e. it has a motor with a powertrain, and a battery for energy storage. These vehicles are known as Battery Electric Vehicles, BEVs
Incentive contract	A contract based on the fact that some of the bus operator's revenue is flexible and based on predefined parameters such as quality or passenger numbers
Production contract	A contract providing RPTAs with ticket revenues; and the bus operator receives remuneration on the basis of the actual costs arising
RPTA	Regional public transport authority
RVG	Region Västra Götaland

# 1. Introduction

## 1.1. Background

Technical development of electric buses has increased dramatically over the past few years, and the technology is currently undergoing expansion and development. This means that many demonstration projects have been implemented in order to examine the options for operating regular services using electric buses (Aldenius, Forsström, Khan, & Nikoleris, 2016). Regional public transport authorities, RPTAs, have begun using electric buses for regular, primarily urban public transport services over the last three to five years.

A similar trend is also apparent in Europe and other parts of the world, particularly China (Swedish Energy Agency, 2019 A). The rate and extent of electric bus introductions in Sweden increased in 2019. There are a number of reasons for the increase in interest in electric buses, besides their rapid technical development: these reasons include the fact that they reduce noise and increase energy efficiency, and emissions of hazardous small particles and greenhouse gases are reduced. These latter three considerations result in effects that have an influence both globally and locally.

As a consequence of technical development, there are now a number of different technologies available for electrification of buses (both vehicles and charging infrastructure), and as a result all stakeholders involved need to make decisions on which new technology to choose. The same technology does not necessarily need to be the most appropriate for all geographical locations: the specific conditions in each individual area can have a major impact on the technology selected.

Revenue and cost items relating to corporate finances and socio-economic factors, as well as their allocation among stakeholders, may be altered as a result of electric bus implementation. Electric buses are a new technology, which places demands on abilities to manage new public transport expertise and responsibilities, and more stakeholders may need to work together on a more in-depth level. Roadmap Sweden (u.d.) writes that buses account for around 53 per cent of all journeys made using public transport. Hence electrification may have a major impact on public transport business models, organisation and cost items; but also on which stakeholders are involved and their responsibilities. Furthermore, electrification may impact on urban planning and on how passengers travel and interact with public transport services.

Switching to an electrified bus fleet will impact on and be impacted by the choice of technology, potential organisation, funding, procurement and contract structures, as well as a broader social perspective. This report will be focusing on these perspectives. Besides the above, digital development also has a major impact on the use and development of public transport. This is why this study charts and surveys the implementation of electric buses in Sweden's three biggest public transport areas – Trafikförvaltningen Stockholm, Skånetrafiken and Västtrafik – working on the basis of the four perspectives: 'Technology', 'Organisation and funding', 'A broader social perspective' and 'Digitisation'.

## 1.2. Purpose

The purpose of this study is to chart how public bus services in Sweden are being electrified and the resulting challenges and opportunities. The study is descriptive in nature, examining the electrification of public bus services on the basis of the four above-mentioned perspectives. Information on practical experiences and impressions in three major regions – Region Stockholm, Region Västra Götaland and Region Skåne – is gathered on the basis of interviews and literature studies focusing on observations concerning electrification of public transport.

## 1.3. Method

This study is based primarily on qualitative methods such as interviews with stakeholders and observations by the authors. A list of people interviewed can be found in the bibliography citing the verbal sources. Our informants represent different groups of stakeholders involved in electrification, or in the implementation of electric buses within each of the regions. Our informants have been selected on the basis of their expertise, positions, organisations and relevance to the study.

Electrification of public bus services is reflected at both national and regional level; and for the most part representatives of regional public transport authorities, RPTAs, have been interviewed in order to examine electrification at a regional level. Interviews with staff at the Swedish Energy Agency, for example, have been used to clarify electrification from a broader perspective at a national level.

Furthermore, literature studies have been implemented focusing on both quantitative and qualitative data. The literature includes academic journals and reports, as well as other information published by authorities, the Government, companies and other private stakeholders. The literature search process involved a “snowball” action, where initially broad search results were narrowed down by following keywords, authors and other topics in our search.

## 1.4. Restrictions

For the purposes of this study, an electric bus is defined as a bus that runs solely on electricity: in other words, the electric bus simply has a powertrain and a battery to store energy. These buses are also referred to as BEVs.

The study applies a system perspective, which involves charting at a more general level. The study examines how the three Swedish regions referred to above have worked and are continuing to work with the implementation of electric buses for their public transport services. The study examines how the switch is being made from conventional buses with internal combustion engines to electric buses that run entirely on electricity, powered by batteries and charged either when stationary (static charging) or when in motion (dynamic charging).

The study is limited to working primarily on the basis of market and industry criteria for public transport services in Sweden, such as various instruments and forms of funding. The study is limited to electrification of urban traffic, on the basis of operation of the equivalent to class I buses.

The study is restricted in temporal terms in that it portrays how the three regions are working on the introduction of electric buses on the basis of prevailing schedules in the summer of 2019. The portrayal of electrification of public transport services may also be considered restricted in terms of the stakeholders that were selected for interview, in that the emphasis is on representatives of the RPTAs in the three regions, as well as three major bus operators.

The report begins with a background aiming to provide a comprehensive introduction to public transport in Sweden, previous electric bus initiatives, forms of funding, and also an EU perspective in respect of the objectives and laws in other cities.

The four perspectives of the study are then described in greater depth. There then follows a summary of each case study on the basis of the four perspectives. What the bus operators think of electric buses is also described in the summary.

The regions are then compared and analysed on the basis of the four perspectives. Finally, the results are summarised and recommendations are provided for future surveys.

The study was performed between May and August 2019 by Anna-Cecilia Lundström, Matilda Ninasdotter Holmström, Erik Torstensson and Matilda Eriksson in the Transport Administration's Planning business area at the National Planning Department, within the scope of the Electric Road Systems (ERS) Programme. Björn Hasselgren and Fredrik Widegren, both of whom work in the Planning business area at the National Planning Department, supervised the work. The Swedish Transport Administration would like to thank everyone involved in interviews, as well as everyone else who gave their opinions and made a positive contribution to the implementation of the study.

## 2. Background

This chapter begins by providing a description of the Swedish public transport stakeholders and important stakeholders in electric bus initiatives. This is then followed by a description of electric bus initiatives from an international and national perspective, before going on to describe various instruments and forms of funding for electric buses in Sweden. The chapter concludes with a theoretical description of how a sociotechnical transition, such as that represented by electric buses, can take place.

### 2.1. Europe

#### 2.1.1. Previous surveys and initiatives

The European Union, the EU, has established a number of different legislative acts relating to public transport, sustainable travel and, specifically, electric buses. It is generally possible to obtain EU funding for projects aiming to develop smart, green, innovative transport solutions via the Connecting Europe Facility or Horizon 2020 (European Parliament and Council, 2009).

The primary EU legislative acts of relevance to electric buses are *the Directive on the deployment of alternative fuels infrastructure* (European Parliament and Council, 2014) and *the Directive on the promotion of clean and energy efficient road transport vehicles* (European Parliament and Council, 2009), with associated follow-up and revision (European Parliament and Council, 2019). Besides the directives cited, the EU has also adopted a battery directive. More information about this can be found in section 3.1.5, Batteries.

The European Commission and the EU Regional Committee launched the European Clean Bus Deployment Initiative in 2016 in order to counteract and understand the barriers and obstacles facing clean buses (UITP, 2018). This initiative aims to help implement clean buses in European cities; and this work also includes electric buses. The initiative clarifies the fact that there are a number of challenges still to be dealt with – organisational, technical and financial – before a transition can take place. It also illustrates the fact that the business models are important to allow involved stakeholders to immerse themselves in the financing model, viewed on the basis of the overall cost of the service (European Commission, 2019).

Besides this, other individual surveys and studies have been carried out on behalf of various committees and institutions. For example, in 2018 the TRAN Committee (the European Parliament Committee on Transport and Tourism) requested a study on charging infrastructure for electric road vehicles (European Parliament, 2018).

A number of demonstration projects involving electric buses have been implemented in Europe, and a number of these have become part of regular services. Cities such as Barcelona, Copenhagen, Heidelberg, London, Milan, Paris and Rome have concluded an agreement, stating that their standard procurement procedures will only include zero-

emissions buses by 2025 (Swedish Energy Agency, 2019 A). There are also a number of international partnerships such as the Electric Vehicles Initiative.

## 2.2. Nordic region

### 2.2.1. Nordic objectives for electric buses

In the Nordic countries, use of electric buses is switching from a phase involving demonstrations and tests to a commercial phase where procurement procedures are taking place within the scope of existing contracts. A OECD and IEA report entitled *Nordic EV Outlook 2018* (2018 B) indicates that Denmark, Finland, Iceland, Norway and Sweden had a total of 104 electric buses in 2018, of which Sweden had around half. In general, it is the capital cities in these countries that have lofty ambitions concerning the implementation of electric buses for public transport services (OECD and IEA, 2018 B). The following targets have been formulated:

- The target defined by Copenhagen is for its entire bus fleet to be electric by 2031 (Krogsgaard Niss, 2017).
- Oslo's target is for 60 percent of its bus fleet to be made up of electric buses by 2025 (OECD and IEA, 2018 B).
- Helsinki is planning to make 30 percent of its bus fleet electric by 2025 (HSL, 2017).

The OECD and IEA estimate that if all of the stated targets were to be implemented, there would be around 2000 electric buses on the streets of these three cities by 2031. Compare this with the 104 electric buses that were operational in 2018 (OECD and IEA, 2018 B).

## 2.3. Swedish stakeholders and previous surveys

### 2.3.1. Swedish public transport stakeholders and electric buses

Each county in Sweden has a regional public transport authority, RPTA, which is responsible for public transport services in the relevant county, region or federation of local government authorities. According to the Swedish Public Transport Act (SFS 2010:1065), the region and municipalities in the same county share responsibility for regional public transport services, but they also have to agree on whether one of the parties is to take on sole responsibility. RPTAs are organised in different ways between the region and municipalities, depending on how responsibilities are distributed between them.

The law (SFS 2010:1065) requires each RPTA to establish targets for regional public transport services on a regular basis in a service provision programme. These service provision programmes have to be updated as required, and are compiled following consultation with corresponding authorities in adjacent counties and other relevant authorities, organisations and public transport operators, along with passengers and representatives of the business community.

If the region alone is the RPTA, the municipalities in the county must also be consulted. The RPTA initiates a public transport service procurement procedure following agreement with the region or municipality in the county. However, which stakeholder is actually authorised to conclude contracts is dependent – as stated previously – on the distribution of

responsibilities between the region and the municipality. When procuring bus services, bus operators are permitted to submit tenders for the transport services procured by the RPTA in question.

While public transport in Sweden is mainly run by private bus operators, RPTAs are responsible for planning and providing public transport services. The municipality is frequently an important stakeholder, as public transport services are provided on municipal land and the responsibilities of municipalities can influence public transport services and their function. Municipalities frequently control land use (Paulsson, et al., 2018), so even if municipalities do not generally plan or provide bus services, municipalities' urban planning and urban planning affect conditions for public transport services (Hansson, Petterson, Khan, & Hrelja, 2018).

Introducing electric buses requires cooperation involving many different stakeholders, and the fact that electric utility companies, universities and suppliers of charging infrastructure have been involved to varying degrees in addition to municipalities, RPTAs, bus operators and bus manufacturers has been emphasised for previous initiatives (Aldenius, Forsström, Khan, & Nikoleris, 2016). In a report from 2019 (2019 A), the Swedish Energy Agency cites – by way of example – parties involved in a procurement procedure for electrified buses for public transport services, and refers to the RPTA, municipality, landowner, grid owner, power supplier and suppliers of both charging equipment and vehicles.

The stakeholders involved in the various electric bus initiatives have differed previously, partly on account of the nature of the project in question; development or demonstration projects, or projects within the scope of regular operations. In general, the former procedure has involved interaction with a number of different stakeholders, including research institutes; while the latter has taken place within the standard procurement procedure (Aldenius, Forsström, Khan, & Nikoleris, 2016).

At the same time, electric bus initiatives in future could also involve other stakeholders, or stakeholders whose roles differ from the traditional public transport arrangement. A representative of E.ON (2019 A) is of the opinion that there is a market window when it comes to electric buses and the energy system that one or more new stakeholders could conceivably fill. The charging solution for electric buses is frequently viewed as an isolated phenomenon, but the same representative of E.ON is of the opinion that charging could also form part of a more cohesive energy system.

Future stakeholders could handle the charging of electric buses on the basis of a coordination and optimisation perspective in respect of other phenomena that also require electricity. This would therefore allow stakeholders to organise and manage charging and electricity consumption at a higher level, from a system perspective. The aim of this is to create cost-effective solutions in terms of capacity, output and energy, but also to identify potential synergies with other vehicle charging infrastructure.

### 2.3.2. Previous surveys and initiatives

A number of different surveys and reports have been published in respect of electric buses; technical reports, scientific reports and descriptions. Many publications have been either compiled or ordered by the RPTA or region responsible. The publications available in respect of the three case studies – Region Stockholm, Region Skåne and Region Västra Götaland – are referred to under their respective headings.

In 2016 K2, the Swedish Knowledge Centre for Public Transport, published a report compiling intelligence and information on electric bus projects in Sweden and Europe. The aim of this work was to chart stakeholders involved and driving progress, the motivation behind them and the technology selected for both buses and charging infrastructure. The authors showed that the electric bus projects studied have a broad reach within all the parameters studied, but there are a number of common themes. When it came to involved stakeholders in Sweden, the ones driving progress were mostly municipalities and regions (Aldenius, Forsström, Khan, & Nikoleris, 2016).

The main driving forces involved elimination of local problems such as noise and particulate emissions, as well as global issues relating to greenhouse gas emissions. Other motivating factors included profiling the city as a world leader in terms of environmental initiatives by implementing new green technology, and the option of applying for funding for demonstration projects from the Government and the EU (Aldenius, Forsström, Khan, & Nikoleris, 2016).

Back in 2016, it was still unusual for such initiatives to be included in standard procurement procedures. Instead, they were primarily involved in development or demonstration projects examining technical solutions. Regardless of the project form, the most common electric bus technology involved all-electric buses of normal size, 12 metres long, and these were mainly charged at their depots. However, there was also conductive charging at terminuses.

Plug-in hybrids were only included in projects where bus manufacturers were involved in the work (Aldenius, Forsström, Khan, & Nikoleris, 2016). A further six cities implemented tests involving one or a small number of electric buses. Five of these cities were part of the GreenCharge Sydost project, which aimed to introduce electric vehicles to South-East Sweden (Borén, et al., Green Charge - demotest i fält med elbuss., 2015).

A coordination assignment specified by the Government for switching the transport sector to fossil-free fuels, known as SOFT (Swedish Energy Agency, 2019 B), is being implemented between 2016 and 2019. This assignment is headed by the Swedish Energy Agency in association with the Swedish Transport Agency, the Swedish Transport Administration, Swedish Transport Analysis, the Swedish Environmental Protection Agency and the National Board of Housing, Building and Planning. This work involves devising a strategic plan for the changeover and creating collaboration in order to achieve synergies with other national initiatives, such as FFI (Fordonsstrategisk Forskning och Innovation) and the Cross-Party Committee on Environmental Objectives. This work has been based on the interim and final targets of the Climate Policy Framework involving a 70 per cent reduction in CO<sub>2</sub> emissions in the transport sector by 2030 and net zero emissions by 2045 (Swedish Energy Agency, 2019 B).



2019 saw the publication of a report as part of SOFT, entitled *Informationsstöd om elbussupplägg till kollektivtrafikhuvudmän* (Swedish Energy Agency, 2019 A). This aims to distribute information and intelligence from RPTAs, municipalities, bus operators and other stakeholders involved. The aim of this work is to facilitate decisions relating to the purchasing and implementation of electric buses by providing information about electric buses, charging infrastructure, batteries, safety, costs, procurement procedures and administration of contracts, as well as compiling previous experiences. It will then be possible to use this information to examine whether electric buses may be profitable from a socio-economic standpoint.

The Elbusspremien scheme from the Swedish Energy Agency and the Stadsmiljöavtal scheme from the Swedish Transport Administration are two important elements in the Swedish Energy Agency's report (2019 A), as the purpose of this report is to make it easier for stakeholders to utilise the forms of funding referred to. Finally, as electric buses are a new technology being applied in an existing market, new expertise is needed by all parties involved (Swedish Energy Agency, 2019 A).

## 2.4. Swedish instruments and forms of funding

This section describes various instruments and forms of funding that will be available when electric buses are introduced to the Swedish market. The bonus-malus system is mainly applicable to vehicles of a maximum weight of less than 3.5 tonnes, thereby ruling out the majority of electric buses in Sweden. Green zones may be used to restrict vehicle access in urban areas, depending on what is emitted by vehicles.

The instruments and forms of funding applicable to electric buses – the Elbusspremien, FFI, Klimatklivet and Stadsmiljöavtal schemes – are described in the section below.

### 2.4.1. Elbusspremien

The Elbusspremien scheme is a form of government funding paid by the Swedish Energy Agency to cover additional costs incurred when purchasing all-electric buses, plug-in hybrids, fuel cell buses or trolleybuses designed to carry at least 15 passengers. Funding as part of this scheme is available to RPTAs, municipalities and limited companies that are authorised to enter into public transport contracts, and, finally, bus operators running public transport services (Swedish Energy Agency, 2019 C). The long-term objective of this initiative is to help improve our climate, reduce air pollution and reduce noise (Englund, 2019).

The Elbusspremien scheme is regulated by Ordinance 2016:836 and electric bus premium regulations (STEMFS 2018:3). The budget for the Elbusspremien scheme currently stands at SEK 80 million per annum until the initiative comes to an end in 2023. For Elbusspremien funding to be granted, applications need to be submitted before buses are put into service, and for bus operators applications also have to be submitted before buses have been ordered (Swedish Energy Agency, 2019 C).

The amount of funding paid varies depending on who the applicant is: bus operators may be awarded 40 per cent of the difference between an electric bus and a comparable bus with an internal combustion engine. Plug-in hybrids are awarded funding of 50 per cent of the difference. Other stakeholders that are eligible to apply for this funding are awarded 20 per cent of the purchase price of the electric bus (Swedish Energy Agency, 2019 C). This scheme focuses only on the cost of buses, so it is not possible to apply for funding for charging technology, for example. Applications for funding for charging infrastructure can be submitted to the Stadsmiljöavtal scheme instead: see section 2.4.4.

A representative of the Swedish Energy Agency (2019 D) states that the process of awarding funding to RPTAs generally progresses more quickly than is the case with private companies. Stakeholders applying for this funding do not need to be the owners of vehicles. This is why there is variation as regards which stakeholders apply for the funding in different parts of Sweden, and in each individual case. There are annual differences as well.

Applications were received from 18 RPTAs and 13 private companies in 2018, while 6 RPTAs and 20 private companies submitted applications in 2019. A representative of the Swedish Energy Agency (2019 D) states that the authority has received more applications than it can fund. Furthermore, the representative of the Swedish Energy Agency stated in the same interview that discussions with various stakeholders and applicants have revealed mixed opinions regarding the impact of the Elbusspremier scheme on interest in investments and electric buses. Some beneficiaries maintain the opinion that the Elbusspremier scheme is a useful contribution, but that they would have invested in electric buses even without it; while others say that they are not sure whether they would have invested in electric buses without the scheme (Swedish Energy Agency, 2019 D).

#### 2.4.2. FFI (Fordonstrategisk Forskning och Innovation)

FFI (Fordonstrategisk Forskning och Innovation, Strategic Vehicle Research and Innovation) is a partnership involving the government and industry, funding research, development and innovation with regard to fossil-free vehicles. This programme is divided into five sub-programmes (Vinnova, 2018), where electric bus initiatives come under the umbrella of the Energy and Environment sub-programme (Swedish Energy Agency, 2017). FFI has funded around 30 projects over the past five years, helping the development of heavy electric vehicles (not just electric buses). ElectriCity, the electric bus demonstration project in Gothenburg, is one example of a project that has received FFI funding (Swedish Energy Agency, 2019 E).

#### 2.4.3. Klimatklivet

Klimatklivet investment funding is awarded to local and regional initiatives aiming to minimise greenhouse gas emissions, with the overall aim of reducing Sweden's environmental impact. Other objectives involve distributing innovative new technology by introducing it to the market, improving health and increasing employment. Initiatives in industry, energy, urban construction and transport services are all specific areas that have received funding. The Klimatklivet scheme is being managed by the Swedish Environmental Protection Agency, and 3200 different initiatives received funding totalling SEK 4.7 billion between 2015 and 2018. The total allowance for 2019 amounts to SEK 1.5 billion. This funding can be distributed to companies, municipalities, regions and other organisations,

but private individuals cannot obtain funding from the Klimatklivet scheme (Swedish Environmental Protection Agency, 2019 C).

Five applications for funding relating to electrification of bus services have been approved, all of which are aiming to support expansion of charging infrastructure. All applications were submitted to the Swedish Environmental Protection Agency between 2016 and 2018. The total amount awarded stands at around SEK 21 million, representing just under half of the total costs for these projects. Four of the applications were received from municipal companies, and one was received from a municipality. There is good geographical spread, with applications from the county of Västerbotten in the north to the county of Västra Götaland in the south. Of the three geographical areas on which this study focuses, only the county of Västra Götaland has received funding – via municipal companies Göteborgs Energi AB and GS Buss AB. This funding was awarded in 2017 and 2018 respectively (Swedish Environmental Protection Agency, 2019 B).

#### 2.4.4. Stadsmiljöavtal

According to Ordinance 2015:579, municipalities and regions are able to apply for funding in order to create sustainable urban environments. These funding initiatives are known as Stadsmiljöavtal (Swedish Transport Administration, 2019 A) – Urban Environment Agreements. This ordinance has been in force since 2015, and the purpose of the initiatives is to “[...] promote innovative, resource-efficient solutions with strong capacity for public transport services, cycling or freight transport” (Ordinance 2015:579, §1), increasing the percentage of public passenger transport or cycling in towns and cities (Swedish Transport Administration, 2018). The supplement relating to sustainable freight transport was added in May 2019 (Swedish Transport Administration, 2019 B).

Sustainability is a cornerstone, and therefore these initiatives should result in energy-efficient transport solutions, with low greenhouse gas emissions. Furthermore, the initiatives should help to meet the environmental quality targets relating to the *Good built environment* quality objective. Together with any other co-funding, this funding should be equivalent to no more than 50 per cent of the total costs for implementation of the initiative. Furthermore, the Stadsmiljöavtal scheme requires specific services to be provided in return in order to help increase sustainable transport or housebuilding within a given timeframe (Ordinance 2015:579). SEK 12 billion has been earmarked for the Stadsmiljöavtal scheme in the national infrastructure plan for 2018 to 2029, and sustainable freight transport represents a maximum of SEK 400 million per four-year period.

Representatives of the Swedish Transport Administration (2019 B) states that this funding can only be used for charging infrastructure for electric buses, although the funding does not include vehicles themselves. Funding for charging infrastructure may be considered eligible for the Stadsmiljöavtal scheme if the initiative forms part of a larger solution in combination with other public transport initiatives. The fact that charging infrastructure for electric buses was given priority in the selection process was announced during the first round of applications in 2015 (Aldenius, Forsström, Khan, & Nikoleris, 2016).

The Stadsmiljöavtal scheme has been used for charging infrastructure for electric buses in a number of municipalities and regions in Sweden, including Karlstad, Östersund, Jönköping, Umeå, Malmö, Helsingborg and Stockholm. In many of these cases, the charging infrastructure applications have also included infrastructure for Bus Rapid Transit, BRT, and the creation of trunk bus routes (Swedish Transport Administration, 2019 B).

## 3. The four perspectives of the study

As stated previously, four perspectives have been selected for more detailed consideration in order to examine the introduction of electric buses. These perspectives are described in greater depth in this chapter.

### 3.1. Technology

This section describes some of the technical criteria relating to electric buses, focusing on energy consumption, charging strategies and the relevant charging techniques, batteries and the social sustainability resulting from extraction of materials for batteries. It also touches upon standards for buses and charging infrastructure, as well as the power grid and its available output linked with the introduction of electric buses.

#### 3.1.1. Electric buses

There are various ways of defining an electric bus: there is a dividing line between vehicles charged externally, and other vehicles. It is also possible to distinguish between all-electric (BEV) vehicles and plug-in hybrids. Plug-in hybrids use a combination of an internal combustion engine and an electric motor: in other words, they have two powertrains (Swedish Energy Agency, 2019 A). Full electric buses run only on electricity supplied via energy stored in batteries (Aldenius, Forsström, Khan, & Nikoleris, 2016). The study defines the electric bus as an all-electric vehicle, i.e. it has a motor with a powertrain, and a battery for energy storage.

Power can be supplied either while the vehicle is in a standstill (static charging) or while the vehicle is in motion (dynamic charging). Electric road systems (ERS) with Slide-in is an example that provide such dynamic charging; more about that below.

Reduced greenhouse gas and particle emissions, lower energy consumption and reduced noise levels are significant aspects of electric buses compared with conventional diesel and gas buses. Disadvantages include potential battery dependency based on the technology selected, as well as potential establishment of charging infrastructure in the street environment. Moreover, electric buses and their charging infrastructure are frequently more expensive than conventional buses, and electric buses may place a strain on the power grid – particularly the local grid – when charging. Finally, there is no standardisation of charging infrastructure (Bloomberg New Energy Finance, 2018).

Electric buses are significantly more energy-efficient than gas and diesel buses. How the vehicle is driven, the number of passengers and – in particular – the outdoor temperature are the primary factors impacting on energy consumption in electric buses (Lajunen, Kivekäs, Baldi, Vespäläinen, & Tammi, 2018). Conventional diesel and gas buses use surplus heat from the engine to heat the bus in cold temperatures, and air conditioning is used to cool the bus in hot temperatures.

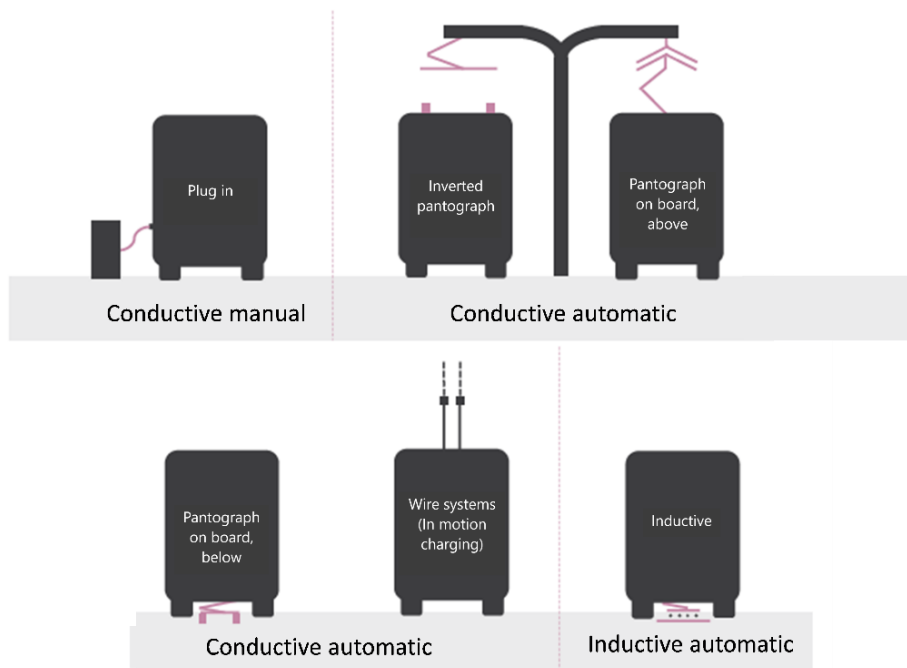
Electric buses do not have internal combustion engines, so the surplus heat created is insufficient to heat the vehicle. This is why cold climates may require additional heating systems. There are various alternatives for this, the most common of them being diesel heaters. However, gas-powered and electric water heaters are also used, as well as heat pumps. These run on fossil diesel or biodiesel, so they do not affect the vehicle's range in the same way that a system powered by electricity would. Energy consumption is also increased when cooling the vehicle, although it is estimated that heating the passenger compartment uses more energy than cooling it (Swedish Energy Agency, 2019 A).

At the same time, the Swedish Energy Agency's (2019 A) comparison of the average energy consumption of the various powertrains per annum, including heating and supplementary systems, shows that energy consumption for various electric bus types is frequently significantly lower than for diesel and gas buses. For example, a 12-metre, battery-powered electric bus has an average consumption value of 1.4 kWh/km and an electric bus charged while in motion has an average value of 1.6 kWh/km, while a diesel bus has an average value of 4.2 kWh/km and a biogas bus has an average value of 5.2 kWh/km. All these buses were 12 metres in length (Swedish Energy Agency, 2019 A).

### 3.1.2. Charging infrastructure for operation of electric buses

Electric bus-systems use charging strategies such as depot charging, supplementary charging or electric road systems, which define how charging is performed (Swedish Energy Agency, 2019 A). Charging technology which is either conductive or inductive is used to transmit the electricity from the power grid to the vehicle (Steen, 2017). Conductive charging takes place via a physical plug, and specific charging technologies may include plug-in options and pantographs connected to overhead cables. Inductive charging users contactless transmission of electricity, either via a specific charging station (static charging) or over a longer distance (dynamic charging) (Bloomberg New Energy Finance, 2018).

These charging strategies can be combined with different charging technologies, and hence they are known as charging concepts. (Swedish Energy Agency, 2019 A). Figure 1 illustrates both charging strategies and charging technologies.



**Figure 1** Overview of charging technologies. Modified from Swedish Energy Agency, 2019 A, p. 24.

### *Depot charging*

*With depot charging, buses are charged at the depot over a period of time, which requires larger batteries in order to meet the vehicles' energy requirements while they operate. Depot charging means that electric buses can be used regardless of the routing, and a charging infrastructure in the street environment is not necessarily required. The disadvantage of depot charging is that electric buses can only be driven within a specific radius around the depot (Swedish Energy Agency, 2019 A).*

The slow charging made possible with depot charging, compared with terminus charging or supplementary charging, means that lower electricity output is required over a longer time. This distributes the impact of electric buses on the power grid over a longer timeframe. However, several vehicles are charged simultaneously at depots, which may result in high simultaneous power takeoff in a single geographical location. This places demands on the power grid capacity and power takeoff, as well as the maximum power takeoff permitted at the depot (Bloomberg New Energy Finance, 2018).

In its report, the Swedish Energy Agency (2019 A) writes that one or more fast chargers may be needed at bus depots with a view to charging buses quickly in situations requiring additional buses. Fast chargers use a lot of power for a short period, and there is higher power takeoff from the power grid when several fast chargers are used simultaneously.

### *Supplementary charging*

Supplementary charging of electric buses normally takes place at bus route terminuses, or at stops along the route. Supplementary charging generally requires smaller batteries than

depot charging, as batteries can be charged along bus routes. Flexibility may be reduced as unlike with depot charging, these buses can only be used on routes where charging infrastructure is available (Swedish Energy Agency, 2019 A).

Another factor to consider is the fact that charging requires the vehicle to remain stationary for a time at the charging stations, which may affect travel times (Swedish Energy Agency, 2019 A). In its report, the Swedish Energy Agency (2019 A) writes that it is best for charging to take place at layover points, which is where buses park in order to regulate the timetable and make up for delays. If there are delays, the charging time can be reduced; and hence accurate turnaround planning is important. In its report, the Swedish Energy Agency (2019 A) writes that several charging stations may be required on routes with frequent services so as to allow several buses to charge simultaneously. Additional stops for supplementary charging may result in reduced vehicle utilisation and higher costs for drivers.

#### *Electric road systems*

Charging via an electric road is either conductive or inductive and mainly takes place while the vehicle is being used. In other words, this is what is known as dynamic charging. Conductive charging can take place via overhead lines, a rail in or on top of the road surface, or a rail alongside the vehicle. Inductive charging involves no contact and takes place over a longer distance (Swedish Transport Administration, 2017).

Demonstration sections for electric road technologies are being implemented within the scope of the Swedish Transport Administration's Electric Roads Program. Two new sections will be opened in 2019 and 2020 to test conductive and inductive charging for urban buses (Swedish Transport Administration, 2019 C). Dynamic charging makes vehicles less dependent on stopping in order to charge, thereby increasing the utilisation level. Battery range problems are also reduced (Swedish Energy Agency, 2019 A). There are electric bus schemes in Sweden – in Landskrona, for example – that have trialled electric buses using a conductive electric road system with overhead lines. This charging technology has a number of different names: Skånetrafiken (2018) calls them Slide-in Buses, while the Swedish Energy Agency (2019 A) refers to this as In-Motion Charging.

This charging strategy increases flexibility, while also making buses dependent on sections where the transmission technology has been established. One disadvantage of this strategy is that it requires large-scale expansion of transmission technology, which costs a lot of money, may not be aesthetically pleasing and ties vehicles to specific routes (Swedish Energy Agency, 2019 A).

### 3.1.3. Standards

#### *Electric buses*

Vehicle standards are governed by international and national laws. However, there are no standards relating to electric buses (Swedish Energy Agency, 2018 A). In its report, the Swedish Energy Agency (2018 A) indicates that there are two clear advantages with standardising charging infrastructure and batteries in vehicles. Firstly, a framework can create a collective reference framework for comparison of products and solutions that can be used by both manufacturers and customers. Secondly, standardisation allows vehicles and other products to be transferred to other geographical locations and still be compatible.



UITP, the International Association of Public Transport, shares the opinion that a standard is needed for the entire electric bus system and the interfaces between different components. This would result in a facilitated procurement process and potential cost savings and uphold the used value of vehicles. Finally, standards may allow different vehicle types to use the same charging infrastructure (Swedish Energy Agency, 2019 A).

#### *Bus Nordic's functional specifications*

Bus Nordic was created in 2018 and is a Nordic standard, along with functional specifications used in bus procurement procedures (Västtrafik, 2018 A). These functional specifications are based on the vehicle classes defined by law. Bus Nordic includes standardisations in the fields of security and safety, seating and comfort, boarding and alighting and moving around inside the bus, information and communication, the exterior and outside, and the driver environment (Bus Nordic, 2018).

These functional specifications mean that better economy can be achieved by allowing these buses to be reused throughout the entire Nordic region, and by allowing Bus Nordic members to make demands of manufacturers and suppliers in terms of creation of new and sustainable solutions (Västtrafik, 2018 A). Some RPTAs are striving to introduce more functional specifications linked with electric buses in Bus Nordic (Västtrafik, 2018 A).

Low-floor, low-entry buses are required in urban traffic, which means that the floor and entrance of the bus have to be close to the ground, making the bus readily accessible for passengers (Bus Nordic, 2018). Both low-floor and low-entry buses fall within the scope of the definition of a low-floor bus as presented by the United Nations Economic Commission for Europe (2015). When the vehicle has a low floor, this may present a challenge regarding battery positioning in relation to weight distribution, as there may not be room for the batteries under the floor, or they may be too heavy to be placed on the rooftop.

#### *Charging infrastructure*

There is neither an international nor a national standard for charging infrastructure, although development work is in progress on both a global and a European scale (Swedish Energy Agency, 2018 A). In 2018, the European Parliament Committee on Transport and Tourism, TRAN, published a report containing a survey and future recommendations for the development of standards for electric vehicles, including cars, bicycles and buses.

Among other things, TRAN recommends that the European Parliament should define minimum standards concerning future charging stations, including payment systems, protocols, data management and reporting, as well as smart charging (European Parliament, 2018). Various trade organisations have issued recommendations, such as the European Automobile Manufacturers' Association, ACEA. They recommend a specific charging technology for both supplementary and depot charging (ACEA, 2017).

#### *Vehicle classes*

Most of the buses operating urban services in Sweden are classified in category M2 or M3, which according to ECOSOC are defined as motor vehicles with at least four wheels used to transport more than eight passengers in addition to the driver (United Nations Economic

and Social Council, 2011). Buses designed to transport more than 22 passengers are divided into three categories: Class I, Class II and Class III. The United Nations Economic Commission for Europe (2015) and Bus Nordic (2018) describe these classes on the following basis:

- Class I vehicles have a number of standing passengers while in motion, which allows them to move around inside the vehicle. Most of the buses operating on urban routes are Class I vehicles, and these are also the vehicles that are initially of interest as regards electrification.
- Class II vehicles are primarily designed for seated passengers and a small number of standing passengers. These buses are common on suburban and regional services in Sweden. The three regions studied are not planning to implement Class II electric buses as things stand at present, but the public transport authority in Oslo is working on introducing Class II electric buses (Bussmagasinet, 2019 A).
- Class III vehicles are designed for seated passengers only and are used for regional and long-distance services. Hence these are not being considered for electrification in Sweden as things stand at present.

There may also be variants in standards. Trafikförvaltningen Stockholm uses Class 1.5 buses, which are Class II buses provided with additional space for pushchairs or standing passengers. These buses are then registered as Class I buses but are Class II buses in terms of safety and comfort, and are frequently included in Trafikförvaltningen's use of the term "Class II buses" (Trafikförvaltningen, 2019 C).

#### 3.1.4. Batteries

Battery development has resulted in increased battery capacity, and the use of lithium batteries is a significant factor in this regard. Lithium is mainly used as a component in batteries in buses and other vehicles. The advantages of lithium batteries are that they provide opportunities for fast charging, they have a relatively long service life and offer high energy density (2019 A). Other important materials that may be found in batteries include graphite, nickel, cobalt and aluminium, found in varying proportions in relation to the total composition of batteries (Romare & Dahllöf, 2017).

One difficulty with batteries involves the tracking of how the materials in them are extracted. The EU lists a number of materials deemed critical for our society, and for welfare, with regard to the economic significance and supply of these materials (European Commission, 2017). Hence the term "critical material" refers to whether they are extracted with serious social issues such as child labour and inadequate working conditions (Swedish Energy Agency, 2018 B). Cobalt and cadmium are prime examples of critical materials (European Commission, 2017).

The OECD recommends that battery manufacturers should use their publication entitled *Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas*, which includes information on extraction of materials in countries affected by conflicts and crises (OECD, 2013). There are also risks concerning access to materials such as lithium, where supplies are not widespread: in other words, extraction of

this material is concentrated to specific countries. Recycling of batteries in vehicles presents a further challenge (Swedish Energy Agency, 2019 A).

The *Directive on batteries and accumulators* (European Parliament and Council, 2006) was adopted in 2006 with a view to combating environmental pollution in order to promote public health, focusing in particular on elimination of cadmium. This directive includes industrial batteries from electric vehicles, as well as industrial accumulators, and makes it clear that disposal of these batteries in landfill sites or by incineration should be prohibited. The directive also makes it clear that responsibility for taking back waste batteries rests with their manufacturers, or third parties acting on behalf of manufacturers.

The EU defined a target; for 45 per cent of batteries to be collected by 2016. Sweden collected 35,600 tonnes of batteries in 2016, equivalent to a level of 61 per cent (Swedish Environmental Protection Agency, 2019 A). The requirements in the directive also state which materials are to be recycled. There are no directives at present, either European or national, that state how lithium is to be processed, apart from the fact that it must have a recycling efficiency of at least 50 per cent (European Parliament and Council, 2006). With this, it should be noted that the recycling requirement is not comprehensive for lithium, and hence is also not comprehensive for the batteries that are currently widely used for electric buses.

### 3.1.5. The power grid and shortage of power output, electricity and capacity

Electricity consumption in Sweden has been relatively constant over the last 25 years, although the percentage of total energy consumption in Sweden accounted for by electricity has increased. Assessment of future electricity consumption in Sweden beyond 2030 also shows that electricity consumption is expected to increase in the residential, service, industrial and transport sectors (IVA, 2016).

The Swedish transmission network is owned by the public authority Svenska Kraftnät and transmits large amounts of energy over long distances, in a similar way to a motorway. This energy is distributed through the distribution grid, either the regional grid or the local grid, to end-users (NE, u.d).

It is important to differentiate between shortage of power output, electricity and capacity, as these require different action. A shortage of power output means that the amount of electricity demanded is not sufficient at one or more specific times. A shortage of electricity means that insufficient amounts of electricity are being produced. A shortage of capacity refers to the capacity of the power grid, relating in particular to the physical design of the power grid (Ellevio, 2019). The Swedish Energy Agency (2019 F) states that Sweden's national electricity production currently meets Sweden's need for electricity.

A representative of the Swedish Energy Agency (2019 F) states that the Swedish transmission network has sufficient capacity to transmit the electricity produced. Capacity shortage problems occur locally; primarily with distribution grids, but also locally on the transmission network in some cases (Swedish Energy Agency, 2019 F). The Stockholm region, the Mälardalen region and the cities of Uppsala and Malmö are the main areas facing

potential capacity shortage (Svenska Kraftnät, 2018). Furthermore, a representative of the Swedish Energy Agency (2019 F) states that capacity shortage occurs as a result of either market design or physical restrictions in the infrastructure.

When bus services are electrified, further capacity and power output demands will be made of local grids so that buses can be charged. Electric buses are generally charged quickly or slowly. Fast charging involves high transmission of energy over a short period: this is common with supplementary charging, but it may also take place at depots (Swedish Energy Agency, 2019 A). Slow charging involves low energy transmission over a long period and most commonly takes place at depots. Whether the power output is high or low, whether charging takes place over a short or a long time and the number of vehicles charged simultaneously place different loads on the power grid (Swedish Energy Agency, 2019 A; Steen, 2017).

A representative of the Swedish Energy Agency (2019 G) states that restrictions for electric buses may primarily be indicated due to a potential shortage of local grid capacity. It is also stated (2019 G) that the national transmission network is currently facing no challenges linked with increased electricity consumption due to buses. One option has been highlighted, where the switch to electric buses could potentially contribute to the creation of new electricity and energy systems due to various partnerships between stakeholders. With this, electric buses could become an important energy carrier or form of energy storage (Swedish Energy Agency, 2019 F).

## 3.2. Organisation and funding

This section describes the organisation and funding of public transport, with emphasis on electric buses. The procurement process and contract structures are described initially. After that, the focus is responsibility interfaces based on electric bus initiatives; and finally potential cost items and socio-economic effects with regard to electric buses are described.

### 3.2.1. Procurement and contracts

#### *Contracts and contract structures relating to public transport*

There are various contract fields for public transport for which RPTAs accept liability, and procurement procedures relating to the operation of public transport services are implemented with the involvement of bus operators for these contract fields. According to the EU, the duration of public transport contracts must be time-limited, and the duration must not exceed ten years for bus services (European Parliament and Council, 2007). There are various procurement form types, but in 2013 a collaborative structure between RPTAs and operators (*Partnersamverkan för en förbättrad kollektivtrafik*) proposed service concession contracts, passenger incentive contracts or production contracts (Swedish Public Transport Association, 2013).

Service concession contracts mean that the party awarded the concession is responsible for most of the operation in question (Trafikförvaltningen, 2019 A). There are supporting documents for commercial services for service concession contracts, and the bus operator also accepts significant business liability and risk (Swedish Transport Analysis, 2015). Incentive contracts are based on the operator receiving a certain amount of flexible income from the procuring authority. Three incentive contract types are common in Sweden: based

on quality variables, a larger proportion of basic remuneration and flexible remuneration based on the number of passengers using the service, or based entirely on the number of passengers using the service (Swedish Competition Authority, 2015).

If the client has to accept liability for most aspects relating to services and RPTAs accept the financial risk, production contracts are considered appropriate instead. Production contracts are a contract form where RPTAs received ticket revenues and the bus operator receives remuneration for costs in accordance with the contract for the assignment allocated to them (Swedish Transport Analysis, 2015).

Liabilities between parties to a contract are distributed in different ways. For example, RPTAs generally have greater liabilities in production contracts compared with incentive contracts (Trafikförvaltningen, 2019 A). The report entitled *Partnersamverkan för en förbättrad kollektivtrafik* proposes supplementation of a selected type of contract with a special Cooperation Contract between stakeholders in order to identify which approach is best for attaining the targets (Swedish Public Transport Association, 2013).

#### *Functional specifications and detailed requirements*

Procurement procedures may involve either functional or detailed requirements. Functional specifications indicate what the objective is; either which functions are demanded, or the effects and results sought. Detailed requirements indicate how the objective is to be achieved and are the traditional way of defining demands. The National Agency for Public Procurement generally recommends functional specifications as this may help to bring about innovative new solutions, as the provider is not restricted to specific choices of technology, product or approaches (Upphandlingsmyndigheten, 2019). Examples of functional specifications for public transport in urban areas may include reducing travelling times, reducing costs or streamlining services (Upphandlingsmyndigheten, 2018). Procurement procedures may include both functional and detailed requirements (Upphandlingsmyndigheten, 2019).

#### *Option clause*

Transport service contracts may also include an option clause, which means that a contract or framework agreement may be amended in accordance with this clause on the basis of certain conditions, as long as the general nature of the contract is not amended. Options normally relate to additional deliverables that the procuring authority or unit may order, but there is no obligation to do so. Options frequently constitute complete supplements that can be included in contracts. If an authority or procuring body chooses to exercise an option, strictly speaking this means that they are not amending the contract, therefore, but that they are choosing to utilise a potential supplement to the contract (Upphandlingsmyndigheten, 2017). Electric buses can be implemented by RPTAs exercising an option clause in applicable contracts: Västtrafik, for example, has done this (Västtrafik, 2019 A).

#### *Introduction of electric buses*

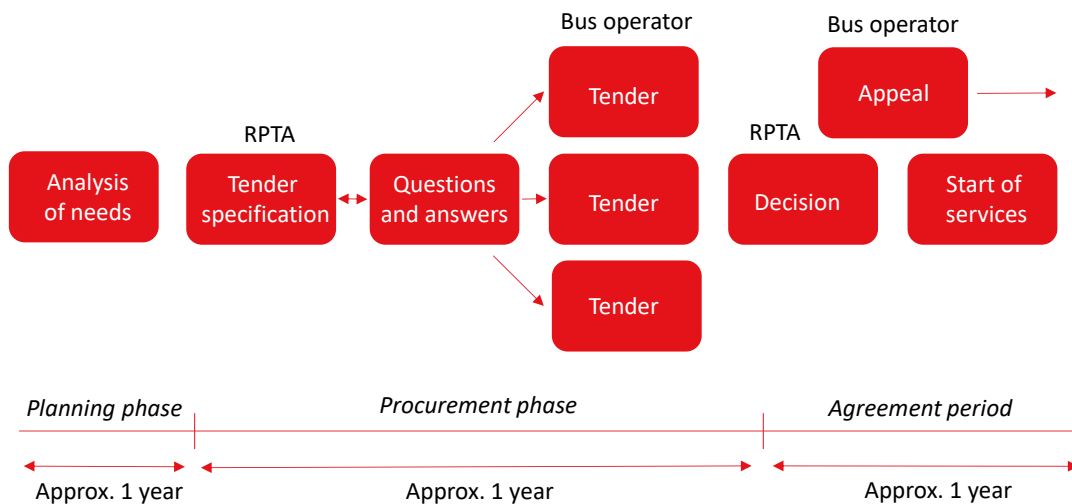
Electric buses may be introduced within the scope of regular contracts and in new transport service contracts, and examples of both can be seen in Sweden (Trafikförvaltningen, 2019

A). For example, electric buses were introduced as part of an existing contract in Norrtälje in 2018, and they were introduced in Helsingborg prior to a new contract procurement procedure (Skånetrafiken, 2019 A). Until recently, electric buses have frequently been introduced as demonstration or test projects in Sweden, which means that their introduction has taken place outside the regular contract structure and procurement process (Swedish Energy Agency, 2019 A).

A number of different factors can influence the opportunities for introduction of electric buses as part of a current contract. Major changes within a current contract are not always permitted, and they may also involve further costs and risks for the parties involved. New costs may be introduced, for example, or criteria for depreciation of previous vehicles and investments may be affected. Depending on vehicle owners and the environmental and vehicle requirements defined in contracts, opportunities to replace vehicles are more or less limited. There are greater opportunities if municipalities or RPTAs own vehicles, rather than if bus operators own them. Introduction of electric buses as part of a procurement procedure for new transport service contracts may be advantageous as prices tended can be opened to competition, requirements can be adapted for the contract and the risks for the parties involved can be reduced (Swedish Energy Agency, 2019 A).

### The procurement process

The procurement process for transport service contracts can be divided into a planning phase, a procurement phase and the contract period phase (Konkurrensverket, 2019). A general description of the procurement process for public transport services is shown in Figure 2 (Lidestam, Johansson, & Pyddoke, 2016).



**Figure 2** The procurement process. Modified from Lidestam, Johansson & Pydeko (2016, p. 9).

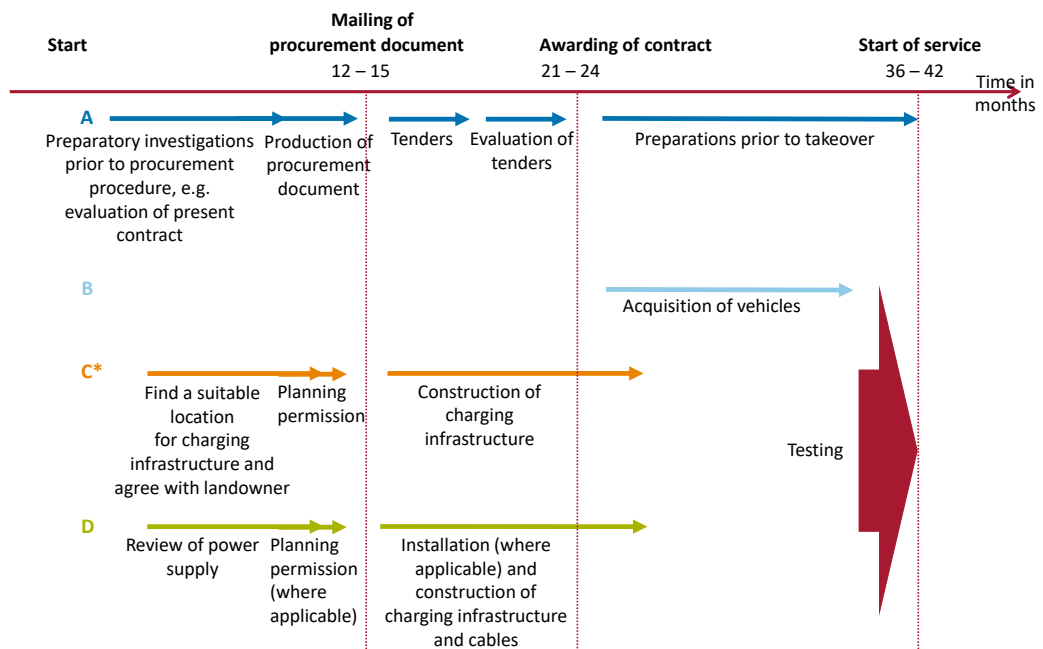
The procurement process for public transport services is extensive, initiated by a major needs analysis for the transport service contract. As a rule, RPTAs then submit a tender specification that describes terms and conditions for the transport service contract. This may also have been preceded by a discussion with interested operators, who are given the

opportunity to submit their opinions on the procurement procedure in terms of the content and formulation of the tender specification.

Following submission of the tender specification, there is a further period where operators are given the opportunity to ask questions concerning the tender specification and receive answers in order to highlight and resolve any unclear points. These questions and answers are open to all stakeholders so that everyone is able to view the same information. Following the end of the tendering period – which may last about a year after the issuing of the tender specification – all tenders are evaluated in order to decide which operator is to be awarded the contract: see Figure 2 (Lidestam, Johansson, & Pyddoke, 2016).

### *The procurement process for electric buses*

The procurement process for electric buses to be used for public transport services can be described as shown in Figure 3 below. It is evident from the description that standard procurement of public bus services is supplemented by parallel processes so that it is possible to introduce electric vehicles.



**Figure 3** Various processes when introducing electric buses to public transport services. Modified from Swedish Energy Agency, 2019 A, p. 58.

Process A provides a general description of a standard procurement procedure for public bus services, similar to the one described in Figure 3. Process B illustrates the procurement of vehicles which can also be initiated prior to the awarding of a contract if an RPTA or municipality is to own the vehicles. Given present conditions in the industry, the procurement procedure for electric buses is estimated at around 14 to 18 months, which is longer than the period required for regular buses. (Swedish Energy Agency, 2019 A).

If electric buses covered by the contract are to be charged on the streets, Process C indicates that discussion will be required with landowners and power grid owners/electricity suppliers in order to select locations for charging infrastructure. Authorisation for charging infrastructure is dependent on the technical solution and location selected. Planning permission is generally required for charging along routes, at terminuses or in other locations, such as terminals and layover points.

If the bus operator is responsible for making decisions on where charging infrastructure is to be located in the streets, this process cannot commence until a decision has been made concerning the awarding of the contract. Finding time to prepare this before services commence may then present the bus operator with a major challenge. If electric buses are only to be charged at the depot, Process C is not required as no charging will take place on the streets (Swedish Energy Agency, 2019 A). Planning permission may nevertheless be required for depot charging.

Process D relates to charging at depots. This makes it necessary to ensure that there is enough of a power supply to the depot. Planning permission may also be needed for the charging infrastructure at the depot; if a new or renovated transformer station is required, for example (Swedish Energy Agency, 2019 A).

### 3.2.2. Allocation of responsibilities

Allocation of responsibilities among stakeholders as part of a transport service contract differs widely from case to case. Ownership rights and liability for buses, depots and stops, transport service offerings, timetables and service information are all aspects that may differ among various RPTAs. Moreover, the allocation of responsibilities does not necessarily have to be the same for the various contract fields within one and the same RPTA. The extent of a transport service contract for an RPTA may also vary in terms of scope, from a single route to routes covering an entire county. This means that the distribution of risk and costs may vary: risks may also be distributed among few or several stakeholders (Swedish Energy Agency, 2019 A).

As regards electric buses, responsibilities and ownership for both buses and charging infrastructure vary with the interface defined prior to a procurement procedure. Electric buses can be owned by RPTAs, municipalities or bus operators. There are a number of possible variants as regards the division of roles and responsibilities between parties when it comes to operation and maintenance of charging infrastructure (Swedish Energy Agency, 2019 A). The responsibility interface and clarification of the same is a key part of the transport service contract authority electric buses are concerned (Trafikförvaltningen, 2019 A).

In general, stakeholders' opinions relating to responsibilities and interfaces vary. Different companies within the same group of stakeholders may have differing opinions on what obligations ought to be included in their responsibilities. Some companies want to take on several roles, while others would prefer just to devote themselves to their traditional core business (Trafikförvaltningen, 2019 A).

Different stakeholders have been more or less involved in the initiatives implemented to date, primarily within the scope of demonstration projects. Above all, RPTAs and municipalities have been actively involved in the introduction of electric buses and



promoted their introduction, but bus manufacturers, power companies and technology companies have also driven some initiatives to a certain extent. Bus operators have been involved by providing transport services, but they have had less responsibility for other issues such as organisation and selection of technology (Aldenius, Forsström, Khan, & Nikoleris, 2016).

### 3.2.3. Cost items and allocation

#### *Costs for electric buses and charging infrastructure*

Costs and their distribution for electric buses are not the same as for traditional buses in the overall calculation, which may result in changes to the overall cost for RPTAs. One challenge with electric buses is that even though the total cost of ownership (TCO) may be beneficial, electric buses frequently involve higher initial costs than traditional buses (Bloomberg New Energy Finance, 2018).

The total cost of an electric bus will vary depending on a series of factors. For instance, the cost for urban buses may be different to the cost for rural buses, and the cost is affected by factors such as the price of electricity, the annual distance travelled, the charging concept, batteries and service life, along with any contributions and subsidies (Transport & Environment, 2018).

In a report, the Swedish Energy Agency (2019 A) writes that the total cost of an electric bus is largely made up of the purchase of the vehicle and the costs for batteries and maintenance. Fuel costs are significantly reduced compared with conventional buses. The same report draws a comparison between the annual costs for electric buses and the annual costs for traditional buses, dividing up cost items by vehicle price excluding batteries, batteries, charging infrastructure, maintenance and energy (Swedish Energy Agency, 2019 A).

The purchase price for electric buses is based on a number of factors, such as the number of vehicles ordered. See Table 1 for a list of purchase prices for buses with different powertrains. It should be observed that these costs relate to 2016 and 2017, and that technology has developed and costs have potentially been reduced since then. The table shows that the template price for electric buses and HVO hybrids varies widely. However, it is possible to distinguish the fact that electric buses are more expensive than the other available powertrains; with the exception of one of the estimates for an HVO plug-in hybrid, which falls within the same price range of electric buses.

It may be noted that renewable fuels are currently used by a large proportion of Swedish public transport services (Bussmagasinet, 2018). For instance, only renewable fuels are used for bus services in the three regions included in this study, and hence buses running on fossil fuels have not been included in the table below.

**Table 1** Assumptions from two surveys relating to purchase prices for buses with different powertrains. All costs are specified in millions of Swedish kronor (SEK) and are based on 15-metre vehicles (Sweco, 2017; Trivektor, 2016).

	All-electric	Gas	HVO hybrid	HVO plug-in hybrid	HVO	Ethanol
<b>Trivektor (2016)</b>	4.9	2.7	3.7	4.9	-	2.53
<b>Sweco (2017)</b>	4.0	2.8	3.0	3.3	2.6	-

Investments in charging infrastructure may also be financially onerous (Swedish Energy Agency, 2019 A). Estimates based on experiences from demonstration projects, published by Sweco (2017), have shown that charging infrastructure for fast charging corresponding to 150, 300 or 450 kW cost between SEK 1.5 and 3 million. The charging infrastructure for slow depot charging is estimated to cost SEK 250,000 (Sweco, 2017).

Driver costs are not included in the Swedish Energy Agency’s cost comparison, but driver costs are a major cost item for public transport services; which means that the driving and, possibly, charging of electric buses – where additional driver time is required – largely affect the overall cost of electric buses. Bus operators stated in interviews that there is a risk of driver costs increasing, primarily with regard to supplementary charging, as buses will be stationary for a number of minutes (Nobina, 2019; Transdev, 2019 A). Around 60 per cent of the cost per kilometre driven is accounted for by driver pay (Nobina, 2019), which means that the overall cost may increase significantly if the driver time increases.

At the same time, electric buses have a cost benefit in that their energy costs are lower and in conventional buses thanks to more efficient energy usage and the fact that electricity costs less than conventional fuels. As a result, electric buses may be more profitable than other alternatives (Swedish Energy Agency, 2019 A).

Batteries are another large cost item. That said, the purchase price of lithium-ion batteries has fallen by 84 per cent over eight years. It is thought that future price development will level out, with a further total reduction of 18 per cent by 2030 (Goldie-Scot, 2019).

#### *Depreciation period and electric bus service life*

The depreciation period for a bus normally stands out between 10 and 12 years and is based on demands from RPTAs concerning maximum vehicle age and sometimes the average age of vehicles in a fleet. If the depreciation period can be increased for electric buses, this would mean a significant cost reduction over the term of a standard transport service contract, which would be a positive factor in that electric buses are more expensive to purchase than conventional buses (Sveriges Bussföretag, 2019).

There is an option of refurbishing vehicles in order to maintain a sufficiently high standard throughout the entire contract period, thereby eliminating the need to replace the entire vehicle (Partnersamverkan för en förbättrad kollektivtrafik, 2018). This ought to be possible,

as electric buses are assumed to have a longer service life than diesel or biogas buses, as it is thought that electric motors do not wear as readily (RT-Forum, 2019).

The used market for electric buses is more or less non-existent (Swedish Energy Agency, 2019 A), which helps to keep costs high when combined with short depreciation periods and the major uncertainties resulting from new technology (Sveriges Bussföretag, 2019).

#### *Socio-economic effects*

Socio-economic costs and revenues include other aspects resulting from the use of electric buses, along with effects on the surrounding community. Above all, electric buses result in better local air quality, with fewer emissions of particles, nitrogen oxides and greenhouse gases. Electric buses also result in less noise and vibration (Sweco, 2017).

Including socio-economic effects means that electric buses can be socio-economically beneficial even if profitability from a business standpoint presents a challenge initially (Swedish Energy Agency, 2019 A). Socio-economic gains such as improved air quality and reduced noise and environmental impact have also emerged as common driving forces in both current and previous implementation of electric buses (Bloomberg New Energy Finance, 2018).

#### *Funding of electric buses*

For earlier projects in Sweden, funding has sometimes been managed differently than with traditional procurement procedures and contracts. Special contracts have been concluded with operators where municipalities and regions have taken on the additional financial risks that may arise when investing in electric buses (Aldenius, Forsström, Khan, & Nikoleris, 2016). Umeå, for example, accepted the cost of both buses and charging stations in 2014/2015 when the city implemented a major initiative involving new electric buses (Umeå Kommun, u.d.).

A number of electric buses in Sweden are now owned by RPTAs, municipalities or vehicle suppliers; but as electric buses become increasingly common, risks associated with electric buses may potentially decline and hence the percentage of electric buses owned by bus operators will increase (Swedish Energy Agency, 2019 A).

### **3.3. Broader social perspective**

This section describes electric buses from a broader social perspective. By this, we mean how electric buses can be coordinated with other electrification processes in society, and how urban planning with regard to the built environment and infrastructure influences and is influenced by electric buses. This section also describes public transport services and electric bus initiatives on the basis of a need for various stakeholders and society to interact.

### 3.3.1. Electrification processes

#### *Coordination of electric buses with other transport types*

In 2018, the number of rechargeable vehicles in Sweden increased by 52 per cent compared with 2017. In this case, rechargeable vehicles include electric cars, plug-in hybrids, electric vans and four-wheeled electric motorcycles (Power Circle, 2019). Increasing interest in electrification of heavy goods vehicles, where the Swedish Transport Administration and others are working with electric road systems, is being noted.

To an extent, it should be possible to coordinate electrification of bus services with other electrification of the transport sector. Coordination and sharing of infrastructure for e-mobility may include making the public transport power grid more efficient and increasing cost-effectiveness, and mean that less space needs to be taken up in the urban environment. Besides the fact that it should be possible to share infrastructure between different modes of public transport, there is also potential in future to integrate the public transport charging infrastructure with other electric modes of transport (Eliptic, 2018 A).

At present, a certain amount of effort is being invested in linking electric buses and other electric vehicles to existing public transport infrastructure. Expansion of electric bus systems and their infrastructure may contribute to electrification of other transport types, but it may also be coordinated with systems that are already electrified. For supplementary charging, for example, there is potential for coordination with regard to reinforcement works in the local power grid, where it should be possible to establish other charging station types when the power grid is reinforced in order to prepare for the charging infrastructure (Eliptic, 2018 A).

Private electric cars are normally charged at people's homes or their places of work (Swedish Energy Agency, 2019 G). Electric buses are frequently charged at special charging points for electric buses, although this means that charging points for electric cars and electric buses are not necessarily close to one another.

Co-use of charging infrastructure for supplementary charging may present challenges as regards ownership of the charging infrastructure and order of priority with regard to buses and other vehicles (Trafikförvaltningen, 2019 B). There are fewer opportunities for coordination for electric buses charged at the depot, as the electric infrastructure is then located at the depot. However, when it comes to depot charging, reinforcement of the local power grid can be used to establish the nearby public charging stations if the area is deemed appropriate for this.

If haulage or terminal operations are run in the local area, reinforcement of the local power grid as a consequence of depot charging may mean that all-electric trucks can also benefit from this, for example. This is also true of electric trucks if haulage or terminal operations are established close to bus depots (Trafikförvaltningen, 2019 B). Overhead catenary infrastructure – if trolleybuses are used – could also be used by other heavy vehicles (Trafikförvaltningen, 2019 B). Such catenary infrastructure could be coordinated with tram services, perhaps primarily with regard to posts for overhead wires and feeder stations, although this may need to involve adaptation of parts of the system (Trafikförvaltningen, 2019 B).

### *Examples of co-use of infrastructure and charging stations*

There are examples of electric buses having co-used existing infrastructure for trams and other modes of transport, which demonstrates the option of sharing infrastructure for various electric modes of transport (Eliptic, 2018 A).

There are a number of examples of trams and electric buses co-using systems. Vienna introduced twelve electric buses in 2012. These use the overhead lines for trams to charge while they are in motion (European Commission, 2013). There is a project running in Oberhausen, Germany, which involves use of tram infrastructure for charging electric buses via two solutions; using the overhead catenary system for trams, or by means of an existing coupling station for a tram station. This project indicated that it was technically and operationally possible to do this, although it also encountered a number of obstacles, linked with organisational maturity and legal aspects. Charging stations for electric vehicles were also constructed in Oberhausen, and these are powered from the direct current infrastructure for trams (Eliptic, 2018 B).

A similar project has been implemented in Warsaw on the basis of the option of using existing tram infrastructure for supplementary charging of electric buses, by diverting energy from the tram power grid to electric bus chargers. The project showed that tram infrastructure can be used for charging electric buses ahead of Warsaw's ongoing electric bus fleet initiative. However, it was concluded that using the standard power grid for charging appeared to be simpler (Eliptic, 2018 C).

Use of the power grid infrastructure for the underground rail service has also been studied in order to see whether this could be used to charge electric buses. A project has been implemented in Brussels in order to test whether existing power grid infrastructure for both trams and underground railways could be used for supplementary charging of buses, by using the existing power grid to supply electricity to electric bus charging stations. This project showed that there is a great deal of potential when it comes to integrating electric bus charging infrastructure with existing tram or underground railway grids, but at the same time there may be challenges such as finding funding and dealing with a lack of space. There is also a risk of such integration leading to systems being locked to a specific technical solution (Eliptic, 2018 D).

A pilot project is currently being prepared at a railway station in the Netherlands with a view to using brake energy from trains to charge electric buses (Railtech, 2019). Co-use of the power grid for underground trains has been examined in London, the study showing that from a technical perspective, the power grid for underground trains could supply electricity to parts of the bus fleet, depending on the charging stations selected.

At the same time, the study indicates that there are legal challenges with regard to aspects relating to energy and power grids, along with the fact that the technology for charging integration was not entirely mature on a technical level. The study in London also notes that power grid infrastructure prioritisation between underground rail services and electric buses may present a challenge when any shortage of capacity arises. This may affect options for charging electric buses (Eliptic, 2018 E).

Co-use of charging stations by different modes of transport has also been examined, and a project is in progress in Szeged, Hungary, where a joint charging station for hybrid trolleybuses, electric bicycles and electric cars has been studied. This multifunctional charger for the various modes of transport has undergone testing. A decision was made in 2018 to continue with the tests for the project, although a number of difficulties were identified during the first part of the project. For example, there are unclear points with regard to maturity of the technology for “multi-charging”, long-term funding and legal uncertainties concerning use of the power grid (Eliptic, 2018 F).

All in all, it can be seen that a number of projects have been implemented, involving attempts to coordinate electric buses with other modes of transport. Although this appeared to be technically possible and a number of cases, several challenges have been identified with regard to funding, legal and technical maturity, for example; as well as issues relating to organisational maturity, lock-in effects and how different modes of transport are to coexist, as well as their mutual prioritisation in the event of co-use. However, it is imperative to continue to monitor development in this regard.

### 3.3.2. Urban planning, the built environment and infrastructure

The opportunities for electric bus initiatives and which technology is selected are influenced by the conditions in place in the built environment and infrastructure in the region and municipalities. Electric buses themselves also impact on towns and cities, and may bring with them new opportunities that may influence how towns and cities are planned.

#### *Supplementary charging*

Urban planning may present a restriction for supplementary charging, which in itself may influence the potential establishment of such a solution (McKinsey, 2018). The chances of finding appropriate locations for supplementary charging may present such a challenge when electric buses and charging points have to coexist with existing structures (Bloomberg New Energy Finance, 2018).

Establishment of supplementary charging in such environments could further reinforce competition for street space in the area. Furthermore, the choice of charging concept may be based on a more or less visible charging infrastructure, which means that they may be visual impact on the urban environment (Swedish Energy Agency, 2019 A).

Municipal perceptions of the visual impression when installing charging equipment in the street environment could present an obstacle to the introduction of electric buses. A shortage of space for charging outside depots could be resolved by re-siting bus stops; however, these are usually positioned for optimisation of route planning, which is why changing routes may be less appropriate (Bloomberg New Energy Finance, 2018).

#### *Depot planning*

The positioning of depots and how central they are affect the cost-effectiveness of depot charging. Depots in more peripheral locations could result in longer distances travelled by empty buses if buses need to head back to the depot to charge. Hence depot positioning is particularly important (Trafikförvaltningen, 2019 C), but at the same time this issue is not unique to electric buses. The positioning of bus depots influences the distances travelled by empty public bus services in general (Mahadikar, Mulangi, & Sitharam, 2015).

However, depots for electric buses could be relocated to underground areas as electric buses do not have the same need for ventilation as diesel and natural gas buses. This could free up valuable space for other uses (Bloomberg New Energy Finance, 2018). Furthermore, a representative of Region Västra Götaland (2019 A) explained during an interview that an electrified, and hence a cleaner, quieter depot could make housebuilding possible at the depot. This is known as an “integrated depot” solution, resulting in more efficient use of space in the city.

However, the representative of Region Västra Götaland (2019 A) also points out that the advantages of potentially building a cleaner, quieter and more compact depot should not be viewed as a consequence of the introduction of just electric buses, but of automated buses as well. Integrated depots already exist as a concept, but they could be easier to implement with automated and electrified buses.

Existing depots, but also terminals or bus stops, may be sited in locations where the local grid is not suitable for the power take-off demanded by many electric buses, and restrictions in the local grid may also influence the devising of new bus routes. This is why early contact with electric utility companies and other stakeholders is important prior to the planning and introduction of electric buses (Bloomberg New Energy Finance, 2018).

#### *Potential for the design of bus stops, terminals and cities*

There are also examples where introducing electric buses has resulted in a change in approach with regard to the positioning of bus stops. Electric buses create new opportunities for public transport in that they are silent and produce no emissions. These features also conditions defining where these buses can operate, and it is possible for them to be driven closer to areas where people move around (Volvo, 2015).

In Gothenburg, bus stations have been sited indoors as part of the ElectriCity electric bus demonstration project. In the long term, electric buses could change the way in which cities are planned and constructed, the project in Gothenburg demonstrating that it is possible to use electric buses in indoor environments (Svergies Radio, 2015).

Electric buses can also be linked with other social functions that potentially provide further accessibility for passengers. Examples of this as referred to in Bussmagasinet (2015) can be found in Gothenburg, where an indoor bus stop was designed as a real library. In itself, this demonstrates that electric buses can create new opportunities for public transport and various social functions.

At the same time, there is a safety aspect to electric buses that also influences their function in the urban environment. Electric buses are quieter than traditional buses, so they present a challenge in that they may be so silent that road users do not hear approaching buses. When Umeå recently introduced 25 new electric buses, for example, these came fitted with a “scare button” to be used to attract attention on the roads (Granath, 2019). This button causes the vehicle to make a rattling noise and attract the attention of pedestrians and cyclists (Transdev, u.d).

### 3.3.3. Interaction

As mentioned in previous sections, a number of stakeholders are affected ahead of electric bus initiatives and this makes new demands of cooperations. Furthermore, development and infrastructure in the region influenced the chances of introducing electric buses in respect of technology selected, charging infrastructure and the scope of initiatives, for example.

There is a major need for interaction between public planning organisations at national, regional and local level, and also between public and private stakeholders, when it comes to public transport (Paulsson, et al., 2018). Interaction can be viewed as a prerequisite for creation of functioning public transport, and creation of efficient public transport requires coordination between organisations with different budgets and responsibilities and which need to work together across organisational boundaries (Hrelja, Pettersson, & Westerdahl, 2016).

For instance, there needs to be a close link between urban planning and planning and development of public transport. As municipalities frequently control land use, they are key stakeholders when it comes to interaction as planning for such use influences future conditions for public transport.

Municipalities need to actively pursue urban planning that helps to implement good public transport; with regard to accessibility for public transport, for example, but also with a view to creating a coherent system for public transport with regard to stops, transfer points and locations. Without interaction, this is difficult. If the relevant stakeholders are unwilling to pull in the same direction at the same time, facilitating a sustainable transport system with public transport and integrated urban planning may present a challenge (Paulsson, et al., 2018).

In an interview, a local electric utility company (Göteborg Energi, 2019) states that they consider communication between involved stakeholders to be crucial when it comes to assessing the future need for power. However, there are two challenges with regard to this communication. Firstly, stakeholders usually demand several different alternative locations with regard to development, which makes it difficult for specific local electric utility companies to plan the actual future power takeoff. Secondly, listed companies cannot always enter into transparent discussions as this information may be considered to create unequal competition on the stock market. As a result, electric utility companies may receive the information at a late point in the process, when a decision has already been made by stakeholders to develop a specific area (Göteborg Energi, 2019).

### 3.4. Digitisation

The following chapter describes the role of digitisation in an increasingly electrified bus sector. Digitisation is a broad concept, and with its influence the bus industry is made smarter in many different ways. Smarter public transport includes making the bus industry more integrated with other industries, and equipping buses themselves with more digital functions and making them connected so that they can also communicate with the infrastructure. It also involves developing smart systems that allow the charging infrastructure to be optimised for electric buses, for example. Much of the impact of digitisation is not linked to electric buses specifically, but is applicable to all buses. Some



elements of digitisation involve making buses more autonomous, so they also include a number of visionary aspects.

#### 3.4.1. More efficient capacity utilisation

The transport sector can become more sustainable in a more cost-effective manner, and use of resources can be optimised by using digital solutions (Näringsdepartementet, 2017). This requires public transport to become smarter so that the challenges presented by increased urbanisation can be overcome (Öberg, Glaumann, Gjelstrup, & Leifland Berntsson, 2017).

The transport sector was previously regarded and treated as independent of other social systems, with separate infrastructure concerning energy consumption and fuel. The report *Så klarar Sveriges transporter klimatmålen* (2019) emphasises the importance of viewing the transport system as part of the community in which it stands. The energy sector and transport sector will start to grow together as electrified vehicles are introduced (Breakit, 2018).

Digitisation may promote mutual integration of systems, the energy system may become more flexible, and boundaries between energy sectors may be erased (International Energy Agency, 2017). The power system and transport sector are one example of how different parts of the energy system can be interlinked (Löfblad, Unger, Holmström, Lewan, & Montin, 2018). Research and various projects examining this are in progress, including the EU project SEEV4-City, which is looking at how electric vehicles can be interlinked in the community (InterregNorthSeaRegion, u.d.).

Increased use of electric buses may result in local grid problems and a shortage of power in certain locations, which demands implementation of smart charging management (Power Circle, 2018). According to researchers at Chalmers University of Technology, the solution may be to introduce digital systems that distribute and regulate electricity in real time based on needs and demands (Chalmers, 2019).

During an interview, a representative of E.ON (2019 B) stated that electric bus charging is predictable, which means that the need for energy – in terms of both quantity and demand times – can be predicted. Information on available capacity and the consumption requirement in buses can thus be created, which in turn may provide information on when capacity can be used or allocated to other parts of the power grid. Energy consumption in households is also relatively predictable, according to E.ON (2019 B), which could create a beneficial combination.

Batteries in combination with solar power and microgrids are creating competition for the traditional monopolies held by power grids. The report *Elnätets roll i framtidens energisystem* (Power Circle, 2018) describes how demands for more digital solutions are facilitating increased efficiency in the use of resources. It is unclear which rules apply to energy storage in the form of batteries, and the report recommends that electric utility companies should be given permission to own battery storage facilities (Power Circle, 2018).

A representative of E.ON (2019 B) states in an interview that the advantage of being able to co-use power is that a bus depot and an office block, for example, can utilise the energy together. The bus depot does its charging overnight, when the office does not need the energy, and the office uses the energy when the buses are running during the day. To make co-use possible, more information is needed on the use of energy in various industries and areas (EON, 2019 B). This will allow various customers' and consumers' energy needs to be measured so that the necessary amount of energy can then be supplied at the right time. A new approach and way of paying for energy will be required in order to implement such interaction and a system of this kind (Åslund, 2017).

In an interview with a representative of Volvo Bus (Volvo AB, 2019), it is emphasised that when electrification takes place, the system approach will become important for individual vehicles, but also for how different vehicles are interlinked so as to be able to achieve optimised power output when charging.

### 3.4.2. IT standard in buses, ITxPT

In an interview with a representative of Lindholmen Science Park (2019), a challenge is described in that we are seeing an increase in digitisation and the number of IT systems on buses. Bus manufacturers, principals and bus operators own their own digital systems, and these are not always integrated with other parties' systems. These systems need to be standardised in order to permit effective introduction of digitisation.

UITP, the International Association of Public Transport, founded the ITxPT (Information Technology for Public Transport) association in 2013 (NEC, 2018), and its format has now become an IT standard for more efficient data communication (Dietl, T., 2018). ITxPT is a non-profit organisation with members from all over Europe, including transport service principals, bus operators, vehicle manufacturers and IT providers (VerkstadsForum, 2018).

The organisation's role is to facilitate easier introduction of plug-and-play, standards and practice when it comes to IT solutions for public transport (ITxPT, u.d.). This standard permits interoperability between different public transport IT systems, which allows the systems to communicate with one another. The representative of Lindholmen Science Park (2019) explained that the objective is to standardise buses and systems in the future, which would allow digital functions provided by different suppliers to be installed.

### 3.4.3. Digital tools in electric buses

Increased use of smartphones and increased connectivity have created opportunities to develop a range of new transport services for buses (Öberg, Glaumann, Gjelstrup, & Leifland Berntsson, 2017). A survey performed by Keolis indicates that public transport passengers are connected and use smart instruments to a great extent (Bussmagasinet, 2019 B). Passengers demand digital functions and real-time provision of information (DynaMate, 2019). Therefore, public transport has to be digitised in order to make it attractive (Öberg, Glaumann, Gjelstrup, & Leifland Berntsson, 2017).

Today's buses come equipped with a range of different digital tools to measure energy consumption, bus locations in real time, passenger numbers, etc. They also come equipped with functions such as USB ports, voice communication, digital information screens and Wi-Fi connectivity (Bussmagasinet, 2019 C). During an interview with a representative of

Skånetrafiken (2019 B), it emerged that one difference between electric buses and other buses is that digital functions measure bus battery status, while the engine status can be checked on the fossil fuel-driven buses. This is just one example of applications. That said, there are also other differences depending on the operator and RPTA in question; particularly with regard to ticketing systems, as they frequently use local systems (Keolis, 2019).

Bus operators choose to implement different digital tools depending on a range of factors. Some functions are demanded by the procurement principal, such as infotainment and security cameras. Other services such as free Internet access are demanded by passengers, which may increase passenger numbers. The bus operator needs certain functions for itself, such as equipment for checking how many people actually use the bus (Westergren, Saarikko, & Blomquist, 2017; Nobina, 2019).

#### 3.4.4. Procurement of digital tool

The Swedish Energy Agency and RISE Viktoria have worked together as part of the Energiförsörjning för elektrifierade bussystem [Energy supply for electrified bus systems] project, EAEB, which culminated in development of a digital calculation tool (Swedish Energy Agency, 2018 A). The purpose of this calculation tool is to analyse, simulate and visualise the electric bus system from a system perspective so as to make it possible to create good conditions during the electric bus procurement process. The primary objective was to create a methodology with associated analysis tools that are able to predict the overall cost, with both robust and economical distribution of the energy supply system for electric buses (Swedish Energy Agency, 2018 A).

The cost can be calculated as a total, but it can also be distributed over various subsystems and stakeholders in respect of depots and timetables, for example. Furthermore, the methodology also takes into account routes for bus services, turnaround planning and variation in bus flows (Swedish Energy Agency, 2018 A). As a result of this, the tool can be used to make decisions more easily on where charging stations should be located and the size of the batteries required by vehicles. This will allow simpler, better conditions to be created for RPTAs when requirements are defined and during the procurement process for electrified bus systems (Swedish Electromobility Centre, 2018).

The analysis tool is web-based and comes from previously implemented models within the scope of the FFI project entitled *Analys av energiförsörjning för elektrifierade bussystem* [Analysis of energy supply for electrified bus systems]. The tool can be used on individual routes as well as complex traffic areas involving several routes with varying numbers of interactions. The results make it possible to compare and understand different ways of designing an electrified bus service system and how this affects frequency of services, stopping times, various vehicle parameters and the positioning of charging infrastructure and depots. The interim elements included charging, energy consumption, turnaround planning and cost calculations (Swedish Energy Agency, 2018 A).

An interview with a representative of RISE (2019) indicates that the digital analysis tool takes into account data from a number of different stakeholders, which has not been

possible previously. This means that electric bus energy, the number of buses, timetables, etc. can be imported into the tool. The representative of RISE (2019) explained that the analysis tool indicates the importance of adopting a system approach and alternative planning in order to create security against unpredictable incidents such as the weather or power outages.

#### 3.4.5. Digital platforms – various corporate examples

The Internet of Things, IoT, makes it possible to collect, process and communicate data and locate and identify objects. This is achieved by means of cloud services, mobile technology and smart sensors (Westergren, Saarikko, & Blomquist, 2017). Real-time information can be analysed and used to develop new services. The flow of data created by multiple connected vehicle can be analysed, which may facilitate process optimisation. The IoT will be capable of making the transport system smarter and increase innovation (Westergren, Saarikko, & Blomquist, 2017).

As digitisation changes public transport, a range of stakeholders will develop various cloud solutions and systems solutions. Operators, manufacturers and principals are carrying out development work and working in partnership with various IoT companies to develop a digitisation. Manufacturers connect their products so that they can log product data directly, which can then be used to develop products and create new services (Westergren, Saarikko, & Blomquist, 2017). Manufacturers such as Scania have begun working in partnership with IoT companies that are helping them with digitisation and electrification, as well as development of autonomous buses (Henricsson, 2018).

A report published by Umeå University, entitled *IoTguiden*, states that bus operators connect their buses in order to gain control over their processes and add value for their customers (Westergren, Saarikko, & Blomquist, 2017). The report also explains that IoT companies provide the physical hardware and some form of cloud solution, or alternatively a local solution: so that data can be distributed to their partners and processed (Westergren, Saarikko, & Blomquist, 2017).

##### *Example of a digital platform developed by an IoT company and the bus operator*

Many stakeholders are investing in IoT. The Swedish telecom operator Telia is just one example, and they have chosen to focus on public transport. Fältcom, a Telia subsidiary, has developed digital platforms for both Nobina and Skånetrafiken (BättreAffärer, 2017). The report entitled *IoTguiden* describes the Fältcom platform, which is a cloud solution facilitating digital communication (Westergren, Saarikko, & Blomquist, 2017). The platform comprises two devices; a stationary device that collects and processes data sent from a mobile device installed on the bus. The report states that complexity is increasing as more technologies and digital tools are demanded, and also as a result of development of different standards (Westergren, Saarikko, & Blomquist, 2017).

The report entitled *IoTguiden* also describes how Nobina has contracts with various subcontractors such as Fältcom, which are providing the open technical platform and permitting communication between systems and buses. The report states that Nobina perceived an advantage in maintaining an open technical platform rather than a complete system solution. An open platform makes it possible to extend various services and functions without increasing complexity or cost (Westergren, Saarikko, & Blomquist, 2017).

Nobina and Telia have also developed an IoT technology so that bus heating can be regulated. This technology will save energy (Björklund, 2019). Control systems and temperature sensors mean that buses will only be heated when required. The temperature is read and adjusted by means of mobile communication thanks to roof-mounted antennas on the bus.

#### *Example of how smarter charging solutions are developed*

Smarter charging solutions are also being developed. A representative of Siemens (2019) describes in an interview how their software for charging points is undergoing further development so that it can be run on MindSphere, their cloud-based IoT platform. Operation can be optimised by gathering data on factors such as battery condition, which buses are ready to use, which chargers are free and fault history (Siemens, 2019).

Smart solutions will become increasingly important when the number of electric buses increases, as this may increase the risk of capacity challenges in the power grid. Siemens also states that even though some data is currently collected from existing chargers, there is major potential in future for developing this in order to benefit from the opportunities provided by electrification.

#### *Blockchains and sustainable batteries*

Blockchains can be used to ensure that batteries in electric buses are produced sustainably (Allt om elbil, 2019). The blockchain network allows minerals to be tracked in order to detect their origin and reduce the risk of child labour to a minimum. Some stakeholders have launched a partnership that focuses on tracking minerals such as cobalt from the mine to the end consumer using blockchain technology. This technology offers a network of validated participants where stakeholders involved contract data in order to guarantee the dependability of the minerals they use (IBM, 2019).

### 3.4.6. Autonomous electric buses

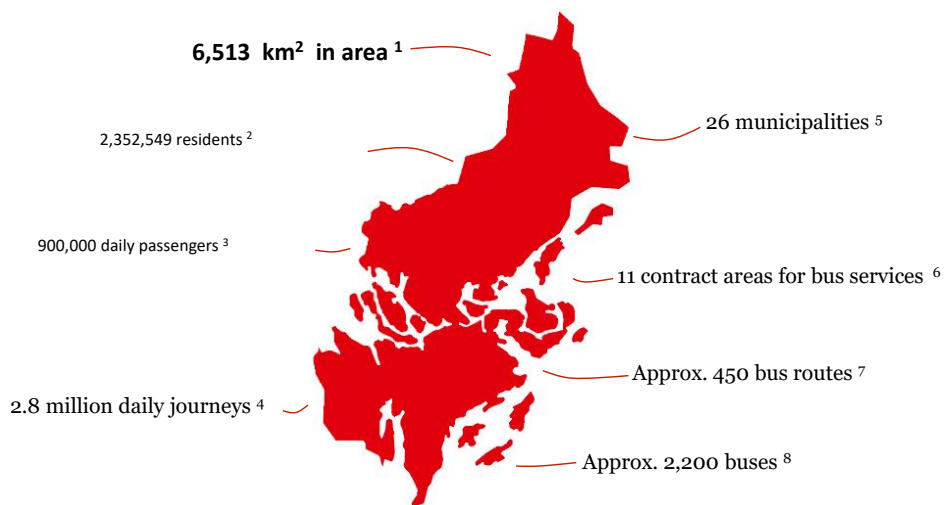
The tests currently being carried out on autonomous buses mainly include electrified buses. The Swedish Transport Analysis report (2019) explains that electrification will facilitate the introduction of automated vehicles. The criteria for charging, which takes place autonomously by means of induction, for example, are better than for fuelling that takes place automatically.

A representative of Siemens (2019) explained in an interview that autonomous charging is important when it comes to more automatic and autonomous buses, as charging could take place without human assistance. Furthermore the report issued by Swedish Transport Analysis (2019) states that automation is supported by the fact that the vehicles interact and are connected. In other words, electrification is made easier if buses are automated, and vehicles need to be connected and capable of interacting if they are to be automated.

## 4. Summary of the case studies and bus operators

This chapter presents summaries for the three RPTAs studied – Trafikförvaltningen Stockholm, Skånetrafiken and Västtrafik – concerning their work with electric buses. The role of bus operators and their efforts to switch to electric buses are also described. This summary is based on each of the RPTAs, as well as the four perspectives presented in chapter 3. However, the digitisation perspective is presented as a collective image for all the RPTAs in the study.

### 4.1. Trafikförvaltningen Stockholm



**Figure 4** Illustration showing Region Stockholm and Trafikförvaltningen in figures. Sources: 1 Statistics Sweden (2019 A), 2 Statistics Sweden (2019), 3 Region Stockholm (u.d.), 4 Region Stockholm (2019), 5 Statistics Sweden (2019), 6 Trafikförvaltningen (2019 C), 7 SL (u.d.) and 8 Trafikförvaltningen (2019 C).

#### 4.1.1. Organisation, driving forces and the current situation

Trafikförvaltningen is part of Region Stockholm and is responsible for procurement of all transport services under the SL brand. There are a total of eleven transport service contracts for the region. For contracts are to be procured in the autumn of 2019. Trafikförvaltningen owns the bus depots as things stand at present, while the bus operators own the buses. This is also true of electric buses and associated charging technology. Around 2200 buses of mixed varieties are used to provide bus services. Around 41 per cent of the county's buses were class I buses in 2017, and around 54 per cent were class II buses. This figure also includes class 1.5 buses.

SL bus services are currently run entirely on renewable fuels; biodiesel, biogas and ethanol. At the same time, it may be noted that there is greater interest in electrified vehicles. In 2019, Trafikförvaltningen published a survey relating to electric bus services in the county of Stockholm (Forsmark & Böhlin, 2019). Trafikförvaltningen's interest in electric buses is based on the fact that Trafikförvaltningen is of the opinion that electric buses make it possible to achieve a number of targets in respect of the environment, health and energy streamlining, for example. There is no target relating to zero-emissions vehicles for bus

services in the regional transport service provision programme, but the Trafikförvaltningen survey suggests that this ought to be introduced as it would make it easier to introduce electric buses in future.

#### 4.1.2. Pilot projects and start of electric bus introduction

Trafikförvaltningen's survey into electric buses indicates that the aim is to introduce a maximum of around 1500 buses to the region by 2030, but at the same time emphasises that introducing around 700 electric buses would be a more realistic target. This estimate is based on existing plans relating to public transport in general, electric buses already implemented and the times when new contract periods are to be initiated. These targets correspond to between 30 per cent and 70 per cent of bus services in the region.

Over the last few years, Trafikförvaltningen has been working with electric buses as part of smaller pilot projects, as well as introducing a number of electric buses for ongoing contracts. Electric buses were introduced in a standard procurement procedure for the first time in the summer of 2019, and Trafikförvaltningen is intending to continue its introduction of electric buses in this manner. This is driven in part by the fact that Trafikförvaltningen has chosen to advocate gradual introduction of electric buses, with electric buses being introduced as part of standard procurement procedures and not in respect of ongoing contracts. However, Trafikförvaltningen does not rule out the fact that electric buses may be introduced as part of valid contracts in future.

Hence the next introduction of electric buses will take place in connection with the four contracts for which procurement procedures are to be implemented in the autumn of 2019. This relates to around 65-70 electric buses of a total of 900 buses for the four contract areas collectively. The electric bus initiative is currently intended to involve class I buses, and the greatest benefits are expected to be seen in densely populated areas.

Trafikförvaltningen's electric bus initiatives can be described as a gradual transition to electric services, where a low level of risk is recommended. Trafikförvaltningen has selected a strategy where its bus fleet will be gradually electrified and include all-electric vehicles that will charge at the depot. According to Trafikförvaltningen's survey on electric buses, depot charging is the simplest alternative to implement and requires the fewest changes in respect of current recommendations and internal processes.

#### 4.1.3. Business models, contracts and distribution of responsibilities

From a business model and contract perspective, depot charging – as stated above – involves the least amount of change compared with how Trafikförvaltningen works at present. According to the Trafikförvaltningen survey on electric buses, further steps can be taken towards electrification as the technology and electric bus expertise develop with regard to Trafikförvaltningen bus services. The electric bus initiative means a change for the organisation where expertise is considered to need to mature, and hence the gradual alignment means that Trafikförvaltningen is able to continue using biogas investments made previously. Established depots will be used for charging these electric buses.

The Trafikförvaltningen survey indicates that distribution of responsibilities when introducing electric bus services is a key issue from a business model and contract perspective. Depending on the structure of the responsibility interface, a transition to electric buses may impact on both the investment budget and the operating budget for Trafikförvaltningen.

For the procurement procedures taking place in autumn 2019, Trafikförvaltningen has the task of ensuring there is enough of a power supply to the depots. The power supply is not considered to be a problem as things stand at present, given the number of vehicles to be electrified. The bus operator is responsible for ensuring that charging technology is available at the depots, will also be responsible for the electric buses in terms of funding, purchasing, ownership and maintenance. Regardless of whether electric buses are introduced as part of ongoing contracts or as part of standard procurement procedures, Trafikförvaltningen applies the guideline of not purchasing vehicles from operators after the end of their contracts.

No decision has been made on whether Trafikförvaltningen will be responsible for the charging infrastructure if a solution other than depot charging is used in future. The charging infrastructure preparations that Trafikförvaltningen is electing to implement will in turn largely control which charging technology and charging strategy bus operators are able to select. However, bus operators are free to choose if they would prefer a different charging infrastructure to the one that Trafikförvaltningen is electing to prepare for.

In an interview with a representative of Trafikförvaltningen, it emerged that electric buses will not involve changes to contract structures in respect of remuneration models. Trafikförvaltningen is currently working with contracts based on giving bus operators a certain amount of fixed remuneration and a certain amount of flexible remuneration, based on passenger numbers. The incentive percentage may be increased or reduced depending on risks that can be associated with a contract and a certain area. However, given current plans electric buses are not considered to be a risk factor that would result in this change being made to contracts.

#### 4.1.4. Procurement procedures

Trafikförvaltningen previously worked primarily with functional specifications for buses in their procurement procedures, but for future procurement procedures they have come to the conclusion that they need to deviate from this to an extent. This is why Trafikförvaltningen will be specifying a detailed requirement regarding a minimum number of electric buses – with no requirements specified for which routes are to use electric buses – prior to its procurement procedures to take place in the autumn of 2019. During an interview with Trafikförvaltningen, it emerged that having only functional specifications was too unclear as it could pave the way for alternative low-CO<sub>2</sub> technologies and not just electric vehicles in order to meet the functional specifications.

Another difference compared with previous procedures is that for the current procurement procedures, Trafikförvaltningen has paved the way for market discussion prior to the start of the procurement procedures. However, this is not due solely to electrification. In spring 2019, Trafikförvaltningen published preliminary decision data prior to the procurement procedures taking place in the autumn of 2019. This was done so that they could enter into discussions with various bus operators at an early stage and show their reasoning with



regard to how bus services are to be electrified, for instance, given the number of electric buses to be used and the distribution of these over the various depots. Given the fact that electrification of public bus services is relatively new to both procurement officers and bus operators, representatives of Trafikförvaltningen have stated that this approach has gone well, as it has paved the way for further discussion and exchange of views on the strategic directions to be planned.

#### 4.1.5. Interaction and investments

Trafikförvaltningen's electric bus initiative means that they are largely interacting with bus operators and power grid owners, while at the same time municipalities have been and continue to be an important stakeholder to interact with. Previous initiatives involving electric buses have also shown Trafikförvaltningen that good interaction between the stakeholders involved is a critical success factor.

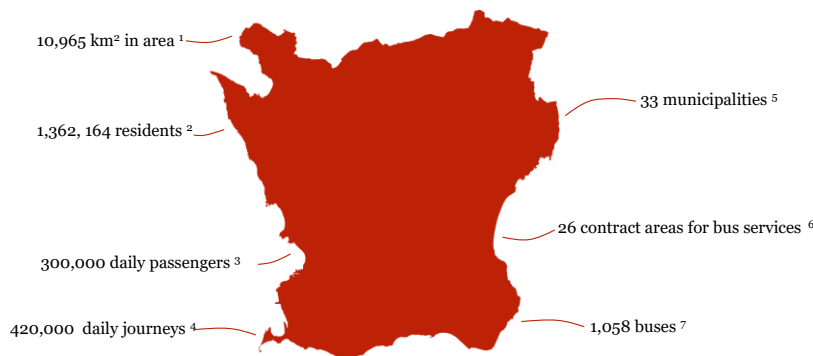
The approach involving depot charging means that new investments in infrastructure will be allocated primarily to depots. Given the adaptations required at depots on account of investment in electric buses, this was not planned for previously and there is no funding for it. Therefore, the adaptations will demand a lot of additional resources and investment funding from Trafikförvaltningen. The government subsidy scheme for purchase of electric buses (Elbusspremien) and other funding incentives are not considered by Trafikförvaltningen as a driving force for the investment being made.

#### 4.1.6. Coordination with other electrification processes and urban planning

Given existing plans, Trafikförvaltningen is not working specifically with the opportunities for coordination with other transport services. That said, the Trafikförvaltningen survey on electric buses emphasises that options may be available, to a certain extent, to implement coordination between electric buses and other electrification of the transport system. However, coordination of charging infrastructure is deemed to be of limited potential for technical and legal reasons. The chances of mutual benefit from reinforcement of the power grid for preparation of charging infrastructure for various modes of transport, on the other hand, is believed to offer greater potential.

The electric bus initiative being implemented by Trafikförvaltningen at present is not deemed to have a substantial impact on urban planning or existing development and infrastructure environment in the region. The physical street environment will not be affected as charging will take place at depots. According to Trafikförvaltningen, there is no scope for indoor bus stops within existing plans either, and greater investment in integrated or more central depots is not anticipated as a consequence of the introduction of electric buses.

## 4.2. Skånetrafiken



**Figure 5** Illustration showing Region Skåne and Skånetrafiken in figures. Sources: 1 Statistics Sweden (2019 B), 2 Statistics Sweden (2019), 3 Skånetrafiken (2018), 4 Skånetrafiken (2019 J), 5 Skånetrafiken (2017 A), 6 Region Skåne (2018 A) and 7 Skånetrafiken (2019 A).

### 4.2.1. Organisation, driving forces and the current situation

Skånetrafiken is Sweden's third largest public transport authority in terms of the number of journeys made. Skånetrafiken has 26 bus service areas and has procured relevant bus areas from operators Nobina, Transdev, Nettbuss and Arriva, Bergkvarabuss and Flexbuss. These bus operators own the buses, while distribution of responsibilities for depots and charging infrastructure is varied.

The Skånetrafiken bus fleet is now entirely fossil-free and mainly uses biofuels. In terms of quantity, biogas is its single biggest fuel. Of a total of 1100 buses, more than 800 run on biogas and 250 run on biodiesel. Skånetrafiken has a vision for the future which involves implementation of all-electric urban bus services, while regional bus services will be operated using a combination of buses running on biogas, electricity and hydrogen, or electric buses. Skånetrafiken has decided that its electricity must be produced from renewable sources bearing the "Bra miljöverk" eco-label. The objective for Malmö is for urban traffic to be electrified by 2031.

Clean air, reduced noise and traffic in areas susceptible to noise and exhaust emissions are important driving forces for the transition to electric buses. The option of operating transport services to hospitals, entrances and shopping centres is another important driving force.

### 4.2.2. Pilot projects and start of electric bus introduction

Electrification is nothing new for Skånetrafiken: they have been operating trolleybuses in Landskrona since 2003. Landskrona has also had an all-electric urban bus fleet with depot charging since January 2019. However, Ängelholm was first to operate depot-charged buses in Skåne, back in 2015. Malmö and Helsingborg both have electric buses using supplementary charging, where buses are charged at terminuses. The transition to electric buses has not been entirely without its problems. In Ängelholm, for example, there have been technical problems with the batteries which could be remedied using temporary biogas buses.

In the autumn of 2019, both Ystad and Trelleborg will see the introduction of urban buses that run on electricity and charge at the depots. Appropriate technology on the basis of the conditions in the traffic region is evaluated during procurement procedures. Skånetrafiken is of the opinion that electric bus implementation in smaller towns is no problem, which is why Skånetrafiken is focusing more extensively on larger cities such as Helsingborg and Malmö.

Skånetrafiken reckons that the bus operators prefer depot charging, but points out that buses that charge at depots have larger batteries and therefore have greater environmental impact. Skånetrafiken is planning to introduce supplementary charging on routes with high-frequency services requiring large vehicles and frequent buses. Ten urban bus routes of this kind are planned in Malmö, and three in Helsingborg. These routes involve frequent services, long cable distances, high levels of bus fleet utilisation during the day and current and future increases in passenger numbers (Skånetrafiken, 2019 C). Skånetrafiken (2019 B) points out that supplementary charging will increase range. This is why buses will not need to return to the depot for charging while they are in service.

#### 4.2.3. Business models, contracts and distribution of responsibilities

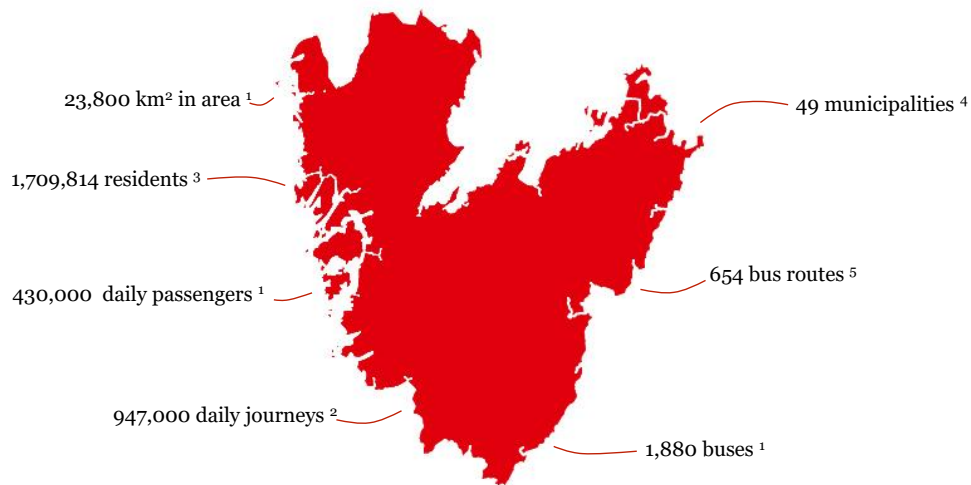
Skånetrafiken defines specific requirements in respect of fuels and environmental performance, for example, instead of functional specifications. For example, they may require use of a specific renewable fuel or renewable energy such as renewable electricity or renewable biogas. Examples of requirements may include targets for reduced energy consumption or CO<sub>2</sub> emissions. Skånetrafiken states that the procurement process for electric buses does not differ from previous procurement procedures relating to gas and diesel buses, except for the fact that any charging infrastructure has to be agreed with the bus operator. Skånetrafiken always awards contracts to the lowest price set out in the tenders.

Distribution of responsibilities for electric buses within Skånetrafiken varies. The objective for Region Skåne, via Regionfastigheter, is to own certain strategic depots such as the ones in Malmö and Lund. This is because Region Skåne wishes to reduce its costs and create competition neutrality between tenderers, as well as securing central locations so as to avoid buses running when empty. Running buses empty is also particularly important in connection with the introduction of electric buses and depot charging.

#### 4.2.4. Interaction

As far as electric buses are concerned, Skånetrafiken is finding that closer cooperation has been developed between municipalities, as well as private stakeholders. For example, batteries and power grids are new areas for Skånetrafiken that require study. Moreover, Skånetrafiken is finding that municipalities that have invested in biogas have left positive attitudes towards electric buses, which may create conflicts of interest. Moreover, electric buses were introduced in Helsingborg as part of a BRT system.

### 4.3. Västtrafik



**Figure 6** Illustration showing Region Västra Götaland and Västtrafik in figures. Sources: 1 Statistics Sweden (2019 C), 2 Statistics Sweden (2019), 3 Västtrafik (2017), 4 Västtrafik (u.d A), 5 Västtrafik (2017), 6 Västtrafik (u.d B) and 7 Statistics Sweden (u.d).

#### 4.3.1. Organisation, driving forces and the current situation

Region Västra Götaland, abbreviated RVG, is the regional public transport authority in the county of Västra Götaland. Västtrafik is the organisational body procuring public transport services in the region. Västtrafik is controlled both generally and strategically by political decisions made by the regional council. Västfastigheter owns and manages a small number of depots where Västtrafik rents out depot locations to bus operators. Bus operators own and manage the remaining depots, and also the vehicles and charging infrastructure and associated peripheral equipment.

Västtrafik's driving forces for the implementation of electric buses include the three primary aspects referred to previously, namely reduced noise, carbon dioxide emissions and particles. The targets include improving health and providing a more attractive public transport service, with more passengers. Another driving force is a political desire to use electrification to achieve these targets, at both regional and municipal levels in Västra Götaland.

Besides the targets stated previously, Västtrafik has a number of objectives relating to various parts of its operations. As regards carbon dioxide emissions, Västtrafik's previous target was for 95 per cent of its transport services to use fossil-free fuels by 2025. However, this target has already been achieved as almost all Västtrafik transport services use biofuels. Therefore, the target has been updated and now involves reducing carbon dioxide emissions by 90 per cent by 2035, and electrification of public transport services is an important step towards achieving this target. All in all, this has been formulated into a target for 30 per cent of bus services to be electric by 2025.

It is stated that the Stadsmiljöavtal, Elbusspremien and Klimatklivet schemes were not decisive in the choice to commence electrification. However, three municipalities have concluded declarations of intent with Västtrafik concerning the implementation and running of electric buses in a similar manner to that applied for these instruments. These contracts aim to create a common way forward by reminding the stakeholders involved of their common objectives, and thereby helping to ensure that electric buses are implemented.

#### 4.3.2. Pilot projects and start of electric bus introduction

ElectriCity was implemented as a pilot project in Gothenburg in 2015, which aimed to demonstrate and evaluate electric buses in an urban environment: at that point, the ambition was to develop and test new solutions for bus stops, safety concepts, traffic management systems and energy supply. A bus stop was also created indoors next to a library at one of the terminuses.

Västtrafik then chose to implement electric buses within the scope of existing contracts, and as part of new procurement procedures as well. A total of 228 electric buses will be put into service in 2019 and 2020, of the ca 1900 buses used for public transport services in the region in 2017. Some electric buses will be implemented within the scope of existing contracts, while others will be subject to new contracts. Of all the regions in Sweden, Västra Götaland will then have the highest number of electric buses.

When a vehicle is replaced under an existing contract, there may be 3 to 8 remaining years on the contract period, and Västtrafik guarantees the value of its electric buses at the end of the contract in order to make the switch economical for the bus operator. Västtrafik therefore buys the vehicles from the bus operator at the end of the contract, and the bus operator awarded the next contract is then able to use these vehicles.

All electric buses that Västtrafik is investing in are class I buses, as these are the most mature for the market and result in reduced noise in urban districts. For electrification, the emphasis has been on trunk routes in urban districts.

#### 4.3.3. Business models, contracts and distribution of responsibilities

Västtrafik leaves the choice of technology to the bus operator in question, and hence a great deal of responsibility and ownership in respect of electric buses is transferred to the bus operator. However, within the scope of existing contracts Västtrafik provides support to bus operators by preparing and applying for advance notification of planning permission for the transmission stations required for supplementary charging.

In general, both supplementary charging and both fast and slow depot charging will be implemented for the region. Västfastigheter is responsible for some of the depots in the region. Its work relating to electric buses includes preparation and laying of cables for the power grid, while bus operators install and own the charging infrastructure. Bus operators are also responsible for preparation of the charging infrastructure at the depots owned by them.

Requirements are specified for electric buses by means of functional specifications in procurement procedures. For standard procurement procedures, regardless of the mode of transport in question, Västtrafik applies what is known as the “Västtrafik model”, which is based on developed interaction, transparency and jointly defined objectives between bus operators and Västtrafik. The Västtrafik model is also applied in procurement procedures relating to electric buses, but the initial discussions take place at an earlier stage.

Västtrafik has held general meetings for bus operators, power grid owners and other parties where general plans have been presented for electrification and issues relating to the power grid, depot and charging infrastructure location, route optimisation, etc. have been discussed. The emphasis has been on understanding the various parties’ criteria, organisations, steering processes and timeframes. Västtrafik’s ambitions have also included initiating procurement procedures further in advance than usual so as to allow bus operators the opportunity to obtain new vehicles, as well as charging infrastructure and peripheral equipment.

#### 4.3.4. Interaction

The stakeholders interviewed in the region are of the opinion that electrification requires developed interaction from several different stakeholder types, primarily public transport services, the municipality and electric utility companies. However, implementation of new technology may create uncertainty, and Västtrafik is of the opinion that it is important to respond to this by means of developed discussion, for example, in order to maintain momentum and the desire to implement the switch.

#### 4.4. Digitisation

##### 4.4.1. The ITxPT standard

Västtrafik is a Strategic Member of the ITxPT partnership and works operationally to develop the ITxPT standard. Within the scope of ElectriCity, a test bed is now being established that will provide an opportunity for Västtrafik and suppliers to test different solutions in order to examine whether they are compliant with the ITxPT standards being developed. According to Västtrafik, operators face the challenge when it comes to being able to use the buses between different principals on account of the different technologies used by the various principals. Furthermore, Västtrafik explains that the standard may be used to manage responsibilities between operators and RPTAs using different methods to those applied at present.

Skånetrafiken is also a member of the ITxPT partnership and is working actively to make its communication platform compatible with the ITxPT standard. According to Skånetrafiken, there is difficulty in persuading the various parts of the systems to communicate with one another, and the ITxPT platform is facilitating this. It is necessary to make it possible to exchange information aboard vehicles between different services and providers, which can be made possible as the platform is reserved for the use of standard.

Trafikförvaltningen is not a Strategic Member of the ITxPT partnership, but it is planning to join in the future. That said, they are gradually working on introducing the ITxPT standard and are of the opinion that digitisation presents many opportunities.

#### 4.4.2. Digital functions and platforms

All of the three principals' digital platforms apply functions such as passenger counting, vehicle positioning, real-time information, various driver support functions, voice channel functions, bus status, the number of mobile devices connected to Wi-Fi, etc. The buses are connected to the communication platforms run by both the principals and the bus operators. Skånetrafiken, Västtrafik and Trafikförvaltningen perceived no specific difference in the need for or use of digital functions on electric buses compared with other buses.

Västtrafik is of the opinion that digitisation can be developed even without electrification. The important thing is to make sure that the equipment on the bus is as energy-efficient and eco-friendly as possible, regardless of what fuel the bus runs on.

Trafikförvaltningen is of the opinion that implementation of digital functions is linked with how new the bus is. Skånetrafiken explains that the biggest difference between electric buses and the buses is that instead of predicting diesel engine failures, battery operating times are monitored instead.

Trafikförvaltningen explains that electric bus charges are connected to bus operators' systems, and that the operators then report energy consumption to Trafikförvaltningen. Further systems are required if supplementary charging is used, but at the same time Trafikförvaltningen have now chosen to focus on depot charging ahead of future initiatives. The representative of Trafikförvaltningen is of the opinion that Trafikförvaltningen is not planning to introduce any new digital systems in connection with electrification of its bus fleet.

The various principals have different policies regarding the procurement of various digital functions for bus operators. Skånetrafiken tests its way forward and has a clear set of requirements. If bus operators are unable to supply what Skånetrafiken is demanding, Skånetrafiken chooses to provide the digital function itself instead. For example, Skånetrafiken made an attempt to give its operators responsibility for the digital displays aboard their buses, but it was found that the system worked better and was more cost-effective when Skånetrafiken itself was responsible for that particular function.

Västtrafik handed over some responsibility to its bus operators with regard to the implementation of digital functions, but how they choose to define requirements varies. For example, Västtrafik requires passenger counting on buses but then gives its operators free rein to decide how to implement that on their buses. Västtrafik also clarified during an interview that passenger counting is a function that bus operators appreciate as the contract between operators and RPTAs are based on passenger numbers. Therefore, counting passengers makes it possible for operators to control how many people travel on their buses. In some cases, Västtrafik chooses to install other digital functions itself.

#### 4.4.3. Driving forces behind digitisation

There are different driving forces with regard to various digital tools, according to Västtrafik. Västtrafik defines requirements for some tools itself, while other tools are defined as part of

the operator's own development. Trafikförvaltningen describes how they place some of the responsibilities for equipment aboard buses with the bus operators. However, Swedish Transport Administration defines requirements according to the ITxPT standard. This means that buses have to be able to exchange information in accordance with that ITxPT standard. This standard gives Trafikförvaltningen the opportunity to have its own digital applications which can then be executed on bus operators' equipment.

Trafikförvaltningen explains that it is important, as the client and owner of the brand, to maintain control over communication with customers so as to be able to improve customer relations. By way of example, they describe how the traffic information application board buses will be owned by Trafikförvaltningen but use bus operators' displays and speakers.

#### 4.4.4. Digitisation in procurement procedures

Västtrafik used the Swedish Energy Agency's analysis tool, EAEB, in their latest procurement procedure as they were aware of the importance of having alternative planning in order to create security in the procured system so as to counter unpredictable incidents such as power outages or disruptions caused by the weather. The analysis tool made it clear, according to RISE, that it is not possible to expect all subfunctions to be always available when building a system with electric buses. Factors such as varying charging time and delays due to occupied chargers, diversions, uphill sections, etc. must be included in the system. Skånetrafiken has also used the analysis tool to carry out analyses of various bus routes on the electrification of their fleet of buses.

#### 4.4.5. Automated vehicles

Trafikförvaltningen explains that the reason why autonomous buses currently run on electricity is that the vehicles introduced to the market are small, electric buses. Furthermore, autonomous buses are likely to continue to develop with electric powertrains as this generally results in simpler design. In an interview, Trafikförvaltningen explains that most factors are indicating that electrification and batteries will develop and become more efficient, but that fuel cell technology will also be developed and could be used for electric power trends. This could make it possible for all traffic to be electrified in future, according to Trafikförvaltningen.

According to Trafikförvaltningen, automation in electrified vehicles is simplified as the design is simpler and fewer functions need to be controlled. That said, electric buses with batteries having to travel long distances presents a restriction. These buses will need to stop and recharge, which will mean longer travelling times or switching vehicles. In this respect, Trafikförvaltningen is of the opinion that autonomous technology for buses using energy sources other than batteries would also have been interesting.

Västtrafik is of the opinion that autonomous electric buses will probably change current requirements in respect of bus stops, for example. Västtrafik reckons that an autonomous bus system will probably require electric buses to be chargeable as they run. To make it possible to run autonomous electric buses on a major scale and avoid having to take buses out of service to charge them, dynamic charging via electric road systems will be required. Västtrafik is of the opinion that factors such as charging, storage and maintenance of electric buses will need to be included in the development and planning of a more automated bus sector.



Skånetrafiken is of the opinion that combining digitisation with other technology – such as electric powertrains – and autonomous buses is of interest. Skånetrafiken underlines how the emphasis needs to be on customers as regards this development as passengers need to feel secure while travelling on buses. In Skånetrafiken's view, a change is required to the legislation in respect of autonomous buses, along with a clear set of objectives regarding the purpose of the technology.

## 4.5. Bus operators

This section describes a number of areas of importance for the introduction of electric buses from a bus operator perspective.

### 4.5.1. Challenges and opportunities

A number of different challenges for bus operators emerged during interviews with different operators (Nobina, 2019; Transdev, 2019 A). Electric buses are a new technology, which affects ways in which day-to-day operations are implemented. This means there is a steep learning curve. However, a representative of Nobina (2019) states that all stakeholders are interested in participating in this development and developing expertise.

Another aspect linked with electric buses as a new technology is that conditions for electric buses are different to those for conventional buses. This means that operators need to plan bus routes in new ways linked with cable routing, and there is a need to include additional buffer time for any delays, as well as for charging vehicles. A conventional gas or diesel bus can run for 23 hours a day and fuelling takes just a few minutes; compared with electric buses, which require longer, more frequent charging periods. This means that cable routing needs to be reviewed (Nobina, 2019).

A representative of Transdev (2019 A) states that provision of skills, providing further training to current mechanics whose expertise and experience have mainly been gained on internal combustion engines, presents a challenge. New fields of competence linked with energy supply and charging technologies, mainly with regard to electrical technology and peripheral safety, will also be added. A representative of Nobina (2019) is of the opinion that skills can be built up by working in close cooperation with bus manufacturers.

According to a representative of Keolis (2019), legal aspects relating to electricity may present a challenge as this requires a different type of expertise and involves new responsibilities for bus operators. A representative of Nobina (2019) states that driver training is always required when new bus models are introduced. That said, the Nobina representative does not think introducing electric buses will involve further training besides what could be considered standard when introducing a new bus model.

Linked with the social perspective, a representative of Nobina (2019) has identified a challenge as regards finding places in cities for both charging infrastructure and depots. There is a risk factor in that planning permission processes for charging infrastructure and peripheral components takes time, thereby delaying implementation (Transdev, 2019 A).

However, this risk remains regardless of which stakeholder is responsible for the planning permission process (Transdev, 2019 A).

A representative of Transdev (2019 A) also indicates that electric buses are more expensive to purchase, while also being cheaper to run than conventional buses. This means that electric buses may involve a higher total cost for RPTAs. Electric buses are more expensive, so this means that tenders that include electric buses are generally more expensive than tenders that do not. RPTAs need to define requirements for electric buses in the procurement procedures as this will allow bus operators to include electric buses in their tenders even though they are more expensive (Transdev, 2019 A).

There may be an opportunity to coordinate maintenance, depots and skills with rail services as electrified trains have similar requirements to electric buses. Electric buses will probably require significantly less maintenance than conventional buses. Engine oil changes are one such example of work that could be phased out (Transdev, 2019 A). A representative of Transdev (2019 A) is also of the opinion that the more maturity there is in expertise and approaches involving electric buses within organisations, the maintenance costs can be reduced.

Electric buses are still at an early stage in their development. A common phenomenon on a new market is that spare parts – for example – may be more expensive than for established technology (Transdev, 2019 A). A representative of Nobina (2019) also states that electric buses could be used for storing energy by charging when power is available from the grid, and then feeding back electricity when the grid requires additional power output. This may reduce battery service life. However, at the same time energy storage is a business opportunity, and all opportunities and challenges have to be considered in an overall assessment.

#### 4.5.2. Ownership and distribution of responsibilities

Bus operators operate on behalf of their client organisation, which means that they provide the services procured by RPTAs. A representative of Transdev (2019 A) states that they generally purchase vehicles and handle delivery and operation, but that the interface in respect of ownership and responsibilities can vary from contract to contract.

Bus operators expressed varied reasoning concerning ownership and distribution of responsibilities in connection with electric buses. One bus operator felt it was positive that RPTAs gave them full ownership of the electric bus issue concerning the choice of electric bus technology, charging infrastructure and cable routing. This could provide opportunities to limit costs when making a transition to electric buses as bus operators will be given the choice to implement various assessments that influence cost (Nobina, 2019).

Another operator is of the opinion that ownership of the charging infrastructure could rest with RPTAs as the service life of chargers is not the same as for electric buses or batteries (Transdev, 2019 A). The charging infrastructure has a longer service life, which means that future choices of technology could be made more difficult due to creation of a lock-in effect.

Finally, a representative of Transdev (2019 A) is of the opinion that electric buses require more in-depth cooperation with new stakeholders; both when electric buses are introduced within the scope of existing contracts and when they are acquired as part of a standard

procurement procedure. The new fields of expertise demanded by electric buses will require more in-depth cooperation with regard to power supply and charging technology, for example (Transdev, 2019 A).

#### 4.5.3. Choice of technology

Electric buses mean new technologies, and hence new choices that will need to be made by operators. Representatives of Transdev (2019 A) and Nobina (2019) both emphasised that batteries bring with them new challenges linked mainly with overall cost and service life, which is shorter than for other parts of the vehicle. A representative of Nobina (2019) is of the opinion that the choice of depot charging and supplementary charging is not always either-or, but that the charging strategies could complement one another. Furthermore, a representative of Nobina (2019) highlights the option of fast charging for buses at depots, which will allow buses to be brought in and charged in 25 minutes. The fact that the solution in question needs to be based on the design of the traffic system is highlighted.

A representative of Transdev (2019 A) is of the opinion that having the bus manufacturer stand responsible for the charging infrastructure and discussions with manufacturers of charging solutions is less risky than if bus operators deal with this. This is because in a worst-case scenario, situations may occur where electric buses and charging technology are incompatible (2019 A).

#### 4.5.4. Digitisation

##### *A connected bus fleet and digital platforms*

A representative of Keolis (2019) is of the opinion that demands will be made of digital functions such as monitoring energy consumption and checking battery status when the bus fleet is electrified. This is why Keolis has kitted out its buses with software that allows such functions to be executed. In an interview, Transdev (2019 A) compares today's buses with an office where the driver goes online and can view large amounts of information and access multiple functions.

An interview with representatives of Nobina (2019) reveals that a digital platform is required in order to set up successful digital interaction and more than just SIM cards and antennas. Nobina's representative (2019) explains that Nobina has developed its platform together with an IoT company, but adapted it to its own needs and activities. Data collection is an important element in service development so that more fact-based decisions can be made. All data generated by vehicles, sensors and other systems can be analysed, allowing resources to be invested in the right things.

Transdev's representative (2019 A) explains that their buses are always equipped with functions such as counting passengers. This is because their contracts are based on passenger numbers. This is why the bus operator's representative (2019 A) is of the opinion that they cannot rely on another stakeholder standing responsible for measuring passenger numbers. Furthermore, buses are equipped with cameras and security alarms in case of disruptive situations arising.

Nobina uses its IoT platform with a view to making its buses smarter and allowing them to communicate, and the platform is ITxPT-approved (Telia, u.d.). Most of the operator's buses are equipped with this platform, and it allows buses to communicate and be monitored via the service management system. A representative of Transdev (2019 A) states in an interview that although electric buses are connected for the purposes of providing access to battery status information and when charging needs to take place.

#### *A connected and automated bus depot*

The interview with Nobina (2019) reveals that Nobina perceive the need for more connected bus depots, and the operator has connected its depots to its digital platform. This allows every bus to be warmed up, for example, as timings for this are defined in the system. Furthermore, the representative explains (2019) that Nobina does not want to charge all its buses simultaneously. Instead, they wish to distribute charging throughout the night and the connected system will allow them to do this. The system provides an automatic dynamic solution, and it will develop as new needs arise and are identified.

In the interview, Transdev (2019 A) describes a project where they are working together with Scania to examine the potential in further automation of the bus depot. Around 50 per cent of damage to buses takes place at the depot, so they perceive a major incentive in automating the bus depot. Transdev's representative (2019 A) is of the opinion that as an operator, they have a great deal of control at the depot. Transdev is also of the opinion (2019 A) that current technology would allow the depot to be automated and handling could be transferred to the service management system.

Nobina's representative (2019) explains that they are not actively participating in any project relating to the development of bus depot automation: they are considering it, but there is no active participation as yet. That said, Nobina (2019) explains in the interview that there is a need for automated bus depots. Current depots are unnecessarily large, with high noise levels.

#### *Autonomous buses*

In the interview, it emerges that a representative of Transdev (2019 A) has a positive view of more automated buses, and is involved in a project in Linköping where autonomous buses will be starting to operate. They feel that development is heading towards a driverless bus industry, but that this will take time. Acceptance will be required, and the technology is very costly as things stand at present. Another representative of Nobina (2019) has a very positive attitude towards the development and introduction of autonomous buses. This bus operator is the first to operate autonomous shuttle services in a mixed traffic environment in Barkarby (a newly constructed housing area north of Stockholm), and expansion of the project to include autonomous full-length buses is planned for the autumn of 2019.

At the same time, a representative of Nobina (2019) explains that it will take a long time to implement fully autonomous buses in a mixed traffic environment. At this time, it will be necessary to be able to control buses remotely. This means a completely different level of information to what can currently be handled by the vehicles and the systems. Greater interaction with other stakeholders will be required, along with a collective platform, and the representative of Nobina (2019) is of the opinion that this is not in place as yet. A more cross-functional approach and closer cooperation with more stakeholders will be required.

The technology itself is not and will not be the problem, in the opinion of Nobina's representative (2019): instead, the biggest problem is presented by the rules and being able to integrate autonomous buses in society. According to a representative of Nobina (2019), we should be asking how autonomous vehicles are to be used. It is highly likely that usage will not be the same as it is present, where buses currently operate on specific routes.

Services can be more flexible and needs-based when autonomous buses are used. One challenge identified relates to how a bus should know whether a passenger is waiting at a bus stop, and whether this passenger wishes to use that particular bus. As things stand at present with the Barkarby project, the bus stops at all stops regardless of whether or not there are any passengers waiting.

Better positioning tools for the users' mobile phones will be required, explains the Nobina (2019) representative, allowing passengers to provide information on their desire to use the bus. Another challenge identified as part of the Barkarby project is the fact that many people out on the roads have no respect for the vehicle. As a result, they walk out in front of the bus, which then stops.

## 5. Comparison between case studies

This chapter compares the regions' efforts with electrification of bus services. This comparison uses features from the four perspectives of the study and is based on results from the interviews and literature studies.

### 5.1. Technology

#### 5.1.1. Charging strategy and technology

Interviews with the three RPTAs involved in the study revealed that Trafikförvaltningen expresses a preference for charging at the depot, while Västtrafik allows its bus operator to make a decision with regard to the choice of technology. Trafikförvaltningen is preparing solely for depot charging, and supplementary charging will only be used if bus operators take the initiative to use it. Trafikförvaltningen is of the opinion that depot charging resembles their traditional arrangement for and management of public bus services, and also emphasises the fact that space on the streets of Stockholm is frequently subject to competition, which is why installing supplementary charging would present a challenge.

Skånetrafiken is evaluating appropriate technology on the basis of the conditions in the traffic region. Depot charging is sufficient in cities characterised by frequent services, small bus fleets and short routes. Supplementary charging is planned on routes with high-frequency services requiring large vehicles and frequent buses.

Västtrafik has no preference in terms of charging strategy: the bus operator has ownership with regard to the issue. Västtrafik is preparing for introduction of electric buses as part of existing contracts by applying for advance notification of planning permission to allow bus operators to select supplementary charging.

#### 5.1.2. The power grid

The RPTAs explain during interviews that a shortage of capacity in the power grid is not something that they consider to be a limiting factor at present as regards the introduction of electric buses. Although this could be a limiting factor to a certain extent, other factors such as bus range and the cost of electric buses are more pressing, given what the RPTAs are saying.

#### 5.1.3. Electric bus batteries

All RPTAs highlight the challenges and issues relating to batteries in terms of social sustainability, recycling and the traceability of materials, and describe this as a new issue that they have to deal with. One thing that the three RPTAs have in common is that they are still very much in an introductory phase of the work relating to electric bus batteries and the challenges they present.

Trafikförvaltningen is choosing to approach the battery issue by requiring bus operators to apply an OECD directive or equivalent. Skånetrafiken has brought up these issues in a battery project together with Volvo, the Faculty of Engineering at Lund University and Save

the Children, and Västtrafik and Trafikförvaltningen are also part of the reference team for the project.

## 5.2. Organisation and funding

### 5.2.1. Driving forces and objectives

All the regions studied have similar targets with regard to their electric bus initiatives; namely less noise, better air quality, fewer greenhouse gas emissions, the increased energy efficiency of electric motors and the fact that electric buses can provide more attractive public transport for both passengers and drivers. Västtrafik also pointed out that the advantages stated create synergy effects in respect of a number of objectives, such as improved health.

RVG/Västtrafik has also set up a quantitative target; for 30 per cent of its bus fleet to be made up of electric buses by 2025. Region Skåne/Skånetrafiken expresses an ambition to electrify its buses, although the respective municipalities have an influence over the implementation within their own areas. Trafikförvaltningen is envisaging potential for electrifying its vehicle fleet, but as things stand at present it is not formally established a quantitative target concerning the introduction of electric buses.

Furthermore, the study showed that the government funding incentives available for electric buses or charging infrastructure, namely the Elbusspremiem, Stadsmiljöavtal and Klimatklivet schemes, have not driven the initiatives implemented, although they are viewed as positive supplements.

### 5.2.2. Interaction, stakeholders and responsibility interfaces

The study shows that implementation and making the switch will involve participation from new stakeholders that have not participated in planning and implementation of public transport services previously, along with the addition of new stakeholders; while established stakeholders will participate in new types of discussion and perform new tasks.

Trafikförvaltningen, Västtrafik and Skånetrafiken have worked with additional discussions at an earlier stage in the procurement process than is the case for conventional services. Trafikförvaltningen has initiated discussions prior to commencement of the procurement procedure in order to discuss with bus operators whether Trafikförvaltningen's plans are feasible, as well as how the definition of requirements in the procurement procedure can be formulated in order to include the right aspects of electrification. Trafikförvaltningen found these discussions to be positive, although they also state that introduction of earlier discussions would probably have happened anyway, even without electrification.

Västtrafik has also held discussions at an earlier stage of its work, and involved stakeholders such as electric utility companies that have not been involved in discussions previously. Västtrafik sets great store by understanding the in-house organisational criteria of all stakeholders, and by sharing intelligence between the stakeholders involved so that all

parties involved understand one another. Furthermore, there has been more developed interaction with municipalities. Skånetrafiken finds that electrification has involved greater interaction with the municipalities, and more stakeholders being involved in the discussions.

As regards new responsibilities for RPTAs, in the case of Västtrafik there is no change to their responsibilities prior to forthcoming initiatives. Instead, the bus operator still maintains ownership of the formulation of public transport services.

Prior to future contracts, Trafikförvaltningen has chosen to stand responsible for guaranteeing the power supply up to the depots that will be running electric buses. As Trafikförvaltningen owns the depots and has taken on responsibility for the power supply to the depots, they therefore have major influence over the choices made and the conditions for the charging infrastructure. In the light of initiatives currently in progress, neither Västtrafik nor Trafikförvaltningen owns the electric buses or the charging technology to be installed: this is the bus operator's responsibility.

The interface for Skånetrafiken is not as clear, as it frequently involves interaction between the municipality in question and Skånetrafiken. Questions being discussed include where charging infrastructure is to be located, who is to stand responsible for and administer it, and the extent to which electric buses are to be introduced. Municipalities previously owned and managed charging infrastructure in the street environment for earlier electric bus initiatives. Skånetrafiken's ambition is for the operator to administer the charging infrastructure and depots, while municipalities and Skånetrafiken will own them.

### 5.2.3. Procurement procedures, contracts and business models

To date, Trafikförvaltningen and Västtrafik have generally worked with functional specifications and thus provided bus operators with more scope for implementing the service, while Skånetrafiken has maintained more control over the details. At the same time, Trafikförvaltningen has abandoned functional specifications to a certain extent ahead of future procurement procedures, in that they specify requirements specifically for the introduction of electric buses.

RPTAs apply different reasoning to whether electric buses are to be introduced as part of existing or new standard procurement procedures. Trafikförvaltningen has previously introduced electric buses as part of ongoing contracts, but in future they will be focusing on electric buses as part of their standard procurement procedures. Trafikförvaltningen is of the opinion that introducing electric buses in new procurement procedures is the least risky approach, but does not rule out the possibility of introducing electric buses as part of ongoing contracts in future. Skånetrafiken and Västtrafik are focusing instead on the scope of existing contracts and standard procurement procedures for new contracts. Skånetrafiken has not amended its approach to procurement procedures to any significant extent, but is of the opinion that new issues relating to costs, approaches and responsibilities will arise when new technology is introduced.

Trafikförvaltningen has chosen to hold market discussions with bus operators at an earlier stage prior to procurement of electric buses. However, this market discussion is not motivated solely by the electric bus initiative. Trafikförvaltningen is of the opinion that electric buses are still a relatively new phenomenon in their public transport services, both



for themselves and for bus operators, so there was a need for early discussion with the market.

Västtrafik has previously worked with a model based on more in-depth discussions with bus operators prior to and after procurement procedures. Västtrafik has held a number of discussions with lots of stakeholders prior to the electric bus initiative, as well as carrying out market surveys prior to the procurement procedure so as to avoid being locked in to specific choices of technology.

Trafikförvaltningen is of the opinion that depot charging is the solution that involves the least change from the current business model and contract perspective, and views this alternative as the least risky approach. Apart from adding responsibility for electricity sales, there is no major difference in the approach. Västtrafik has not made any changes to its business model, but they are linking electric buses with new green and innovative business models.

### 5.3. Broader social perspective

#### 5.3.1. Coordination with other electrification processes

Both Trafikförvaltningen and Västtrafik highlight the fact that there may be potential in coordinating electrification of buses with other electrification processes in the transport sector. However, this is not something that the three RPTAs in the study are working with specifically ahead of future electric bus initiatives. They emphasise the fact that technical and legal issues may make coordination difficult.

In Stockholm, Trafikförvaltningen is also examining whether the power grid for the underground rail service could be used for charging electric buses, but there is a chance that this will not be possible for legal and other reasons. Whether the overhead tram lines could be used by electric buses was examined in Gothenburg, but the technical systems were not compatible. Besides that, Trafikförvaltningen underlines the fact that any coordination in terms of charging infrastructure requires several different vehicle types to have similar charging requirements. For example, the driving patterns for a haulage company may differ from the routes used by public transport services.

RVG has been tasked with working with coordination of electrification; that is to say, Västtrafik is not working with this. Skånetrafiken has not specified any plans or cooperations concerning electrification with other transport systems.

#### 5.3.2. Urban planning, the built environment and infrastructure

The study shows that in the three regions studied, introducing electric buses has no appreciable impact on how urban planning is formulated. All the regions are holding discussions with the units at the municipal level that are responsible for urban planning and design, but the emphasis is on the positioning of supplementary charging stations, if this approach is to be used. The regions have different criteria depending on their current urban

design stop for instance, there is often a shortage of street space in Stockholm and so depot charging would be advantageous there. Therefore, the electric bus initiative in Stockholm will have no significant impact on street space in the region and how it is planned. Skånetrafiken also perceived problems with regard to street space, as this may affect the urban environment.

### 5.3.3. Depot positioning and indoor bus stops

Electric buses create opportunities for positioning bus depots and stops in new locations in connection with social functions or embedding them in the urban environment. For example, one project in Gothenburg demonstrated an indoor bus stop next to a library. The Trafikförvaltningen survey on electric buses (2019 C) indicates that the function of an indoor bus stop can be achieved even without electric buses by building a waiting room next to a bus stop, for example.

However, none of the regions studied are planning new locations for either depots or stops as a result of electric buses. A Trafikförvaltningen depot is frequently used by vehicles with different powertrains, which means that the depot will also accommodate conventional vehicles even though electric buses are quieter and produce no direct exhaust emissions. This is why electric buses have not changed how they are planning for or positioning depots.

## 5.4. Digitisation

One thing that the three principals have in common is the fact that they are working to introduce the ITxPT standard for their digital platforms. That said, there are differences concerning membership of the ITxPT partnership. Västtrafik and Skånetrafiken are Strategic Members, with major influence on the partnership; while Trafikförvaltningen is not a Strategic Member at present, stating that they are planning to obtain this membership in future. All the principals have approximately the same digital functions on the digital platforms, and their buses are connected to both the platform owned by the RPTA in question and the bus operator's platform.

It can be stated that there are differences between the incentives for the principals, the RPTAs and the bus operators as regards implementing digital functions. The principals wish to add value for customers and therefore stand responsible for the digital functions relating directly to passengers. However, the principals frequently choose to transfer responsibility for the digital functions to bus operators if these functions do not affect passengers to the same extent. In these cases, requirements are defined via ITxPT so as to allow the functions and the systems to communicate with one another.

Bus operators have incentives to introduce digital functions and connect their buses so that they can use data to optimise their processes and activities. Data collection can help bus operators to distribute their resources more effectively. Remuneration in contracts is frequently based on passenger numbers, so digital functions such as passenger counts are important.

Greater automation of both depots and buses could benefit operators enormously and have extensive potential. One bus operator highlights this as interesting, as a lot of damage is done to buses at depots. Another operator perceives the need for an autonomous, electrified bus depot as a solution to the issue whereby current bus depots do not make efficient use of

space and are frequently noisy. That said, the same operator concludes that the technology is expensive and that the costs have to be offset against the benefits so that they can find incentives to make investments.

At the same time, autonomous technology for electric buses represents a restriction when it comes to allowing buses to travel longer distances. These buses will need to stop and recharge, which will mean longer travelling times or switching vehicles. In this case, one RPTA is of the opinion that autonomous technology on buses using energy sources other than batteries would be of interest.

Furthermore, one RPTA emphasises that electric road systems have the potential to facilitate a more large-scale autonomous bus fleet. Hence autonomous technology is an interesting option for electric buses for many stakeholders, but many unclear aspects are still to be resolved. Skånetrafiken emphasises that for them, it is important for the technology to have a clear purpose, giving them incentives to invest in it. Changes to the law will also be required for the technology to have a proper impact. Bus operators are of the opinion that autonomous buses have potential, but that this will take time: clear objectives and changes to the law are required.

## 6. Analysis and reflection

The analysis below is based on the results from the study of the interviews and literature. The analysis is based in part on theory relating to systems, technical and sustainable adjustments and lock-in effects, found for example in Kemp, Rip and Schot (2001).

### 6.1. Lock-in effects

The choice of technology may involve lock-in effects, or “path dependency”, in that the choices made today restrict future options available, along with the fact that continuing along the same path is simpler and more justifiable on a financial level. A number of lock-in effects linked with the study’s electric bus initiatives examined have been identified, namely capital expenses and contract length, choice of technology, previous investments and deep-rooted approaches and behaviours. The lock-in effects do not appear to be isolated: they influence and are influenced by one another.

The cost of buying an electric bus is higher than the cost of buying a conventional diesel or gas bus, and this cost is depreciated over the number of years in which the vehicle can be used, which is defined by the RPTAs as the maximum age of individual vehicles or the average age of the fleet. However, the depreciation period may be shorter than the actual time for which an electric bus can be used for services. This means that the financial value of the vehicle is depreciated over a period shorter than its actual (technical) service life. Annual depreciation is thus higher than it needs to be, as it is distributed over fewer years in relation to the potential number of years for which the bus can be used. Previous contract structures with requirements in terms of maximum and average age could thus potentially create a lock-in effect that will make it more expensive to introduce electric buses.

The contract structure is another aspect that helps to create a lock-in effect. Contracts nowadays are for no more than ten years at a time, and this approach is generally applied by the three RPTAs interviewed. Many of Sweden’s public transport services using buses will undergo procurement procedures over the next few years, which means that choices of technology will be locked to the entire contract period, and possibly thereafter as well. Given the rapid technical development that is taking place, and the rapid technical development that is expected to take place, this means that bus operators will be buying electric buses and charging infrastructure that may become obsolete during the contract period. This has been the case for the biogas initiatives implemented previously, for example.

Options or negotiations within the scope of existing contracts can be used to switch technology during the contract period, but this will involve increased costs with regard to the depreciation of old equipment. Besides the fact that the contract period may create a lock-in effect with regard to a specific choice of technology, the desire and guidelines limiting the options for introducing new buses as part of ongoing contracts with various RPTAs they also create a lock-in effect. If an RPTA advocates not introducing new technology to ongoing contracts, this means – for example – that the scope of electrification of a contract area is locked to the number of electric buses that were introduced at the time of the procurement procedure.

Leasing of both vehicles and charging infrastructure may be one option which will help to counter lock-in effects as a result of the contract period. If electric buses are introduced

within existing contracts, Västtrafik has also chosen to guarantee residual values and buy vehicles from bus operators at the end of the contract. However, these vehicles will then be used in future contracts, which in itself may result in a certain lock-in effect with regard to specific choices of technology.

Previous approaches may also have an impact on what technology is selected, as there may be ingrained – both conscious and unconscious – behavioural patterns and norms that promote the choices of the technology used previously. For example, Trafikförvaltningen prefers depot charging as this charging strategy is most similar to their current approach and is considered to be the least risky option.

Any discussions on boundaries as a consequence of the new interfaces that may be presented by electric buses will also be avoided if they are introduced in accordance with previous approaches and responsibilities. Another factor that may create inertia in introduction is whether directives and policies counteract or facilitate introduction and changes in approach, as pointed out by the RPTAs interviewed. This may be applicable to all stakeholders involved, such as bus operators, RPTAs and electric utility companies.

Trafikförvaltningen stated that their previous investment in biofuels meant lock-in effects to a certain extent; such as capital tied up in biogas tank systems at depots, which are at risk of not being used for the entire period planned. Trafikförvaltningen has therefore implemented electric buses gradually so as to avoid creating new lock-in effects.

Skånetrafiken and Västtrafik have previously invested in biogas and the associated infrastructure, but they are not of the opinion that they are locked to a specific technology as a result. Both Västtrafik and Trafikförvaltningen state that they perceive potential for biofuels to be allocated to other modes of transport where electrification is not viewed as an option.

## 6.2. Momentum of introduction

When introducing new technology, momentum can be created if stakeholders show an interest, political funding is given and the technology fills a gap in the market. As regards electric buses, all the RPTAs state that the political organisation has provided funding and demonstrated a desire to implement the switch to an electrified bus fleet. Furthermore, there are also of the opinion that there is local involvement in several parts of the country, and also on an international level. The state subsidies available may amplify momentum for the introduction of electric buses. At the same time, the regions interviewed emphasised that while the subsidies available have been appreciated, they were not deciding factors with regard to whether or not they should electrify the fleet.

Five driving forces emerged during the interviews with the respective RPTAs' reduction of noise, particle emissions and greenhouse gases, more attractive public transport services for passengers and drivers, and finally the fact that electric buses help to bring about a more energy-efficient transport sector.

### 6.3. The scale of the switch and comparison with the Nordic region

#### 6.3.1. Scope and scale in Sweden

From the information provided by the RPTAs studied, it can be stated that there is variation in the rate at which the switch is taking place between the three regions studied.

Trafikförvaltningen is maintaining a gradual approach towards the implementation of electric buses, which means that a smaller number of electric buses will be introduced at the time of the next standard procurement procedure than is the case for Västtrafik, in the main. As stated previously, this is in part a result of lessons learned previously with regard to the implementation of biogas and biofuels in the region, but also because this approach is viewed as less risky and takes into account previous investments in vehicles and infrastructure. Skånetrafiken also perceives electric buses as offering potential for the future and is introducing them gradually.

Västtrafik is implementing the switch more quickly and positively by procuring a large number of electric buses as part of its standard procurement procedure for the forthcoming year. Västtrafik reckons that a target is in place and that this must be met: in other words, their efforts are focusing on their target. The decision to implement the switch from a political level has also been important to its implementation. This has given all stakeholders and mandate to work with the issue, as well as reducing uncertainty and risks associated with the implementation of new technology.

The two approaches – gradual or rapid, positive implementation – may define which choices are made in terms of technology, business models and other peripheral issues, as well as how the switch is received. The fact that some regions are leading the way with the switch will allow other regions to learn lessons from them and benefit from the support offered by drivers, passengers, residents and other people upon whom electric buses have an impact.

#### 6.3.2. Comparison of targets in the Nordic region

Only Västtrafik has defined a quantitative target for the introduction of electric buses; that *30 per cent of its vehicle fleet must be made up of electric buses by 2025.*

Trafikförvaltningen and Skånetrafiken state that they perceive potential in electrifying urban transport services, but they have no defined targets. However, there may be in municipalities within Region Skåne, which have defined targets concerning the number of electric buses. A comparison with a number of Nordic capitals can be drawn in order to place the Swedish targets in context. See Table 2 for a list of some of these targets.

**Table 2** Confirmed targets regarding the number of electric buses to be included in the bus fleets of the respective regions or capitals by a certain year.

<b>Sweden</b>	<b>Nordic region</b>
Trafikförvaltningen – not confirmed	Copenhagen 100 per cent electric buses by 2031 (Krogsgaard Niss, 2017)
Skånetrafiken – not confirmed	Oslo 60 per cent electric buses by 2025 (OECD and IEA, 2018 B)
Västtrafik 30 per cent electric buses by 2025 (Västtrafik, 2018 A)	Helsinki 30 per cent electric buses by 2025 (HSL, 2017)

Table 2 shows that the Nordic capitals generally have higher targets for the introduction of electric buses than the RPTAs studied in Sweden. The highest target among the RPTAs studied in Sweden is the same as the lowest target for the Nordic stakeholders studied, despite the fact that Sweden has two ambitious national targets within the scope of its framework on climate policy; to reduce greenhouse gas emissions from the transport sector by 70 per cent by 2030, and to achieve national net zero emissions by 2045 (Regeringskansliet, 2017). At the same time, it should be noted that as things stand at present, the regions studied mainly used biofuels and thus are managing to reduce CO<sub>2</sub> by means other than electrification. Thus further analysis should be performed on the basis of more Nordic countries, and the links to each country's national targets in respect of climate, sustainability and electrification should also be considered.

It should also be pointed out that Trafikförvaltningen and Skånetrafiken are nevertheless working to introduce electric buses, even though they have no specific targets in that regard. While Trafikförvaltningen has no confirmed target relating to electrification in its transport service provision programme, a set of objectives does indicate that between 30 per cent and 70 per cent of transport services should involve electricity in the county of Stockholm by 2030.

Given the extensive preparatory work carried out by the RPTAs studied, one relevant question may consider whether the RPTAs working in practice with higher levels of ambition than their respective targets would indicate.

### 6.3.3. Digitisation

In general, it can be stated that digitisation is not dependent on electrification: the two can take place independently of one another. Digital platforms and functions are applied on all buses, regardless of what fuel is used. The digital functions used on buses are based more on how new the bus is, what requirements are defined and what the most eco-friendly options are. That said, it is important for bus operators to ensure that electric buses are connected so that they can identify bus range and view information on when charging will be required.

It is also very important to ensure that electric bus chargers are also connected so that charging can be distributed overnight. One RPTA is of the opinion that new digital systems will be needed if supplementary charging is implemented. That said, they themselves are not planning to introduce any new systems when electrification takes place. So from this perspective, digitisation appears to be an important factor in the electrification of the bus fleet from a bus operator standpoint, but it is not as significant for RPTAs. This could be explained in part by the fact that bus operators are closer to day-to-day operations than RPTAs and hence perceive a need for extended data in order to optimise operations.

Digitisation may also allow the electrification of public transport services to take place more efficiently. It may promote integration of systems with one another, and network problems could be avoided by having different digital systems. There is also a link between electrification and digitisation in the form of automation.

Electrification simplifies the further automation of buses. For example, it is said to be easier to automate charging than fuelling with traditional fuels. Furthermore, Trafikförvaltningen is of the opinion that automation will be simplified in electric vehicles as the design is simpler. Principals, bus operators and other stakeholders are of the opinion that services will develop towards a more autonomous approach, and so electrification is important as this will facilitate that development.



## 7. Conclusion and recommendation for future work

The study shows that there is a great deal of interest in electrified bus services among the stakeholders interviewed. It is possible to perceive a political interest in a number of regions, where targets have been formulated for electric buses, at both regional and local level. At the same time, the initiatives implemented within the regions studied are relatively modest as regards the targets defined for electric buses in other Nordic countries, but the comparison needs to be expanded upon in this regard. The RPTAs focused on in this study do not currently advocate a complete transition to electrified buses; unlike the public transport authority in Oslo, for example. A gradual transition will allow RPTAs and operators to learn and avoid mistakes.

The study focuses on charting the work done by Trafikförvaltningen, Skånetrafiken and Västtrafik on the introduction of electric buses. The limitations of the study mean that electric buses used for public transport services in smaller regions have not been studied; nor has the international perspective. Therefore, including these two perspectives would be relevant for future work in order to provide a more nuanced and comprehensive view of the electrification of bus services. The RPTAs on which the case study focused are the biggest in Sweden, and in many regards their electrification and criteria for the same can be compared with one another; which is why there is a need to interpret electrification further on the basis of the perspectives of a number of stakeholders.

As far as the initiatives involving electric buses in each of the regions is concerned, it is clear that there has been a transition from the demonstration and pilot projects that previously characterised electric bus initiatives, and electric buses are now becoming part of regular public transport services. They are being introduced as part of ongoing contracts and as part of new standard procurement procedures. However, this introduction is at an early stage and it will only be possible to evaluate the results of the regions' introduction of electric buses for public transport services in a few years' time.

The significance of bus operators is noteworthy as regards the transition to the current wider focus on electric buses. Bus operators are of major significance in the implementation of the switch and the regular operation of electric buses as part of regular public transport services. Bus operators have largely come across as positive driving forces as regards this switch.

As far as technology is concerned, what has emerged is that bus operators have a great deal of influence over the direct choices of technology linked with electric buses and charging technology. Although bus operators' options are controlled by the requirements defined by RPTAs ahead of each contract, bus operators have the greatest insight into and awareness of the choices made with regard to technology, and whether these choices will impact on day-to-day service provision.

The RPTAs studied are pursuing a line of reasoning with regard to the charging strategy, and there is variation in the extent of their involvement in the decision on the charging strategy eventually implemented by their bus operators. It is also apparent how the battery issue in respect of electric buses is a relatively new area for public transport services, and the study

shows that there has been development in approaches and procedures as regards handling social sustainability.

The procurement process, contract structures, costs and interfaces have been studied with regard to organisation and financing. Electric bus initiatives as part of standard procurement procedures have not evolved any major differences in the procurement process, apart from earlier discussions – and more discussions – initiated by RPTAs. The study also shows that electrification of bus services means that established public transport stakeholders may be given new responsibilities concerning the ownership of charging infrastructure or the power supply, for example.

It is also noted that new stakeholders such as electric utility companies are becoming or have become more significant when it comes to public transport services. Therefore, the introduction of electric buses means that defining interfaces and responsibilities has become more important, as management of electric buses is still relatively new. The recurring significance of interaction for public transport services and the electric bus initiative has been noticeable.

It is possible to see that the RPTAs studied are working in a similar way to previously, which may indicate that they are locked in to old behaviours or avoiding taking risks, which is why established approaches and habits are persisting. Potential lock-in due to old directives and policies may also result in a lack of appreciable alteration of the procurement process, contract structure and responsibilities.

Funding and cost distribution for vehicles and their associated equipment is a key issue when introducing electric buses, as electric buses cost more to buy than traditional buses. From a cost perspective, requirements for the maximum age of individual buses or the average age of the fleet are more significant when introducing electric buses than when using traditional technology.

Requirements regarding the age of the fleet create a lock-in effect to a certain extent, given bus operators' ability to create economies in the investments made in electric buses. Both old and new choices of technology can create lock-in effects to an extent for current and future electric bus investments, as the choices are locked to the period for which the contract is valid.

The study also shows that the regions have different financial incentives to introduce electric buses: this can be explained by previous biofuel initiatives, which may make holding off on the introduction of electric buses a rational choice.

As regards the social perspective, the study shows that there is potential on a theoretical level to alter urban planning and the design of cities, but that the switch to electric buses in the regions does not involve this as things stand at present. To an extent, there is also potential in linking electrification of the bus fleet with other modes of transport, and some of the RPTAs are citing this as a possibility. However, this appears to be difficult for both technical and legal reasons.

As regards digitisation and electrification, the study shows that these are taking place in connection with one another but are not fully dependent on one another. Rather, digitisation of bus services is seen to be taking place independently of electrification; but

electrification is being supported by digitisation to some extent. The clearest link is with automation, a subset of digitisation, as electrification may facilitate the introduction of autonomous vehicles. Bus operators perceive a greater need for digitisation in connection with electric buses, in order to identify vehicle range and view information on when charging is required.

Bus operators' view of electrification of bus services has been touched upon in the study, but the switch to be implemented by bus operators should be studied in greater depth. As bus operators handle the day-to-day running of bus services, they will be the stakeholders which will work most closely with electrification and the changes it brings. This will give bus operators a unique insight into the transition to electric buses, which should be studied in greater depth.

Further, it should be noted that the electrification of bus services as described in the report is still new and that the results of the major initiatives currently being implemented are not available as yet. Therefore, it would be best to return to each of the regions and RPTAs in order to chart the results of the initiatives currently being implemented.

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