Steering green buses

The opportunities and challenges of introducing renewable fuel in public transport

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Steering green buses - The opportunities and challenges of introducing renewable fuel in public transport

Abstract

The aim of this thesis is to compare and analyse the introduction of renewable fuel in the public transport sector, focusing on the challenges and opportunities encountered by involved stakeholders on the regional and local levels. The results contribute to answering three research questions: 1) How do organisational factors and local and regional contextual factors influence the introduction of renewable fuel? 2) What are the challenges and opportunities of using green public procurement as a policy tool to introduce renewable fuel in the public transport sector? 3) How do the challenges and opportunities regarding the introduction of renewable fuel differ depending on the type of renewable fuel? Four papers are included in the thesis. Paper I compares and analyses how factors identified in green public procurement research (strategies, requirements, cost, size and knowledge) influence the choices made when introducing renewable fuel in two Swedish regions. The findings show that the influence of the factors is highly case-specific and that differences in their strategic approach caused regions to express requirements for fuel differently in tender documents. Functional requirements were used by the public authorities to increase the share of renewable fuel in a cost efficient way and at the same time allow room for flexibility and leave more control to the operators. Specific requirements were strategically used to create local markets for biogas, which poses higher demands on political backing, knowledge by the public authorities, and an acceptance of increased costs. These findings were further elaborated in paper II, where introduction of renewable fuel in ten more Swedish regions was studied. The results confirmed to a large extent the challenges and opportunities from paper I. Further, regions that had introduced another renewable fuel than biodiesel had either used specific requirements or introduced the fuel in publicly operated bus services. The scope of paper III complements the findings by looking more in detail at how environmental requirements have been expressed, by performing a content analysis of Swedish tender documents. The results show that size of the procurement and type of traffic influence how environmental requirements are set. Further, both ambitious functional requirements and specific requirements for fuel are more common in large tenders in city traffic – this confirms and exemplifies the importance of context when renewable fuel is introduced through public procurement. In paper IV, the focus is solely on the introduction of electric buses by comparing experiences in Sweden and England. It was concluded that most challenges are case-specific on the city level, for example, passenger demand and bus route characteristics, but also financial and regulatory support from the national government can have an influence. Additionally, the relationship and division of roles between involved stakeholders are central to overcome challenges in all cities. Overall, this thesis concludes that green public procurement can be successful for introducing renwable fuel. By expressing requirements differently in the tender documents, public authorities have been able to influence the introduction to a varying degree which has led to different challenges and opportunities for the involved stakeholders as well as different outcomes for renewable fuel. Nevertheless, introduction of emerging technologies (eg. electric buses) was shown to be a challenge when public transport was procured. Alternative introduction strategies were seen for electric buses, such as test projects, introduction under current procurement contracts, increased collaboration between stakeholders and more responsibility to cover for uncertainties taken by the public authorities. In summary, the challenges and opportunities of introducing renewable fuel are highly case-specific and strongly associated with the specific fuel in question.

Key words Public transport, Renewable fuel, Electric buses, Sustainable transport, Green public procurement, Environmental requirements

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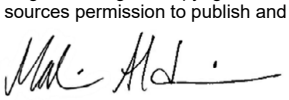
Signature  Date 2021-09-07

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To my family

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Populärvetenskaplig sammanfattning på svenska

Att bussektorn ska bidra till transportsektorns omställning till förnybara bränslen är de flesta överens om - hur det ska gå till, hur ansvaret fördelas och vilket förnybart bränsle man ska välja är inte lika självklart. Ett flertal faktorer påverkar vilket tillvägagångssätt som är det lämpligaste vid införande av förnybara bränslen. Exempel på viktiga faktorer är organisatoriska strukturer, regionala strategier, politiskt stöd, kunskap, ekonomi, tillgänglig infrastruktur och geografiska förutsättningar. I varje enskilt fall är det därför viktigt att utgå från de förutsättningar som finns, samt vad målet är med att införa förnybara bränslen – vill regionen kostnadseffektivt bidra till nationella klimatmål, adressera ett lokalt miljöproblem eller gynna utvecklingen av en specifik marknad eller ny teknik?

Införandet av förnybara bränslen i bussektorn i Sverige har gått fort och 2020 kördes över 90 % av fordonskilometrarna på förnybara bränslen - andel och typ av förnybart bränsle skiljer sig emellertid åt mellan regionerna i Sverige. En av anledningarna till skillnaderna är att kollektivtrafiken i Sverige huvudsakligen är organiserad regionalt. Ca 90 % av all regional och lokal busstrafik är idag upphandlad av regionala kollektivtrafikmyndigheter, medan resterande del av trafiken antingen drivs i egen regi eller körs kommersiellt av privata operatörer. Följaktligen är offentlig upphandling och de miljökrav som ställs viktiga för införandet av förnybara bränslen – ofta benämnt grön offentlig upphandling.

I denna avhandling ligger fokus på att förstå de utmaningar och möjligheter som regionala aktörer står inför när de ska införa förnybara bränslen. Genom att jämföra erfarenheter i olika svenska regioner, samt en utblick till erfarenheter i England, ges en bättre bild av hur dessa utmaningar och möjligheter påverkas av kontext, organisation och val av bränsle. Eftersom så stor del av den svenska kollektivtrafiken är upphandlad gör avhandlingen en djupdykning i användningen av grön offentlig upphandling.

När offentlig upphandling används i svensk kollektivtrafik, ställs miljökraven oftast som tekniska skallkrav - antingen funktionskrav på ett mål man vill uppnå eller specifika krav på teknik eller bränsle. Vilken typ av krav som ställs är ofta beroende av regionens mål och förutsättningar. Hur kraven ställs påverkar i sin tur vilket bränsle man får och vilka utmaningar och möjligheter som involverade aktörer

upplever under införandet. Funktionskrav lägger mycket av ansvaret på den upphandlade operatören och anses vara det mest kostnadseffektiva och flexibla sättet att ställa om – emellertid har det endast lett till användning av det mest kommersiellt gångbara förnybara bränslet, vilket i dagsläget är biodiesel. I de fall regioner velat införa ett annat förnybart bränsle än biodiesel har oftast specifika krav krävts. Oftast har det varit kopplat till en bredare strategi i regionen där andra mål än ökad andel förnybara drivmedel spelar en roll – t.ex. att skapa en marknad för ett nytt bränsle eller minska luftföroreningar eller buller. Biogas har i många fall även införts i regioner med busstrafik i egen regi där man har haft möjlighet till en successiv omställning utan långa upphandlingsprocesser med risk för inlåsning. Egen regi kräver dock mycket kunskap hos kollektivtrafikmyndigheten och konkurrens för att minska kostnaderna saknas. För nya bränslen och tekniker, så som elbussar, kan det vara svårt att ställa bra krav i upphandlingarna då osäkerheten runt ansvarsfördelning och teknikens utveckling är stor. I dessa fall har testprojekt utanför normal trafik eller införande under befintliga avtal setts som ett bra första steg.

Erfarenheterna om införandet av förnybara bränslen i kollektivtrafiken i denna avhandling bygger främst på empiriska erfarenheter. Jämförande studier mellan regioner och städer har gjorts med hjälp av en kombination av dokumentstudier, intervjuer och workshops med involverade aktörer. Förhoppningen är att lärdomarna om hur olika faktorer påverkar införandet av förnybara bränslen kan förenkla processen både i Sverige och i andra länder, genom att man utgår från gällande förutsättningar i varje fall när man väljer tillvägagångssätt och bränsle.

List of publications

Paper I: Aldenius, M., Khan, J. (2017). Strategic use of green public procurement in the bus sector: Challenges and opportunities. *Journal of Cleaner Production*, 164, 250–257.

Paper II: Aldenius, M. (2018). Influence of public bus transport organisation on the introduction of renewable fuel. *Research in Transportation Economics*, 69, 106–115.

Paper III: Aldenius, M., Tsaxiri, P., Lidestam, H. (2021). The role of environmental requirements in Swedish public procurement of bus transports. *International Journal of Sustainable Transport* (Online).

Paper IV: Aldenius, M., Mullen, C., Pettersson-Löfstedt, P. Electric buses in England and Sweden – a multi-actor perspective on overcoming barriers to introduction. Submitted to *Transportation Research Part D: Transport and Environment*

My contribution to the publications

Paper I: Jamil Khan carried out the interviews and I was responsible for the theory chapter. The remaining responsibility for analysing data and designing and writing the article was shared between the authors.

Paper II: I was the sole author.

Paper III: I was responsible for writing and designing the paper. The method and data collection were developed and carried out together with Helene Lidestam. Helene Lidestam also commented on the design and text in the paper throughout the process. Panagiota Tsaxiri was mainly responsible for writing about previous research.

Paper IV: I was responsible for designing the study, as well as collecting and analysing data and writing the paper. Caroline Mullen contributed through discussions and comments on the data analysis and text, and especially contributed to the sections about the English system. Fredrik Pettersson-Löfstedt contributed to writing the discussion and conclusion.

Related publications and reports not included in the thesis

Aldenius, M., Forsström, E., Khan, J., Nikoleris, A. (2016). Elektrifiering av stadsbussar: En genomgång av erfarenheter i Sverige och Europa. K2 Working Papers 2016:12.

Khan, J., Aldenius, M., Norinder, H., Palm, J., Backman, F. (2017). Grön offentlig upphandling i transportsektorn. Swedish Knowledge Centre for Renewable Fuel (f3). Lund University.

Hultén, J., Wretstrand, A., Pettersson, F., Aldenius, M., Anund, A. (2018). Vilken framtid har bussen? Omvärldsanalys inom ramen för projektet Buss 2030. K2 Working Paper 2018:1

Lantz, M., Aldenius, M., Khan, J. (2019). Styrmedel för en ökad produktion och användning av biogas. Lund University.

Lantz, M., Aldenius, M. (2020). Produktion och användning av batterier för eldrivna bussar: Energianvändning och emissioner av växthusgaser. K2 Working Paper 2020:3.

Aldenius, M., Khan, J. (2020). Hållbar kollektivtrafikupphandling – Erfarenheter från forskningen. Energikontor Sydost.

Camén, C., Tsaxiri, P., Aldenius, M., Lidestam, H. (2020). Flexibility in contract design – is that possible? *Research in Transportation Economics,* 83, 100899.

Table of Contents

1 Introduction

The transport sector is a major contributor to climate change and accounts for almost a quarter of direct CO_2 emissions from fuel combustion globally, whereof road transport accounts for almost three-quarters of transport emissions (IEA, 2020). The transport sector also contributes to local health, environmental and urban development problems (Hickman and Banister, 2015). Thus far, there has been limited progress in environmental sustainability in the sector (IEA, 2020). However, the EU has set long-term targets to address the problems. One of these targets is to decrease greenhouse gas (GHG[1]) emissions from the transport sector by 60% by 2050 (European Commission, 2016a). Further, there is a target to decrease car use without compromising mobility (European Commission, 2011). In the strategies to achieve these targets, public transport has an important role to play by taking market share from car journeys (Banister, 2008), although the environmental and climate benefits of public transport depend on many factors such as type of vehicle technology and fuel (Holmberg, 2013).

The opportunities for renewable fuel introduction in the public transport sector is highly dependent on geographical context. Sweden has made exceptional progress in the shift away from fossil fuel in the public transport sector. In 2020, over 90% of public transport was operated using renewable fuel, although type and share of renewable fuel differed across regions (The Swedish Public Transport Association, 2021). In Sweden and many other European countries, regional and local public authorities are primarily responsible for public transport, but outsourcing operations to private operators is an increasing trend (International Transport Forum, 2020). In Sweden, it is often the region that assumes the role of public transport authority (PTA) and therefore has strategic responsibility for regional and local public transport. A region in Sweden is a self-governing body comprising elected politicians responsible for different policy areas such as health care, regional development and public transport (Riksdagsskrivelse 2020/21:133). Bus operations are commonly contracted out to private operators. Around 90% of bus transport in Sweden is publicly procured (The Swedish Bus and Coach Federation, 2019a). Nevertheless, Swedish public transport in a region or municipality could still be publicly owned without the involvement of private operators. When the Public

[1] GHG will be used in this thesis when referring to emissions effecting the climate in general. However, CO_2 is used in cases where reference is made to a specific CO_2 target.

Transport Act (Prop. 2009/10:200) came into force in 2012, the market was also deregulated, enabling open entry by private operators. Thus far, deregulation has had limited effect on regional and local public transport and open entry is unusual. Apart from the possibility of different organisational structures, the context of Swedish regions such as geography, urban structure, demography and regional politics also differs (Riksdagsskrivelse 2020/21:133). Governance on the regional level with the involvement of both public and private stakeholders in different organisational constellations and the differences in regional context makes an argument for comparative studies of Swedish regions in order to understand what influences the introduction of renewable fuel in public transport.

The dominance of Swedish regional public authorities outsourcing operation to private operators naturally places focus on how public procurement can be used by the authorities as a policy tool to introduce renewable fuel, often termed *green public procurement* (GPP) (European Commission COM (2008) 400). There are different ways to use GPP as a policy tool. The European Commission (2019) proposes that either technical specifications or award criteria should be used when including environmental criteria in the procurement of public transport. In the Swedish public transport sector, technical specifications via functional requirements (meaning to achieve a goal without exactly specifying how it should be done; for example, specifying the share of renewable fuel) or specific requirements (for example, demanding a specific fuel or technology) are by far the most common way of using GPP. Award criteria are a way of including incentives in the award stage of the procurement process to motivate bidders to act in a desired manner. This is uncommon in the Swedish public transport sector, but is used in other countries and sectors.

There has been relatively little research on the use of GPP as a policy tool for the introduction of renewable fuel in public transport (Cheng *et al.*, 2018; Chersan *et al.*, 2020), in spite of the recognition of the great potential of GPP in the transport sector (European Commission, 2004; Preuss, 2007; von Oelreich and Philp, 2013; European Commission, 2016a; Quintero *et al.*, 2019). However, the literature on GPP has increased steadily since the early 2000s and factors limiting the uptake of GPP is a common topic. Commonly identified organisational and contextual challenges for uptake of GPP include cost, strategy and goals, size of the procuring entity and lack of knowledge (Cheng *et al.*, 2018). Nevertheless, focus is on whether environmental criteria have been included in the procurement process at all, and very little research focuses on what influences the way in which environmental criteria are expressed and what challenges and opportunities the different criteria entail for the introduction of green products and services. Two Swedish studies published this year touch on the topic by addressing the lack of knowledge for formulating environmental criteria for fuel in the public transport sector (Ammenberg and Dahlgren, 2021a; Lindfors and Ammenberg, 2021). Recognising how previous research often focuses on challenges to uptake of GPP, gaining

experience from a sector that has made significant progress in the introduction of renewable fuel is an opportunity to also highlight ways to overcome the challenges.

Additionally, when studying the introduction of renewable fuel, it is important to analyse the different types of renewable fuel separately. Renewable fuel varies, for example, in terms of environmental performance and economy (Patil, Herder and Brown, 2010; McKenzie and Durango-Cohen, 2012; Xu *et al.*, 2015) and require different infrastructure and recourses (Xylia and Silveira, 2017). Across countries in the EU, but also across Swedish regions, the type of renewable fuel used in the transport sector varies considerably (Xylia and Silveira, 2017; Ammenberg and Dahlgren, 2021b). Thus, it is of interest to analyse what factors influence the choice of renewable fuel type, such as context and organisational structures, as well as the challenges and opportunities that a choice entail.

In summary, the introduction of renewable fuel in the public transport sector is happening simultaneously but at different rates throughout the world. Thus, there is an opportunity to learn from experiences. Nonetheless, despite Sweden making significant progress in the introduction of renewable fuel in the public transport sector and despite the literature identifying the public transport sector as having a great potential to use GPP as a policy tool, relatively little research has been conducted on the uptake of GPP in the public transport sector. Previous research has also had a strong focus on the challenges of the uptake of GPP. Using the Swedish public transport sector as a case provides a chance to compare the challenges and opportunities of introducing renewable fuel depending on organisational approach and local and regional context, such as strategies and goals, available financial and knowledge resources, size of region or procuring entity, availability of physical resources such as fuel and infrastructure, as well as the characteristics of operational planning in the current public transport system. Studying introduction of renewable fuel in the Swedish public transport sector also allows comparisons of how introduction differs depending on which renewable fuel has been introduced.

1.1 Aim and research questions

The broad aim of this thesis is to compare and analyse the introduction of renewable fuel in the public transport sector, focusing on regional and local levels. More specifically, the focus is on the challenges and opportunities regarding the introduction of renewable fuel encountered by the various stakeholders such as PTAs, municipalities and bus operators. The findings are strongly based on empirical material, primarily through interviews with different stakeholders, as well as document studies. To help contribute to the aim, the thesis addresses the following four research questions:

1. How do organisational factors and local and regional contextual factors influence the introduction of renewable fuel?
2. What are the challenges and opportunities of using green public procurement as a policy tool to introduce renewable fuel in the public transport sector?
3. How do the challenges and opportunities regarding the introduction of renewable fuel differ depending on the type of renewable fuel?

The research questions are addressed through the four research papers included in the thesis (see Table 1). The papers focus on one or more of the research questions.

- Paper I compares how regional context (e.g. regional political strategies, fuel availability, regional size) in two Swedish regions influence the use of GPP as a policy tool in the public transport sector and what challenges and opportunities it entails.
- Paper II builds on Paper I and compares the introduction of renewable fuel sin 12 Swedish public transport regions – including cases in which the authorities outsource the operation to private operators through competitive tendering and cases in which the authorities own and manage operation of the buses themselves.
- Paper III studies how environmental requirements have been set historically in Sweden in different contexts (types of traffic, size of procurements and different Swedish regions) to promote change from the use of conventional fossil fuel to the use of renewable fuel in the public transport sector. The paper is based on tender documents over a 10-year period in Sweden.
- Paper IV examines the challenges and opportunities of introducing electric buses, a not yet commercially viable technology. The study compares cases in Sweden and England and studies how stakeholders' experience is influenced by national organisation and policies, as well as the regional and local context of the current public transport system.

Table 1 The association between the papers and the research questions.

Paper	Description	RQ1 Organisational factors and local and regional contextual factors	RQ2 Challenges and opportunities of GPP	RQ3 Type of renewable fuel
I	Compares GPP in two Swedish regions	x	x	x
II	Compares 12 Swedish regions	x	x	x
III	Tender documents in Sweden, 10-year period	x	x	
IV	Electric buses in two countries	x		x

1.2 Delimitations

In this thesis I have chosen to focus on the experience of stakeholders on regional and local levels. This primarily includes regional PTAs, municipalities and private operators. The national authorities also play a role in the introduction of renewable fuel in the public transport sector through, for example, policy instruments and regulations. Nevertheless, in this thesis, the national level is only analysed from the perspective of regional and local stakeholders.

Apart from limiting the focus to regional and local levels, this thesis also focuses on public bus transport. This means that public transport by train, light rail and boat has been excluded, as well as school bus services and long-distance buses. The main reason for excluding light rail and trains is that most services, particularly in Sweden, already run on electricity from renewable sources. In 2017, rail services were only responsible for 0.2% of GHG emissions from the national transport sector in Sweden (Prop. 2019/20:65). The main reason for excluding long-distance buses is that they are not primarily managed on the regional or local level. Thus, from here on in this thesis, *public transport* refers to regional and local buses, unless otherwise stated. In the same way *operator* refers to their role as bus operator.

The introduction of renewable fuel in public transport is analysed from a Swedish perspective, limiting the possibility for generalisation to the organisational structures and context of other countries. However, the dominant form of organisation in Sweden with public authorities outsourcing operations to private operators is also becoming increasingly commonplace in other countries. Thus, there is a lot to learn from Swedish experiences on how GPP can be used to introduce renewable fuel in the public transport sector. A comparison with England in one of the articles also helps to gain a perspective of the Swedish system.

The term *renewable fuel* includes both biofuel (biodiesel, biogas and ethanol) and electricity in this thesis and the main focus on sustainability is on climate and local environmental aspects, such as reducing GHG and decreasing air and noise pollution in urban areas.

1.3 Outline

This thesis commences in Chapter 2 by providing a background to describe the prerequisites for the organisational and contextual factors and the fields of research in which the papers were written. The first part of the background compares renewable fuel currently available for the public transport sector and gives an overview of which fuels are used in the bus sector in Europe and Sweden. This is followed by a description of the EU and Swedish targets, directives and policy

instruments that have the potential to influence the introduction of renewable fuel. I will then introduce different ways of organising the responsibilities for planning and operation within the public transport sector. Last, I describe how GPP can be used to introduce renewable fuel.

The background is followed by a description of the fields of research relating to my papers. Chapter 3 is divided into two parts: The first part concerns the literature on GPP since this thesis largely focuses on the introduction of renewable fuel in a market that is based on competitive tendering. The second part covers existing research on the introduction of renewable fuel in the public transport sector.

Chapter 4 includes a description of the research approach to this thesis and the empirical material and methods used in the papers. In Chapter 5, I summarise the main findings from the four papers included in the thesis. In the discussion section in Chapter 6, the findings from the papers are discussed in relation to each other, but also in relation to Chapters 2 and 3 of the thesis. Lastly, the conclusion in Chapter 7 discusses how my research contributes to the existing literature on GPP and what implications my findings may have regarding the introduction of renewable fuel in the public transport sector.

2 Background

This background chapter aims to provide a deeper understanding of the context in which my research is conducted. I describe the situation in Sweden regarding renewable fuel, policy setting, the organisation of the public transport sector and GPP in more detail than in the papers, and describe the Swedish situation in relation to the European context. An extensive background section ensures the reliability of research when further discussing the implications from the findings regarding the introduction of renewable fuel in other contexts. The point of departure of the chapter is in the current situation for renewable fuel. In section 2.1, I review the characteristics of the fuel available for the public transport sector, and the extent of introduction in Europe and Sweden. This section aims to highlight the differences between renewable fuels and also show that the situation in Sweden is unique compared to other countries. Section 2.2 presents the policy setting in which the regional introduction of renewable fuel takes place, by showing the opportunities for the EU and Sweden to exert influence using targets, directives and policy instruments. Showing the national conditions under which regional authorities make their decisions is important in order to discuss the possibilities of learning from the Swedish experience in other national contexts. Furthermore, the conditions under which fuels are introduced is affected by the organisation of the public transport sector in any given country. Thus, section 2.3 presents possible ways of organising responsibilities between stakeholders and how this is conducted in Sweden. Lastly, in section 2.4, I go into more detail about how public procurement can be used at the regional level to promote the introduction of renewable fuel in the public transport sector. Understanding the limits and possibilities of GPP as a policy tool is important to comprehending why GPP is used in different ways in various Swedish regions and why they face different challenges and opportunities.

2.1 Renewable fuel used in the public transport sector

Diesel is the most common fuel used in buses and in large parts of the world it is still the primary fuel for bus fleets. However, there are several alternative options to diesel and currently the type of fuel varies across countries (ACEA, 2021b) and even across regions in Sweden (Xylia and Silveira, 2017; Ammenberg and Dahlgren, 2021b). In order to understand what influences the potential for the introduction of

renewable fuel, it is important to understand the characteristics of the different fuels. This section presents the three most common renewable fuels used in the public transport sector in Sweden: biodiesel, biogas and electricity. A shorter description of ethanol and hydrogen is also given. The focus is on how the fuels differ from each other regarding climate and environmental characteristics and technological maturity. A comparison of climate and environmental performance can be seen in Table 2.

There are different kinds of *biodiesel* depending on the origin of the feedstock and how it is processed. Biodiesel is largely used as a blend in fossil diesel, but for heavy vehicles it has also been used pure. Biodiesel can be produced from vegetable or animal oils. Rapeseed methyl ester (RME) and fatty acid methyl ester (FAME) have been available for many years. They are commonly blended with fossil diesel, but with modified diesel engines they can also be used pure in vehicles. Hydrogenated vegetable oil (HVO) has entered the market in recent years. It is a biodiesel that has similar characteristics to fossil diesel, with the added benefit that it can be used in conventional diesel engines and distributed using the existing infrastructure without the need for any new investments. Compared to RME and FAME, HVO also has lower emissions of GHG and nitrogen oxides (NOx) from a well-to-wheel perspective (The Swedish Energy Agency, 2016; Lindström *et al.*, 2017). Nevertheless, exhaust emissions from biodiesel are comparable to fossil diesel. Biodiesel also faces challenges associated with indirect land use change and origin of feedstock. For HVO in particular, there is an ongoing debate about the use of palm oil and palm fatty acid distillate (PFAD). Future availability is also uncertain since it competes for recourses with other modes of transport (e.g. aviation) (European Commission, 2020b).

Biogas can be used as a low blend in natural gas or used pure and can be distributed in gas or liquid form (the liquid form makes up a very small proportion of the current volume). One of the advantages of biogas is the potential regional environmental and societal co-benefits if biogas is produced regionally from waste, manure or sludge and upgraded for use in vehicles. Compared to a diesel engine, a gas engine also contributes less to GHG emissions, particles and noise pollution. Nevertheless, a gas engine is less efficient than a diesel engine. Another challenge is the availability of biogas since biogas production and the infrastructure for distribution is less developed than for diesel. Due to the current dominance of diesel, introducing biogas is often also a greater step than introducing biodiesel, since it requires investments in new vehicles and also sometimes fuelling infrastructure (The Swedish Energy Agency, 2016; Lindström *et al.*, 2017). Biogas is also an attractive fuel for other modes of transport and sectors (e.g. heating and industry). Thus, its future in the transport sector is uncertain (European Commission, 2020b).

Electricity has been used to power buses for many years, although traditionally in trolley buses with continuous charging similar to light rail systems. Recently, battery electric buses started entering the market and are regarded as an attractive

technology, particularly for urban public transport. One of the major benefits of electric buses is that it is free from emissions and noise during the operational phase. Electric buses also have comparably energy-efficient engines and low running costs. However, there are still many challenges such as shorter range, the need for new charging infrastructure and high investment costs (Lindström *et al.*, 2017). There is also no guarantee that it is a sustainable option, because it is highly dependent on the source of electricity generation and the battery production (Nordelöf, Romare and Tivander, 2017).

Ethanol has been around as a fuel for several years and even though it is currently being used to a very low extent as a pure fuel in Sweden, it is a common blend in petrol (The Swedish Energy Agency, 2016; Lindström *et al.*, 2017). However, its future development has been affected by policy changes and debates about the feedstock's competition with food crops. Ethanol can be produced from multiple feedstock but crops such as corn are the most common. GHG emissions depend on the feedstock that is used but the emission reduction can often be compared to that of RME and FAME (USDA Foreign Agricultural Services, 2019).

There has been interest in *hydrogen* or fuel cell buses for many years but it has still not entered the market commercially. One reason is the much higher investment costs compared to diesel buses. In order to achieve large scale introduction there is also a need to increase electricity production and develop the infrastructure (European Commission, 2020b). Several ongoing and planned test projects are being conducted throughout Europe. Like electric buses, hydrogen buses have the benefit of generating no exhaust emissions and hydrogen engines are energy efficient. In addition, hydrogen buses also have a longer range and shorter fuelling time than most electric buses (Fuel Cell Electric Buses, 2021).

Table 2 Comparison of climate performance from a life cycle perspective and environmental performance during the operational phase of the most common renewable fuel currently being used in the public transport sector, based on the above overview.

	Reduced GHG emission (well-to-wheel)	Reduced air pollution	Reduced noise pollution
Biodiesel	Small to large positive effect depending on feedstock and how it is processed	Small positive effect	Negligible effect
Biogas	Medium to large positve effect depending on feedstock	Medium positive effect	Negligible effect
Electricity	Zero to large positve effect depending on source	Large positive effect	Large positive effect

As seen, there are several alternatives to fossil diesel. The type of fuel used and how far the replacement of diesel has progressed varies across countries. In the next section, I present the current situation in Europe.

2.1.1 Fuels in the European bus sector

The European bus sector is still heavily dependent on diesel. In 2019, almost 95% of the European bus fleet comprised diesel buses. Alternative vehicle technologies represent a very small market share: gas (2.7%), liquid petroleum gas (LPG) (0.2%), battery electric (0.6%) and hybrid electric (0.7%) (see figure 1). It is important to note that these statistics only focus on vehicle technology and do not state whether the source of electricity is renewable or whether the fuel used in diesel and gas buses is fossil or bio based. Nevertheless, an ongoing increase in alternative technologies can be seen. In 2020, 9.5% of newly registered buses in Europe were hybrid electric, 6.1% electrically chargeable[2] and 11.4% used other renewable fuel[3] (ACEA, 2021b).

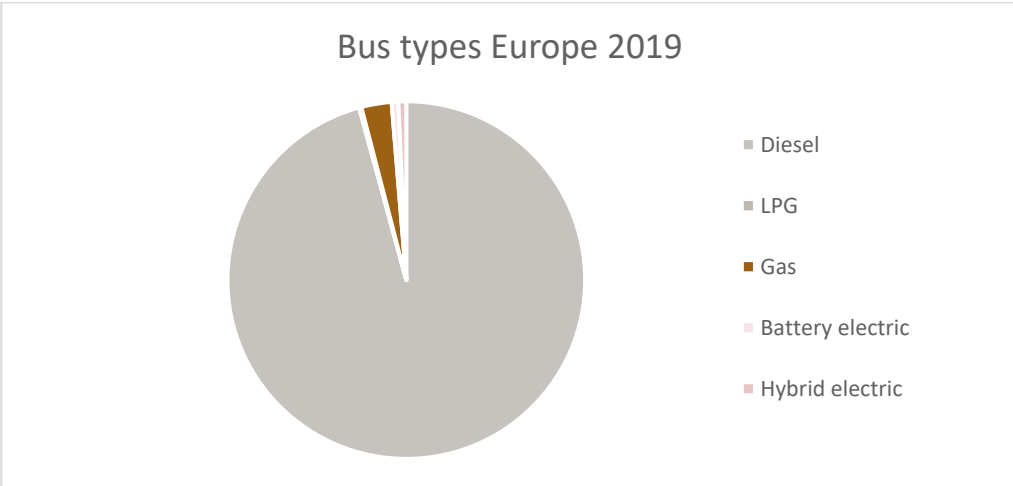

Figure 1 Bus types in the European bus fleet in 2019 (ACEA, 2021b).

The uptake of renewable fuel varies across Europe. Regarding gas buses, in 2019, Sweden had a significantly higher share than other countries in Europe: 17.6%. The second highest share had the Czech Republic with 6.7%. Also, in Italy and Spain, the number of gas buses is quite high, even though it does not represent a large share of their fleet (ACEA, 2021b). However, few of the gas buses run on biogas (European Commission, 2020b). The most important biofuel on the European transport market is biodiesel – on energy basis EU represents 75 % of the World market. Sweden, together with France, Germany, Spain and Italy represented 63 % of the total biodiesel consumption in the EU in 2018 (USDA Foreign Agricultural Services, 2019).

[2] full battery electric vehicles, fuel-cell electric vehicles, extended-range vehicles and plug-in hybrids

[3] natural gas, LPG, biofuel and ethanol vehicles

Regarding electric buses, a few countries have made progress in the introduction. Viewing the share of the bus market in 2019, Lithuania, The Netherlands and Luxemburg had the highest share of battery electric buses (ACEA, 2021b). However, statistics of the most recently registered electrical chargeable buses in 2020 shows that, The Netherlands (446 buses, 69.4% market share), Germany (338 buses, 6% market share) and Poland (200 buses, 13.7% market share) had the highest number of buses (ACEA, 2021a). In 2020, Sweden had 165 newly registered electrically chargeable buses (9.9% market share).

Statistics for England are also of interest for this thesis as English cities are used as cases in one of the papers. However, since England is a part of the United Kingdom (UK) statistics and facts will in some cases in this thesis be provided for all of UK instead of only England. The statistics show that the UK is not a country with a high share of electric buses or renewable fuel. In 2019, 98.8% of its buses were diesel buses (ACEA, 2021b). However, in 2020, 286 of newly registered buses (6.2% of the market share) were electrically chargeable (ACEA, 2021a).

This section shows that the European bus sector is still heavily dependent on diesel buses. It is interesting to note that Sweden is quite exceptional regarding the use of biogas and biodiesel, but not electric buses. Since Sweden is in focus in this thesis, I will in the next section go into more detail about the share and type of renewable fuel used in the Swedish public transport sector.

2.1.2 Fuels in the Swedish bus sector

Like in the rest of Europe, the Swedish bus fleet is still dominated by diesel buses. As can be seen in figure 2, almost 80% of buses were diesel buses in 2019, while the rest primarily comprised gas buses (The Swedish Bus and Coach Federation, 2020).

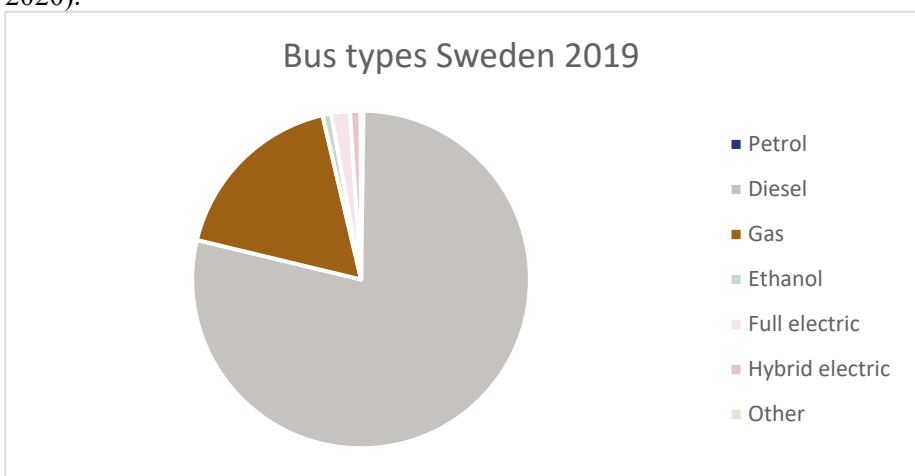

Figure 2 Bus types in the Swedish bus fleet in 2019 (The Swedish Bus and Coach Federation, 2020).

However, Sweden is quite exceptional in its use of biofuel. It is therefore of interest to look at vehicle kilometres operated on renewable fuel. It can be seen that most diesel buses run on biodiesel and most gas buses on biogas. In 2020, over 90% of vehicle kilometres in the public transport sector were run on renewable fuel, primarily biofuel. The transition to renewable fuel happened quickly in Sweden and over the last ten years, many regions have gone from being fossil fuel dependent to using almost only renewable fuel. Figure 3 shows the changes between 2010 and 2020 (The Swedish Public Transport Association, 2021). Biodiesel has been the main contributor to the shift away from fossil diesel and in more recent years, HVO in particular. The second most common fuel is biogas. It is interesting to note how HVO increases quickly from one year to the next, while biogas increases slowly but steadily over an extended period. Electric buses still make up a small share of the bus fleet: only 2.7% in 2020 (The Swedish Public Transport Association, 2021). Nevertheless, much has happened in recent years. In a report from 2016, most electric buses were seen to be part of test projects (Aldenius *et al.*, 2016), while in 2019, electric buses in commercial service had increased considerably (Lundström *et al.*, 2019).

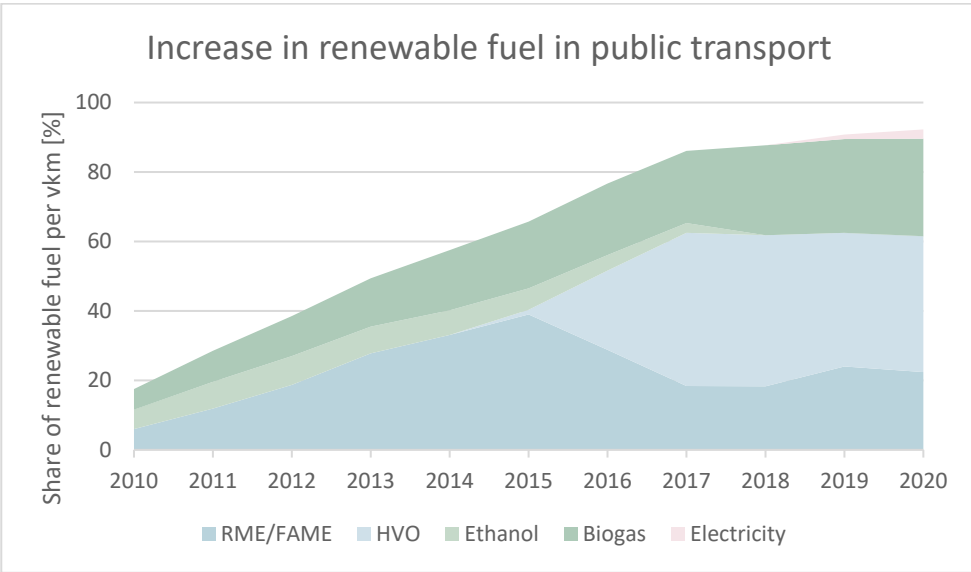

Figure 3 The increase in renewable fuel in Swedish public bus transport between 2010 and 2020 measured in terms of share of renewable fuel per vehicle kilometre (vkm) (The Swedish Public Transport Association, 2021).

The type of renewable fuel varies across regions and the situation in 2020 can be seen in figure 4. All the regions use biodiesel to some extent, although while some use almost only biodiesel, a few regions, for example, Skåne and Västmanland, operate most of their fleets on biogas (The Swedish Public Transport Association, 2021).

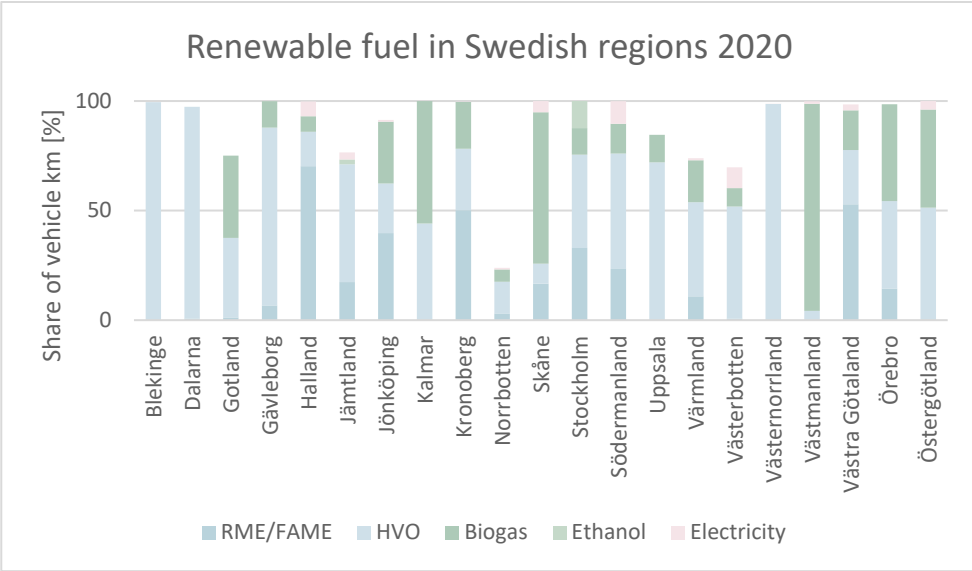

Figure 4 Share and type of renewable fuel in Swedish public transport regions in 2020. Please note the following regions have a high share of missing information: Norrbotten, Jämtland, Gotland, Värmland, Västerbotten. Stockholm's latest reported information is from 2017 (The Swedish Public Transport Association, 2021).

To summarise, in much of Europe, most buses still run on fossil diesel, although renewable fuel has been increasing in the later years. Sweden has progressed quite far in the shift away from fossil fuel, particularly through the use of biofuel, which is higher than in most other countries. However, regarding the introduction of electric buses, Sweden has not come further than the rest of Europe. It is also important to highlight that there are different benefits and challenges, depending on which type of renewable fuel is introduced. Thus, it is important to the motivation for the introduction of renewable fuel and the kind of resources that are available.

In many countries, strategic decisions concerning public transport are made on the regional and local levels (see section 2.3). Nevertheless, the EU and national level can also put pressure on countries to introduce renewable fuel, which is discussed in the next section.

2.2 Policy setting for renewable fuel in the public transport sector

The motivation to introduce renewable fuel in EU countries is influenced by targets, directives and policy instruments on both an EU and national level. Few targets and directives are directly aiming at renewable fuel in the public transport sector, but

public transport has an important role to play in fulfilling the targets and directives for climate, energy and the environment. In this section, I will describe the possibilities for the EU level and Swedish national level to influence the introduction of renewable fuel.

2.2.1 Targets and directives at the EU level

The EU can primarily influence regional decisions regarding the introduction of renewable fuel in the public transport sector indirectly through targets and directives that influence policy instruments and regulations on the national level. This includes overall climate targets such as the European Green Deal (COM/2019/640) and the Paris Agreement, in which the EU aims to be climate neutral with net-zero GHG emissions by 2050. The overarching targets put GHG emission reduction high on the political agenda, but there are also targets for the share of renewable energy and improved energy efficiency for 2030 (European Council, 2014). The introduction of renewable fuel in the public transport sector can also be seen as a way of contributing to the broader sustainability goals in Agenda 2030, for example, *Sustainable cities and communities* and *Climate action* (United Nations, no date).

The most relevant directive for the introduction of renewable fuel is the EU's Renewable Energy Directive (Directive (EU) 2018/2001), which provides a framework for how to define biofuels. Energy savings through the introduction of renewable fuel in transport is also taken into account when achieving overall obligations for energy savings in the Energy Efficiency Directive (Directive (EU) 2018/2002). Also, the EU's noise regulations (540/2014) can influence choices by specifying a maximum noise level. These regulations have, for example, influenced the recommended environmental requirements for noise pollution for public transport in Sweden. The development of policy instruments on the national level has also been influenced by the EU's regulations on state aid and competition (Regulation No. 651/2014). In Sweden, for example, the regulations have influenced the long-term planning for tax exemptions for biofuels.

In cases in which public procurement is the main way of organising the public transport sector, the authorities also have to comply with EU directives concerning procurement. For the procurement of the public transport sector, the two most important directives are Directive 2014/24/EU on procurement and Directive 2014/25/EU on procurement by entities operating in the water, energy, transport, and postal service sectors. These directives regulate how criteria can be set and that such criteria must comply with the guiding principles of the free movement of goods and services and freedom of establishment, non-discrimination and equal treatment, transparency, proportionality and mutual recognition.

The new EU directive for clean and energy-efficient road transport vehicles (Directive 2019/1161) is very interesting for public transport procured in the future

and affects the introduction of renewable fuel from 2021 onwards. This directive contains specific environmental targets for the procurement of buses. Between 2021 and 2026, the member state targets vary between a 24% and 45% share of buses running on renewable fuel. After 2026, the targets have been set between 33% and 65% of buses running on renewable fuel. For Sweden, the higher targets apply. In addition, 50% of the share should be fulfilled by procuring zero-emission buses (buses with no exhaust emissions). Clean buses are defined as buses that run on renewable fuel included in the alternative fuel infrastructure directive (2014/94/EU) (hydrogen, battery electric (including plug-in hybrids), natural gas (both CNG and LNG, including biogas), liquid biofuel, synthetic and paraffinic fuel, LPG). Zero-emission buses go beyond the directive and take into account air pollution. Since Directive (2019/1161) includes targets from 2021 forward, it has had little relevance to the developments studied in this thesis, but will be highly relevant going forward.

This section has shown that thus far, the EU has primarily influenced the introduction of renewable fuel in the public transport sector indirectly through directives that regulate renewable fuel, the use of public procurement and state aid rules. In the next section, I will describe how Sweden has chosen to set targets and regulate the introduction of fuel through laws and policy instruments.

2.2.2 Policy instruments, targets and directives at the Swedish national level

The primary framework in Sweden for addressing climate issues is the climate policy framework (Prop. 2016/17:146). The framework includes both a climate act (Klimatlag (2017:720) and climate goals. The goals include an overall climate target of zero net GHG emissions by 2045. For transport in particular, the target is to have a vehicle fleet that is independent of fossil fuel by 2030 (Government Offices, 2017). The transport sector must also contribute to Swedish environmental quality objectives. Perhaps most relevant is the objective *Reduced climate impact* in which improved energy efficiency and the introduction of renewable fuel are important measures. However, decreasing air pollution and noise can also contribute to objectives related to health, such as *Clean air* and *A good built environment* (Prop. 2008/09:93). Regarding laws and regulations, Sweden has also developed a procurement law in accordance with the EU procurement directives: the Swedish Public Procurement Act (2016:1145).

The most direct way that the national level in Sweden influences choices made on the regional level concerning the introduction of renewable fuel in the public transport sector is through policy instruments and funding. The primary policy instrument in Sweden is tax exemption for renewable fuel, although there are also policy instruments that specifically target one type of fuel or support infrastructure development. In Sweden, petrol and diesel are taxed through a carbon dioxide and

energy tax. The total tax in 2019 was around 36% (49% including VAT) of the total consumer price of diesel. The Swedish carbon dioxide tax is the highest in the world, but the total tax on fuel is higher in some countries such as the UK, Switzerland and The Netherlands (Johansson, 2021). Pure or high blends of biofuel are exempted from energy and carbon tax, allowing them to compete with fossil fuel on the market (The Swedish Tax Agency, 2021). This could significantly impact the type of renewable fuel that is the outcome of the tender process for public transport, since tenders are often evaluated based on the lowest bid (also see section 2.4). However, tax exemption has to be approved by EU state aid rules and the uncertainties regarding whether the EU will approve the tax exemption has sometimes made it difficult to formulate long-term strategies (Johansson, 2021). In recent years, these rules have affected, for example, the investment in biogas. However, in 2020, a ten-year extension to the tax exemption for biogas (2021–2030) was approved by the European Commission (2020a).

There are also policy instruments that support specific fuels either directly or indirectly. In 2016, a subsidy focusing specifically on electric buses was introduced, called the *Electric Bus Premium* (Elbusspremien). The Electric Bus Premium enabled PTAs and municipalities to apply for funding for investments in battery electric buses and plug-in hybrids (SFS 2016:836). The premium was updated in 2018 so that operators could also apply and the potential funding was raised to 20% of the investment cost, and at the same time it paved the way for fuel cell buses. However, it was still not possible to receive funding for charging infrastructure in the Electric Bus Premium (SFS 2017:1341). Also, having policy instruments directed at biogas is exceptional in Sweden compared to other countries. In many countries, policy instruments are primarily directed at biogas production, whereas in Sweden, tax exemption on biofuel supports the use of biogas in the transport sector (The Swedish Tax Agency, 2021).

Other policy instruments support sustainable investments on the regional and local levels. *The urban environmental agreements* (Stadsmiljöavtalen) and the *Climate Leap* (Klimatklivet) allow regions, municipalities and cities to apply for funding, for example, to support investments in fuel and charging infrastructure. The purpose of the urban environmental agreements is to identify more effective solutions that contribute to lower GHG emissions and to the Swedish environmental quality objective *A good built environment*. Test projects for new transport solutions and charging infrastructure for electric buses are examples of measures that can get funding (Regulation 2015:579). The Climate Leap does not specifically aim at funding transport solutions. Instead, the focus is on physical investments with major benefits for the climate. Apart from regions and municipalities, companies and other organisations can also apply. Both charging infrastructure for electric vehicles and biogas fuelling infrastructure have been built with support from The Climate Leap (The Swedish Environmental Protection Agency, 2021).

Apart from government initiatives, targets have also been set in the public transport sector by a partner co-operation comprising both the public transport industry and public authorities[4]. These targets are more ambitious than for the rest of the transport sector and have had a large influence on introduction of renewable fuel in procured public transport. The targets are described in an environmental programme and the latest updated version was published in 2018 (Partnership for improved public transport, no date). However, the targets in previous versions have influenced the decisions on fuel choice studied in this thesis. In Table 3, the targets from the 2010, 2013 and 2018 versions of the environmental programme are presented. Apart from targets becoming increasingly more stringent in all areas, the climate target has gone from focusing on increasing the share of renewable fuel to decreasing CO_2 emissions per person kilometre (Partnership for improved public transport, 2010a, 2013, 2018a). The targets have been particularly important for the procurement of public transport since it has influenced environmental sector standards for proposals on how to set environmental requirements in Swedish tender documents. The guidelines contain proposals for functional technical requirements for fuel, energy use, air pollution and noise pollution. Most of the recommended requirements are divided into minimum, base and extended requirements (The Swedish Public Transport Association, 2009; Partnership for improved public transport, 2010b, 2011, 2014, 2018b). Examples of how these technical requirements can be expressed are given in section 2.4.

To summarise, targets in both the EU and Sweden primarily focus on reducing GHG emissions although some targets are directed at the introduction of renewable fuel in the public transport sector. There are also directives and laws regulating renewable fuel and public procurement. However, the most concrete influence on the Swedish national level is through policy instruments such as tax exemption for renewable fuel and funding of investment costs for buses and charging and fuelling infrastructure. Also, the environmental targets set for public transport within the sector itself are influential in Sweden. These targets have largely influenced the recommendations for environmental requirements in public procurement. This is closely related to how the public transport sector is organised in Sweden. Further details about what the organisation of the public transport sector means to the introduction of renewable fuel will be presented in the next section.

[4] A partner co-operation between the Swedish Public Transport Association, the Swedish Bus and Coach Federation, the Association of Swedish Train Operating Companies, the Swedish Association of Local Authorities and Regions (SALAR) and the government-owned company Jernhusen.

Table 3 Targets in the environmental programme 2010 (Partnership for improved public transport, 2010a), 2013 (Partnership for improved public transport, 2013) and 2018 (Partnership for improved public transport, 2018a). For the climate and energy target 2018, the targets are for all modes of public transport, but separate targets have also been formulated for each mode and fuel. Pkm stands for person kilometre and vkm for vehicle kilometre.

	2010	2013	2018
Climate target	At least 90% of passenger transport should use fossil free energy by 2020.	Net emissions of CO2 should be a maximum of 8 gram/pkm in 2025.	CO2 emissions (Well-to-wheel)) in gCO_2/pkm, decrease compared to 2016. 2025: 15 (-40%) 2030: 7 (-70%)
Energy target	Public transport should use 2% less energy per pkm in 2020 compared to 2007.	Energy use in public transport should be a maximum of 0.15 kWh/pkm in 2025.	Energy use (in vehicle) in kWh/pkm should decrease compared to 2016. 2025: 0.2 (-25%) 2030: 0.16 (-40%)
Air quality target	Emissions of NOx and particles per pkm should decrease by at least 50% from 2009 to 2020.	For buses in 2025, the average emissions per vkm should be 1 g/kWh for NOx and 0.015 g/kWh for particles.	NOx (g/kWh): 2016: 1.8, 2025 0.7, 2030: 0.3 Particles (mg/kWh): 2016: 10.5, 2025 8.0, 2030: 7.0
Noise target	Noise from public transport should decrease.	Noise from public transport should decrease.	Share of electrification in urban traffic: 2025: 30%, 2030: 50% Average kilometre value for outside noise from vehicles: 2025: -2dB, 2030: -3 dB

2.3 Organisation of responsibilities in the public transport sector

In the previous section, the influence of the policy settings on the EU and Swedish national level was discussed. Targets, directives and policy instruments can be seen as the national government's main way of influencing the public transport sector, since the main responsibility for public transport in many countries is on the regional and local levels. In many cases, private stakeholders are also involved in operating buses. Depending on how the public transport sector is organised, the responsibility for introducing renewable fuel can fall upon different stakeholders. To understand the practices learned from my studies of the Swedish introduction of renewable fuel, it is important to understand the conditions for the introduction of renewable fuel in the public transport sector. Thus, in this section I present an overview of how the public transport sector can be organised and what this means for the distribution of responsibility between the public and private sector. The section also contains a part that specifically focuses on the organisation of the public transport sector in Sweden to show the prerequisites under which the papers were written.

Van De Velde (1999), categorises the organisation of the supply of public transport in Europe into two groups: *authority initiative* and *market initiative* (figure 5). In an authority initiative regime, the PTA has the legal monopoly of initiative and all market entry is based on an authority initiative. In an authority initiative regime, a distinction can be made between public ownership and private concessions. Public ownership can either be through public management in which vehicles are run and owned by the authority or a public company at arm's length, or by delegating the management of public assets to a private operator (for example, through tendering). In private concessions, a private company is selected by the PTA (for example, through tendering) to operate public transport services (usually the entire transport network). The vehicles and infrastructure are often owned by the private company. In a market initiative regime, the supply of a transport service is based on autonomous market entry via a more or less regulated market process. In the case of market initiative with open entry, private operators have the option to operate a bus service if it is considered profitable, while in regulated authorisations, private operators have to apply for authorisation before operating a service, which gives the authority the option to decide which, how many and under what conditions operators enter the market. Competitive tendering can be used in all types of organisational forms for all or parts of the service (Van De Velde, 1999).

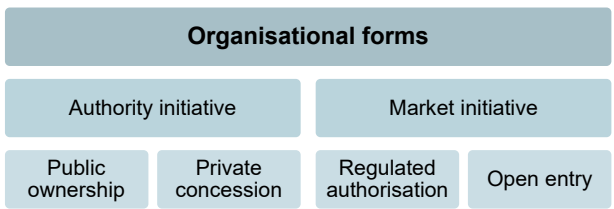

Figure 5. Organisational forms for public transport based on Van De Velde (1999)

The organisational forms in figure 5 is a way to categorise the broad spectrum of ways to organise the public transport sector. However, most countries combine various ways of organisational forms. In this thesis, the categorisation will be used as a way to place Swedish organisation of the public transport sector in relation to other countries, as well as a way to compare the main differences for the introduction of renewable fuel regarding who is responsible for planning and operation.

Thus, my main interest in this thesis is in what organisation means for the distribution of responsibility between the public and private sector. Van De Velde (1999) identified three main areas of responsibility that can be distributed differently between public and private stakeholders: strategic planning and objectives, tactical planning of services, and operation. *Strategic responsibilities* concern the question 'What do we want to achieve?' This includes setting long-term goals for market share, profitability and the environment, for example. For the introduction of

renewable fuel it can mean setting targets for GHG reduction, air pollution or the share of renewable fuel. Depending on whether strategic responsibilities are with the public or private sector motivations often varies. Public authorities are often motivated by broader societal benefits, whereas the private sector is often motivated by economic profitability. *Tactical responsibilities* concern which services can help achieve the goals. This includes more detailed service characteristics such as route design, timetabling, fares and pricing. Route design and timetabling in particular will be seen to influence the possibilities to introduce electric buses. The party responsible for tactical planning is highly dependent on the organisational form. Lastly, there are *operational responsibilities* concerning how the services are to be produced.

In this thesis, the focus is on organisation based on authority initiatives, primarily private concessions through the competitive tendering of transport services, in which regional PTAs are responsible for strategic planning and private operators are responsible for operation, while tactical responsibilities can be specified in the procurement contract. Unless otherwise stated, competitive tendering discussed in this thesis takes place in an organisational form that resembles private concessions. However, cases of public ownership through public or delegated management are also discussed. The introduction of renewable fuel in the public transport sector based on market initiatives has not been studied, although the lack of electric buses when organisation is based on open market entry is mentioned in paper IV. To put the Swedish way of organising the public transport sector in perspective, an overview of organisation in Europe is provided in the next section.

2.3.1 Organisation of public transport in Europe

The pure organisational forms described above are very rare. Instead, intermediate ways are often seen in countries and several organisational forms can exist within one area (Van De Velde, 1999). The most common way of organising public transport globally has changed over the last century. In the early 20th century, private planning and operation were most common. After the 2nd World War, organisation shifted in many countries and public authorities took over the planning and operation of public transport. However, in the 1980s, many countries started to open up for re-entry of the private sector to address, for example, rising costs and increase the attractiveness of public transport. This has meant that a common organisational form is for planning to be the responsibility of public authorities, while operation is carried out by the private sector. Public authority responsibility can be at different levels of governance. Over time it has moved from the national to the regional or local level in many countries in order to better respond to local needs, give better value for money and increase transparency (International Transport Forum, 2020). Below are examples of how the public transport sector is organised in some European countries.

The re-entry of the private sector took place in multiple ways in European countries, from tendering of operations to deregulation, meaning operation of bus services have been left to the private sector, while strategic and tactical planning powers have been retained by public authorities to varying degrees. For example, in London tendering of bus services to private operators commenced in the late 1980s and today all bus services in London are tendered. Barcelona provides an example of a mixed system in which parts of the public transport services are publicly managed while other public transport services are tendered out to a varying degree (International Transport Forum, 2020). In Germany, the municipalities are often responsible for local public transport and a combination of public operators and tendered private operators operate the bus services (Rye *et al.*, 2018). In The Netherlands, regional authorities often tender out both the planning and operation of bus services to private operators (International Transport Forum, 2020). Nevertheless, even though authority initiatives is the dominant form in Europe, elements of market initiatives also exist and have been growing in some countries. Sweden and Germany are examples of countries in which transport laws have paved the way for the possibility of deregulation, although it has been realised to a small extent in local bus transport. It is primarily in the UK outside London that open market entry has been the dominant form. Looking beyond local transport, a large proportion of long-distance coach operations in Europe has been deregulated (van de Velde, 2014). Nevertheless, in traditionally deregulated markets, public authorities are also being seen to take back some of the control. For example, in the UK, a new Bus Service Act came into force in 2017, which allows for combined authorities to tender bus services similarly to how this takes place in London (Butcher and Dempsey, 2018). For further information on the UK, see paper IV in this thesis.

As can be seen, public transport in Europe comprises a mix of organisational forms. The variations of organisational approaches can be seen on the country level and sometimes even on the municipal level, combinations of public and private regulation co-exist. Competitive tendering has been a growing trend in Europe, but is still not the dominant form in most countries. Competitive tendering can manifest in different ways and be used in various organisational forms. It can include tendering for single bus routes or whole network services, leave more or less freedom of service design to the operator, contain different awarding procedures, and different contractual specifications and incentive mechanisms. Competitive tendering as an environmental policy tool for regional authorities will be described in more detail in section 2.4 since it is the dominant way in Sweden of distributing responsibility across the public and private sector (van de Velde, 2008).

In Sweden, competitive tendering is currently dominating in regional and local public transport even though a few cities and regions have retained public management, while long-distance buses and railway services has been deregulated to a larger extent and open market entry is the dominant form (van de Velde and Wallis, 2013). However, since 2012, the deregulation of local bus transport has also

been allowed. In the next section, I will cover the development of Swedish organisation of the public transport sector in more detail.

2.3.2 The Swedish public transport market – development, responsibilities and the current market

Before 1960, market initiatives were the predominant form of public transport organisation in Sweden, either by public or private operators, depending on local circumstances (Ringqvist, 2016). After the 1960s, the share of subsidising taxes gradually increased, giving increasing control to the public sector. The first national legislation on public sector responsibility for regional public transport was introduced in 1978. However, in 1989, public transport operation in Sweden opened up for competitive tendering, leaving a rather large role to the market and, since the mid-1990s, competitive tendering has been the main way of organising the public transport sector (The Swedish Confederation of Transport Enterprises, no date). In 2012, a new Public Transport Act (2010:1065) was introduced. The act allows for the deregulation of the public transport sector, which enabled open market entry for private operators (SFS 2010:1065). However, thus far, this has been realised to a limited extent in Sweden (Transport Analysis, 2015). There are also a few cases in Sweden in which public transport is both planned and operated by the public authorities. Currently, 90% of the bus market in Sweden is publicly procured – whereby regions are responsible for strategic planning but contract out operations to private operators. Tactical responsibilities are defined in the contracts and the operators can be given different degrees of freedom (The Swedish Bus and Coach Federation, 2019b).

The Public Transport Act (2010:1065) also stipulates that every region has to have its own PTA comprising the county, municipalities or a combination of both. Sweden has 21 regions and 290 municipalities (Swedish Association of Local Authorities and Regions, 2021). The responsibility of the PTAs includes responsibility for the strategic long-term decisions in their regions. The strategies should be reported through a mandatory regional transport supply programme covering targets for both commercial and contracted public transport services. The transport supply programme should, for example, include *measures to protect the environment* (SFS 2010:1065, chapter 2 §8). The purpose of transport supply programmes is also to ensure that public transport contributes to reaching the overall societal environmental goals and they should be based on the transport political targets and other national, regional and local targets, plans and programmes of interest for a sustainable development and growth (Prop. 2009/10:200, p. 47). The decisions are, of course, influenced by national regulations and policy instruments, but the PTAs are given much freedom to set their own goals in the transport supply programmes.

The regions are also responsible for regional development according to law (2010:630) which means, for example, they need to promote a better environment,

decrease climate impact and support the energy transition. This should be established in a regional development strategy. Municipalities are responsible for community services such as schools, local land use and transport planning, environment and health, but also partially for public transport together with the regions. Historically, local municipalities in Sweden have great influence over detailed and comprehensive land use planning. In terms of public transport, this can affect, for example, bus depots and charging infrastructure in urban areas (Swedish Association of Local Authorities and Regions, 2021).

As mentioned above, most public transport in Sweden today is procured from private operators by the PTAs. The three largest PTAs (in the areas of Stockholm, Västra Götaland and Skåne) accounted for around 50% of the supply in 2019 (Transport Analysis, 2020). Another significant difference can be seen regarding the size of procurements, which can vary from one to over 300 buses. The reasons for larger procurements were economy of scale, while smaller procurements were a way to foster competition. In 2015, buses were operated by 68 private operators, which varied in size although over 80% were operated by the ten largest operators (Transport Analysis, 2018). Contracts in the Swedish bus sector commonly last for eight years (WSP, 2014), although a trend towards longer contracts has been noted (Dickinson and Wretstrand, 2015). The total cost of public transport in Sweden in 2019 was SEK 51 billion, of which around 50% came from revenues and the rest was funded by subsidies (county funding 92%, municipal funding 6%, state funding 2%) (Transport Analysis, 2020).

To summarise, there are few countries in which the responsibilities for planning and operation lie solely with either the public or private sector. Many countries have a mix of organisational forms, which is also the case in Sweden. However, it is becoming increasingly commonplace for regional and local authorities to be responsible for strategic planning, but let the private sector operate the bus services. Sweden is a typical example of how this can be done through public procurement. How public procurement can be used to promote the introduction of renewable fuel will be covered in the next section on GPP.

2.4 Green public procurement

The previous section highlighted that competitive tendering can be used in all types of organisational forms. In this section, I will focus on private concessions in which PTAs are responsible for strategic planning but contract out operations to private operators. Responsibility for tactical planning can vary across contracts. Competitive tendering is the main way of delivering public transport in Sweden and is therefore central in this thesis. Competitive tendering is also interesting as it has become increasingly common in the rest of Europe in recent years (International

Transport Forum, 2020). Thus, the rest of this section will be devoted to public procurement and how it can be used to introduce renewable fuel. First, I will describe the process of procurement in the Swedish public transport sector. The potential to use public procurement to support the introduction of renewable fuel in the public transport sector is then discussed, with a focus on which type of criteria can be used. When environmental criteria are included in public procurement, it is often called *Green Public Procurement* (GPP). GPP is defined by the European Commission in Communication (COM (2008) 400, p. 5) as:

> A process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured.

In some studies, the term *Sustainable Public Procurement* (SPP) is used. However, per definition, this also includes social and economic sustainability, which will not be a focus of this thesis. In the next chapter, in section 3.1, I will go into more detail about the research conducted on the challenges and opportunities with the use of GPP, but also include relevant input from research on SPP.

The potential for GPP to contribute to environmental goals is particularly high in sectors in which a large share of the market is represented by public purchasers, which is true for the public transport sector (European Commission, 2016b). To better understand how different GPP criterion can be included in the procurement process, I will first describe the process of procuring public buses in Sweden, based on Lidestam, Johansson and Pydokke (2016) (figure 6). Procurement is a stepwise process, spanning several years. First, there is an announcement and meeting with interested parties and a needs assessment is conducted. Approximately one year later, the tender documents are presented with the technical specifications and the potential operators are allowed to ask questions – this must be an open process so that everyone receives the same information. Approximately one year after the tender document has been presented, the tenders should be submitted. The tenders are confidential. This is followed by the award stage with an evaluation of the tenders. How the tenders are evaluated and what is evaluated must have been clearly specified from the outset. After the decision has been made, there is a possibility to appeal. Often, services will commence one year after the decision has been made and then a contract will be entered into for a period of 8–12 years.

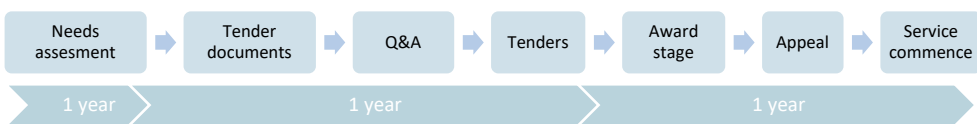

Figure 6 Procurement process of buses based on Lidestam, Johansson and Pydokke (2016).

Several of these stages can be important in the GPP process. For the public transport sector in Sweden, the focus is often on environmental criteria expressed as technical specifications. Thus, this is the focus of this thesis. However, there are more ways to use GPP. Apart from how technical specifications can be expressed in the form of environmental requirements, this section also contains a description on how award criteria, selection criteria or contract performance clauses can be used.

Technical specifications are specified in the tender document and are minimum compliances to be met by all tenders. Tenders that do not meet the requirements must be rejected and it is therefore very important that the technical specifications are equally clear and understandable to all tenderers (European Commission, 2016b). The requirements can be expressed either as functional or specific requirements. Functional requirements are expressed as a functional- or performance-based definition describing the desired results, the expected output, and how it will be measured (Quintero *et al.*, 2019). Functional requirements for public transport can, for example, be set as a desired reduction in GHG or air pollution, or as a lowest level for share of renewable fuel. This way of setting requirements means the operator has to propose the most appropriate solution. By using specific requirements instead, the public authority assumes greater responsibility. Specific requirements describe the desired product, for example, by specifying which renewable fuel or fuel- or charging technology should be used. The EU has developed GPP criteria for different sectors, including road transport, which contains a section for bus services. They contain proposals for technical specifications, both core (focus on easy application and low costs) and comprehensive (for authorities wanting to go further in supporting the environment and innovation) criteria including GHG, fuel, air pollutant, tyre pressure and rolling resistance (European Commission, 2019). However, in Sweden, a partner co-operation in the public transport sector has also developed its own guidelines for environmental technical specifications (The Swedish Public Transport Association, no date).

Award criteria are a way of stimulating environmental performance without using statutory requirements. These type of criteria are a possibility to keep the tender process open for bids that might not have reached the level of performance required by technical specifications. Award criteria can be useful if the authority is unsure about the costs or market availability of a product. Award criteria can also be used with advantage together with a minimum level of technical specifications (European Commission, 2016b). All contracts must be awarded on the basis of the most economically advantageous tender (MEAT) according to Directive 2014/24/EU. At the award stage, the authority evaluates the costs together with predetermined factors. The award criteria are then weighted and scored so that tenders offering better environmental performance can be awarded higher points (Quintero *et al.*, 2019). Award criteria proposed by the European Commission (2019) include higher points when the tenderers offer bus fleets composed of vehicles equipped with a

desired vehicles technology, for example by setting a percentage for the procured service or specifying a vehicle technology for a predefined route.

A *contract performance clause,* like technical specifications and award criteria, is associated with the procured product. However, it is monitored during the execution of the contract and not during the procurement process and can entail penalties or bonuses (Quintero *et al.*, 2019). An example could be a clause stating that when vehicles are replaced, the new vehicles must contribute to improvement in terms of GHG emissions and air pollution (European Commission, 2019). *Selection criteria* differ from the other described ways to use GPP by referring to the tenderer instead of the product (Quintero *et al.*, 2019). Selection criteria often relate to technical or professional ability, e.g. experience of and resources for environmental management systems (European Commission, 2016b).

To summarise, the regional authority can have a strong influence on the introduction of renewable fuel in the public transport sector by including environmental criteria in the procurement process, for example, through technical specifications in the tender documents, award criteria in the award stage or by including a contract performance clause that comes into effect during the execution of the contract. Environmental criteria often concern the use phase, such as GHG emissions, air pollutant emissions and noise pollution. However, it can also concern the production of the energy carrier or vehicle manufacturing (Quintero *et al.*, 2019). How regional authorities choose to express technical specifications or what solution is favoured in the award stage can also be influenced by policy instruments on the national level, such as carbon dioxide, energy taxation, funding of vehicles, fuel production and infrastructure.

The focus of this chapter has been on presenting the background to the field in which my studies were conducted. In the discussion section, I will further discuss the implications of the findings from my papers in relation to the differences between type of renewable fuel, organisational approach and contextual factors. In the next chapter, I will present the fields of research related to the research in my thesis.

3 The field of research

This thesis primarily contributes to research in two fields: research on green public procurement (GPP) and the empirical field of renewable fuel in the public transport sector. In this chapter, I will present relevant research in these two fields to illustrate the research gap that this thesis is addressing. This chapter presents research published both before and after my papers were published. The research will be further discussed in relation to the findings from my papers in the discussion section in Chapter 6.

3.1 Research on green public procurement

The literature on GPP has played a fundamental role for the research in this thesis and has played a crucial role in three of the included research papers (papers I, II and III). Literature on SPP is also included in cases when the focus is on the environment, but will be referred to as *GPP* when general conclusions are drawn in this section. In section 2.4, the practical use of GPP was described. In this section, the focus is on how research discusses the challenges and opportunities of GPP. For further details on the identified factors, I refer to papers I, II and III.

Since most public transport in Sweden is organised based on competitive tendering between public authorities and private operators, public procurement significantly influences the introduction of renewable fuel. Nevertheless, until recently, almost no papers focused on the use of GPP in the public transport sector (Cheng *et al.*, 2018; Chersan *et al.*, 2020). This lack of research can be regarded as quite surprising considering that public transport has long been identified as a sector with a great potential to use GPP (European Commission, 2004; Preuss, 2007; von Oelreich and Philp, 2013; European Commission, 2016a; Quintero *et al.*, 2019). However, in recent years, some studies on the introduction of renewable fuel conducted primarily in Sweden and The Netherlands discuss the potential of using GPP. These studies are presented together with research on renewable fuel in section 3.2. A need for further best practice studies is also identified by Chersan *et al.* (2020).

GPP literature focusing on challenges in the uptake of GPP plays a particularly important role in my research. A focus on challenges is relatively common in GPP literature and quite a large branch of research uses qualitative methods to analyse

the challenges for the uptake of GPP in general (Cheng *et al.*, 2018). This research helped to identify the most common factors influencing the uptake of GPP, which were used as the basis for the analysis in my first paper. These factors include cost, strategy and goals, size, knowledge, information and collaboration, as well as requirements. Recent review papers of GPP literature by Cheng et al. (2018) and Chersan et al. (2020) draw similar conclusions regarding which challenges are most commonly identified as influencing the uptake of GPP. Below, I summarise the literature on GPP that inspired the choice of factors analysed in my papers. Since the way in which requirements can be set is covered to a large extent in section 2.4 and literature comparing the different ways to set requirements is scarce, it has not been assigned its own heading below. Instead, the challenges of requirements are included in the other factors. The review of factors is complemented by more recent research published after my papers were written. The more recent research seems to draw similar conclusions to previous findings, and primarily provides further examples of how the factors affect the uptake of GPP.

3.1.1 Cost factor

The *cost* factor is often the first challenge to be considered regarding environmental products. It is studied in both papers I and II and is also commonly discussed in previous research on GPP. Several papers identify higher costs, or the fear thereof, as one of the main barriers to the inclusion of environmental requirements in tenders (Preuss, 2007; Walker and Brammer, 2009; Brammer and Walker, 2011; Günther *et al.*, 2013; von Oelreich and Philp, 2013). Research on public transport in Sweden specifically states that more detailed technical specifications in contracts can increased costs, were environmental requirements are one example (Vigren, 2015; Lidestam, Johansson and Pydokke, 2016). However, Preuss (2009) shows that although costs can be a challenge in association with environmental requirements, it is not always the case. Marron (2003) argues that when the use of GPP leads to a higher cost it must be carefully evaluated whether such a cost is justified. Thus, the author argues that it is important to look at both the direct and indirect effects. The same studies claim that GPP can be an effective tool when used in combination with other policy instruments (Marron, 2003).

In a new study, Wendt-Rasch *et al.* (2021) confirm that fear of increased costs relating to setting environmental requirements can be a barrier. However, not all stakeholders regard costs as a constraint. Further, the study finds that the goal of cost efficient procurement contracts can be in conflict with political requests for more environmental requirements, when the requests do not include an increased budget (Wendt-Rasch *et al.*, 2021). There is also an ongoing discussion, particularly within economic literature, as to whether GPP is an effective environmental policy instrument (Marron, 1997; Lundberg and Marklund, 2013, 2018; Lundberg, Marklund and Strömbäck, 2016). However, there is a lack of empirical research on

how the inclusion of environmental requirements impacts cost effectiveness. See paper I for a further discussion on the effectiveness of GPP.

3.1.2 Strategy and goals

The influence of regional strategies are in focus in this thesis. However, depending on the sector studied, the importance of *strategies and goals* can concern different levels of governance or top management in a company. A study by Brammer and Walker (2011) compares SPP in 20 countries and concludes that national leadership support has a large influence on the extent to which sustainable procurement is incorporated in planning strategies and target settings. Another study compares the uptake of SPP in local authorities in England and shows that the lack of a strategic approach to sustainability is a barrier to SPP in almost all authorities (Preuss, 2007). On a company level, Walker and Brammer (2009) conclude that the main driver for including SPP is supportive top management within a company, creating a positive climate and attitude towards sustainability. This importance of political and management support is also confirmed in a new study of green chemical requirements in Swedish municipalities, where the lack thereof is listed as one of the main barriers (Wendt-Rasch *et al.*, 2021).

3.1.3 Influence of size

The influence of *size* is mainly considered in two ways in my papers. In paper I and II, I focus on the comparison of regional size in terms of bus fleet and population density. In paper III, the focus is on the size of the procurement contract in terms of procured vehicle kilometres. Previous research has also studied the influence of size on the uptake of GPP. Michelsen and de Boer (2009) compare Norwegian municipalities and noted that GPP is more established in larger municipalities. Here, the importance of strategies explains why larger municipalities develop effective GPP (Michelsen and de Boer, 2009). Testa *et al.* (2012) speculate whether the reason that smaller authorities face higher barriers is a question of economic resources or the ability to define the responsibilities, roles and functions of an organisation to address GPP challenges. Marron (2003) claims that the potential of GPP is higher when more products are purchased. Previous literature also highlights collaboration between organisations and authorities as a way of increasing the amount of procured goods and enable a more ambitious use of GPP (Marron, 2003; Michelsen and de Boer, 2009; Ottander and Söderström, 2005). In more recent research, the discussion of the importance of size continues. Rosell (2021) analyses the importance of size on a macro and meso level in relation to GPP adoption factors regarding award criteria in European countries between 2006 and 2017. The results show that GPP uptake has increased over time and that larger and more developed countries, larger contracts, joint procurement and higher value contracts are more

likely to include GPP. The results further show that the level of development within a sector, type of contract (purchase contracts are more likely to include award criteria than service contracts) and level of authority (regional and local authorities are more likely to adopt GPP) affect the likelihood of adopting GPP (Rosell, 2021). Also, a case study of GPP at the local, regional and provincial levels in Spain based on quantitative data shows that environmental criteria are more common when the project budget is larger (Fuentes-Bargues *et al.*, 2019). Another study studying what influences the adoption of green award criteria in public contracts in European countries shows that higher contract values and joint procurements are found to correlate with greener contracts (Yu, Morotomi and Yu, 2020).

3.1.4 Knowledge, information and collaboration

The importance of *knowledge, information and collaboration* is discussed in both papers I, II and IV in this thesis, particularly in relation to the choice of setting functional or specific environmental requirements. Also, in previous literature, the need to increase knowledge, information and collaboration is regarded as important. The literature contains several proposals on how knowledge should be increased. For example, increased collaboration between procurers and suppliers (Witjes and Lozano, 2016), guidance and the clear definition of sustainability in the selection of criteria (Bratt *et al.*, 2013), the adoption of guidelines, intensive training and raising the awareness of purchasers and teaching them to adopt a new mind set for evaluating environmental performance (Testa *et al.*, 2016). On a national level this can mean guidance and templates for GPP is provided by national authorities (Michelsen and de Boer, 2009), while Testa *et al.* (2012) state that the EU and national level should focus instead on raising awareness and know-how than on toolboxes and guidelines. In contrast, a study comparing the uptake of SPP in several countries did not find that a lack of supplier availability or knowledge/awareness issues are seen to influence the engagement with SPP (Brammer and Walker, 2011). However, new research continues to highlight lack of knowledge, lack of tools and training and insufficient communication between procurers and suppliers as important barriers to setting environmental requirements (Wendt-Rasch *et al.*, 2021). Wendt-Rasch *et al.* (2021) further note that expert knowledge is required despite the availability of general tools and guidance, meaning the development of collaboration models might be necessary in order for small public administrations to access the requisite skills. Another new study argues that when competitive dialogue (comprising a dialogue phase and a bidding phase, where in the former phase public authorities can discuss the contracts with bidders) is used there is a higher possibility of applying green award criteria than in other processes (Yu, Morotomi and Yu, 2020).

To sum up, research on GPP from different sectors and levels of governance seems to agree that strategy and goals, cost, size, knowledge and information and

requirements are important factors to discuss in relation to the challenges and opportunities of GPP. However, even though much research mentions environmental criteria in relation to evaluating the uptake of GPP, most research discusses it in terms of whether or not environmental criteria are included. This thesis provides knowledge based on experience of the public transport sector, which has come relatively far in the uptake of GPP and most contracts contain environmental criteria to some extent. This gives an opportunity to compare how ambition level and different ways of expressing criteria are influenced by the context. In recent years, in line with my research, other papers have also covered the topic of environmental requirements in the public transport sector. The papers foremost address factors influencing GPP concerning the lack of knowledge when designing environmental requirements (Ammenberg and Dahlgren, 2021a; Lindfors and Ammenberg, 2021), the relationship between regional strategies and the requirements for biogas in procurement contracts (Lundmark *et al.*, 2021), and the challenges of procuring electric buses (Bakker and Konings, 2018; Borén and Grauers, 2019). Further details on the results of these studies will be presented in the next section, which concerns research on the introduction of renewable fuel in the public transport sector.

3.2 Research on the introduction of renewable fuel in the public transport sector

Much previous research on renewable fuel in the public transport sector focuses either on the technical and environmental performance of the fuel and/or fuel economy. However, recently, more research focuses on the challenges of the process of introducing renewable fuel, in line with my own research interests. In this section, I will first present research covering the introduction of renewable fuel in general – either by comparing several renewable fuel or without specifying the type of renewable fuel. Second, I will separately present research focusing on the introduction of biofuels respectively the introduction of electric buses, since much research often focuses on one or the other. I will present the focus of the studies and the main results in order to show the research gap that my thesis is addressing and provide a basis for the discussion section in Chapter 6.

Recently, in line with the research focus in this thesis, a few Swedish studies have been published. Lindfors and Ammenberg (2021) published a paper focusing on developing a method for setting environmental objectives based on life-cycle environmental performance data, in which fuel options are assessed in relation to their impact on GHG emissions, air quality, biodiversity, resource recycling and reuse, acidification and eutrophication. This paper aims to address the previously identified challenge of a lack of knowledge among procurers. The method is thought

to be used as a tool to support the formulation of either technical specifications or award criteria (Lindfors and Ammenberg, 2021). In relation to my research, it is relevant how it addresses the challenges of only procuring the least expensive renewable fuel. A similar topic is covered in a paper by Ammenberg and Dahlgren (2021a). The authors study the public procurement of bus transport in Sweden from the perspective of regional PTAs. The paper addresses the need for increased knowledge and support methods for choosing the best option for sustainable bus technologies by developing a multi-criteria assessment method (Ammenberg and Dahlgren, 2021a). In a follow-up paper, this method is assessed by using it to compare several renewable fuel including biodiesel, biogas, electricity and ethanol. The fuels are compared in relation to several factors, the most relevant to my research including technology maturity**,** availability, infrastructure investment, total cost of ownership, cost stability, energy efficiency, GHG emissions, air pollution and noise**.** The results show that all fuels have their strengths and weaknesses that affect their introduction. For example, buses with diesel and petrol engines are more technically mature than electric buses, while the total cost of ownership is relatively uncertain for all renewable fuel. The authors also conclude that the infrastructure investment is very case-specific and dependent on what is available in each case. Regarding environmental performance, the authors state that this is dependent on how the fuels are produced, used and combined (Dahlgren and Ammenberg, 2021).

An older study, helpful in identifying the focus of my thesis, is a paper by Xylia and Silveira (2017), studying the performance factors that impact the differences seen in the success of Swedish regions in decarbonising bus fleets. The paper concludes that political will, strategic planning and policies are key factors that affect performance in the regions, in most cases to a larger extent than other factors such as population density and size of bus fleet, technology, driving conditions or length of journeys (Xylia and Silveira, 2017). Another Swedish study by Mutter (2019) analyses the dynamics of competition between renewable fuel by comparing the introduction of electric buses in two Swedish municipalities with a biogas-based bus fleet. The study shows that previous investments in biogas can be an obstacle to the introduction of electric buses when there is a strong association between the bus system and the regional biogas infrastructure (Mutter, 2019).

Apart from Swedish studies, a paper by Corazza *et al.* (2016) looks more broadly at European experiences of introducing cleaner buses and seeks to identify barriers to wider utilisation in order to provide policy recommendations to bus stakeholders. The authors state that diesel buses are still strongly favoured in Europe because they are still more affordable but that there is also a lack of knowledge among operators to help them choose the most convenient renewable technology. The authors point out that operators need increased support if a shift from diesel to renewable fuel is to be realised, a claim that is interesting in relation to the case of the Swedish public transport sector in which PTAs assume much responsibility. The authors provide proposals on how to support the introduction of renewable fuel in Europe. On the

local level there is a need to improve the awareness of energy management and the environment by incorporating environmental EU targets and integrating public transport in local energy management plans. The importance of giving attention to and rewarding local best practice experiences in order to spread and inspire environmental quality measures is also mentioned. The paper also highlights the importance of more research that focuses on analysing implementation scenarios, evaluating best practice and consolidating knowledge (Corazza *et al.*, 2016), which is the area in which I hope my research will contribute.

These broader comparisons of the introduction of renewable fuel in the public transport sector are most common in the Swedish context. In the next section, we will see that the same is true for research on the introduction of biofuel.

3.2.1 Introduction of biofuel

Biofuel includes biodiesel, ethanol and biogas. However, most research on introducing biofuel concerns biogas. Reflecting on the current status of renewable fuel in buses in Europe, most of the studies regarding the challenges and opportunities with the introduction of biogas buses are conducted in the Nordic countries. Many of the studies do not purely focus on the introduction of biogas buses but rather focus on biogas as a sector in which public transport is seen as a potential user of biogas. In this section, I will mainly present the part of the results of this research that discusses the use of biogas in the public transport sector.

Common to all the studies on biogas is an emphasis on the importance of support from public authorities and decision makers. The ways in which the use of biogas has developed is seen as being strongly influenced by policy instruments (Fallde and Eklund, 2015; Fenton and Kanda, 2017; Ammenberg *et al.*, 2018) and policy instruments have been seen as being necessary to compensate for extra investment costs (Forbord and Hansen, 2020). However, national authorities not only have an important role through the use of policy instruments. Clear, long-term strategies are also seen as important in order to overcome uncertainty among investors (Fenton and Kanda, 2017; Ammenberg *et al.*, 2018; Lundmark *et al.*, 2021).

Regional public authorities and municipalities in Sweden are highlighted as important, particularly through the use of public procurement to phase out fossil fuel (Ammenberg *et al.*, 2018; Lundmark *et al.*, 2021). Regional stakeholders are seen to have the power to manage and mobilise resources (Fallde and Eklund, 2015). A recent study by Lundmark *et al.* (2021) examines the development of local biogas transport systems in Sweden and identifies the need to prioritise biogas vehicles in public procurement as being one of four important factors for the development of successful local biogas systems. The procurement of the public transport sector and infrastructure in particular gave municipalities the opportunity to create niche markets for biogas and reduce the risks associated with biogas production. The

successful use of GPP for biogas is highlighted to be dependent on political ambition and also initial dialogues before the tendering process. Nevertheless, the authors also note that biogas might not be the correct choice in all municipalities, depending on the availability of substrates (which is often lower in sparsely populated regions) (Lundmark *et al.*, 2021).

Compared to, for example, biodiesel, biogas is often seen to have co-benefits for the region, apart from GHG reduction. Thus, introducing biogas is seen as an opportunity for a region to address multiple interests simultaneously. However, this also means that more stakeholders are involved and a more collaborative approach is required (Ammenberg *et al.*, 2018). Lundmark *et al.* (2021) argue that the establishment of effective actor networks working towards a collective goal is essential for biogas value chains. Small networks with a few motivated actors are also seen as influencing the early development of a biogas market for transport in a study by Fallde and Eklund (2015). A study by Ammenberg *et al.* (2018) concludes that improved knowledge is needed among decision makers and customers not only to focus on exhaust GHG emissions when comparing fuels, but also to include other socio-economic benefits of, for example, biogas. Fallde and Eklund (2015) also point out that introducing biogas is a learning process for all the involved stakeholders.

Research highlights an increasing fear of strategic uncertainty regarding the role of biogas in competition with electricity. Conflicting political priorities and also shifting strategic objectives are highlighted as challenges on a system level (Fenton and Kanda, 2017). Electric vehicle development are thought to influence the future of biogas in the transport sector and some actors recognise the risk that it can take over. However, from a international perspective, all renewable fuels are needed (Ammenberg *et al.*, 2018).

The literature on biofuel has a strong focus on biogas, often with a broader system perspective on biogas production and utilisation in the Nordic countries. Moving on to the literature on electric buses in the next section, studies from other parts of the world will also be presented.

3.2.2 Introduction of electric buses

Electric buses have increased in popularity in the public transport sector in recent years, which is reflected in research. Research that models technology or compares life cycle analyses of environmental performance and costs has been published for many years, but less research has been conducted on the introduction of electric buses. Nevertheless, as the number of electric buses increase in service, so does research on the challenges and opportunities faced during their introduction. In my thesis, the introduction of electric buses is given special focus in paper IV, but the challenges of electric buses in relation to procurement are also discussed in papers

II and III. The general challenges in the previous literature correspond with the findings in my papers and include uncertainties surrounding costs as electric buses constitute a technology that is under development, as well as lack of experience, a need for operational changes and charging solutions due to the shorter range of electric buses, difficulties including electric buses in tenders, and the need for more collaboration as there are many new stakeholders. Research on what is called *zero-emission buses* will also be included, since this often mainly refers to electric buses. In this section I will give an overview of how these challenges are discussed in the previous literature. For a more detailed presentation of literature on electric buses, see paper IV.

Since full battery electric buses are rather new on the market, investment costs are still high in comparison to diesel buses. This challenge is acknowledged in most research on electric buses and there is also much research that compares costs between technology solutions and other fuel. Also, in research on the introduction of electric buses, increased costs are mentioned as an important barrier for electric buses. Thus, some research highlights the need for national funding to help overcome the cost barrier (Bloomberg New Energy Finance, 2018; Li, Castellanos and Maassen, 2018; Mohamed, Ferguson and Kanaroglou, 2018). Nevertheless, the total cost of ownership of electric buses is still uncertain (Bakker and Konings, 2018) and research indicates that, under the right circumstances, there is a possibility of low running costs to compensate for the higher investment costs (Lajunen, 2018; Grauers, Bor and Enerbäck, 2020).

A technical challenge specific to full battery electric buses is their shorter range compared to hybrid electric, biofuel and diesel buses. Previous literature identifies that the shorter range leads to several challenges regarding their introduction. The most common challenges discussed include type of charging solution (Varga and Iclodean, 2015; Mohamed, Ferguson and Kanaroglou, 2018) and need for scheduling and operational modifications (Häll *et al.*, 2019). Two main categories of charging solutions are often discussed in the literature: overnight charging in a bus depot or top-up charging. The strengths and weaknesses of the type of charging technologies are further debated in relation to costs, bus route flexibility, need for more buses and standardisation (Varga and Iclodean, 2015; Glotz-Richter and Koch, 2016; Bakker and Konings, 2018; Bloomberg New Energy Finance, 2018; Mohamed, Ferguson and Kanaroglou, 2018).

The range of buses and type of charging infrastructure are also influenced by the context of each city, such as topography, distance between stops, passenger demand and climate (Clean Fleets, 2014). Thus, local circumstances should be carefully considered when choosing charging solutions and bus routes (Krawiec *et al.*, 2016; Bakker and Konings, 2018). In order to identify the right charging solutions, Mohamed et al. (2018) propose running demonstration projects before introducing electric buses.

In relation to the tendering process, charging infrastructure is highlighted as a challenge in terms of both installation and utilisation of charging equipment (Häll *et al.*, 2019). Further, the tendering process, not least the formal contract, is seen to be among the most significant challenges in studies on the introduction of electric buses from The Netherlands and Sweden. For example, is it difficult to account for risks and uncertainties with a new technology (Bakker and Konings, 2018; Borén and Grauers, 2019; The Swedish Energy Agency, 2019).

In a report based on experiences from multiple cities, the authors propose shifting from a focus on procuring vehicles to procuring systems and more collaboration between the involved stakeholders in order to ease the tendering process (Zeeus, 2018). A paper by Borén & Grauers (2019) specifically addresses the challenge of collaboration in the Swedish procurement process by developing proposals for collaboration models for procuring electric buses. In The Netherlands, Bakker and Konings (2018) find that the distribution of tasks between transport authorities and private operators during the procurement of public transport limits the opportunities for collaboration and discourages the introduction of electric buses. The results also show that political will is vital to overcoming barriers and there is a need for PTAs to take the lead and share risks, such as financial and operational risks, with operators. Of great interest to my research is Bakker and Konings (2018) proposal that electric buses would benefit from PTAs setting specific requirements in tender contracts to provide long-term decisions, or alternatively using award criteria (Bakker and Konings, 2018). Another proposed solution is that several cities collaborate in the joint procurement of new technologies to allow the industry to develop products on a larger scale (Zeeus, 2017).

To sum up the research on renewable fuel, much research purely focuses on the introduction of one type of fuel, either biogas or electricity. Studies of biogas often focus on the entire biogas market in which the public transport sector is exemplified as a potential buyer, while studies on the introduction of electric buses have only emerged in recent years and often focus on the view of one stakeholder or one country. Very few studies compare the challenges and opportunities of the introduction of several fuels and how it is influenced by organisation and regional and local context. Here, I hope to contribute through my research, primarily by focusing on the challenges and opportunities that occur when the public transport sector is procured. The relationship between my findings and previous research will be further discussed in Chapter 6. However, I will first present how my research approached developed and the methods and materials I have used in my papers.

4 Research approach, empirical material and methods

4.1 Research approach

The overarching aim of this thesis is to compare and analyse the introduction of renewable fuel in the public transport sector in Sweden on the regional and local levels. As a first step, a broad overview was conducted of the organisation of the public transport sector in Sweden, current policy instruments, as well as previous research on the introduction of renewable fuel in the public transport sector. The aim of the overview was to identify existing research gaps and also learn about the empirical field (Esaiasson *et al.*, 2017). This helped to identify several aspects that laid the foundation for my thesis. This included the key role of public procurement, the focus on buses, interest in international comparisons, and the use of interviews and document studies as my main research methods. Additional aspects were identified as being important, but were ultimately excluded or just briefly touched upon in the thesis due to a narrowed down focus. The topics considered included national influence through policy analysis. However, national influence subsequently received secondary focus in the first three papers since the key role of GPP motivated a focus on the regional and local levels. In the fourth paper, the influence on the national level received more attention through a comparison between two countries. However, the main focus was still on local challenges and no policy analysis was conducted. The use of innovation procurement as background literature was also considered but excluded because I chose not to focus on how new innovations can be developed during the duration of contracts.

The first overview played an important role in further narrowing down the focus and contributed to GPP's key role in this thesis. However, the development of the papers has been an iterative process in which theory and the empirical material have informed each other (Srivastava and Hopwood, 2009). Three of the papers largely draw on previous research on GPP, although empirical research on the introduction of renewable fuel and electric buses in the public transport sector has also been important. The rapid development of the empirical field has also influenced the focus of the papers. particularly paper IV, which focuses on the introduction of electric buses. Thus, the aim of my research has not been the development of theory. Nevertheless, my research can still be regarded as contributing to existing literature,

particularly within the field of GPP, applying new empirical material from a previously sparsely studied field. Below I present the origins of the four papers and how they relate to each other. Figure 7 shows an outline of the relationship between the papers.

The first two papers are closely related with a strategic approach to test and develop theory based on the literature on GPP and the organisation of the public transport sector. In paper I, relevant factors were identified in the GPP literature and tested in two public transport regions in Sweden. In paper II, the results of the first paper were then tested in ten further Swedish regions and conclusions were drawn together with the literature on GPP and on the organisation of the public transport sector.

Based on the analyses in the first two papers, it was clear that GPP is an important tool for regional authorities in Sweden to introduce renewable fuel, but that it is used in different ways in the regions. While the two first studies, based on interviews, were a useful way of gaining knowledge about the stakeholders' view of the process, a research gap was identified relating to how the use of GPP has developed and how the differences identified in papers I and II are affected by contextual factors. Thus, in paper III, a content analysis of tender documents was used as the main method to study how environmental requirements have been set in public procurement contracts. This provided the opportunity to cover all regions in Sweden over a ten-year period and confirmed some of the stakeholders' views from the first papers.

The fourth study (paper IV) was based on the developments in renewable fuel technologies that occurred during the period of my PhD and purely focused on the introduction of electric buses. Unlike the other papers, this paper does not include GPP literature. Instead, the focus of this paper was motivated by the empirical findings in the interviews and previous research on the challenges of introducing electric buses. By specifically focusing on one technology, it was possible to take a broader approach regarding the positions of the stakeholders who were interviewed, as well as include both a local and a national perspective on introduction of electric buses by comparing cities in Sweden and England.

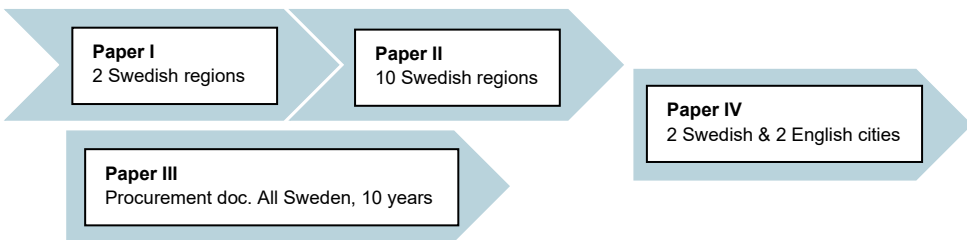

Figure 7. The association between the four papers included in the thesis. Paper I and II are closely connected – identifying relevant factors from theory and testing them on empirical cases. Paper III complements the interview findings in the first two papers with a content analysis of tender documents covering all regions in Sweden. The pure focus on the introduction of electric buses in paper IV builds on the findings from the first papers in which it was seen to be difficult to set requirements for new technologies in tenders. Paper IV also helps to gain a perspective on the Swedish case through a comparison with English cities.

The papers cover the perspectives of different stakeholders, different geographical areas, different organisational approaches and policy tools, and the introduction of different types of renewable fuel. An overview of what is studied in each paper can be seen in Table 4. In the rest of this chapter, I will describe in more detail the choices made in relation to the studied cases, empirical material and methods. I will also reflect on how these choices have influenced my results, since all the choices I made as a researcher affects the outcome of the study. Lastly, I will discuss how validity and reliability have been addressed in the thesis.

Table 4 Summary of the focus of the four research papers included in the theis regarding stakeholders, cases, renewable fuel, organisational structure and the approach to regional introduction.

	Paper I	Paper II	Paper III	Paper IV
Stakeholders	PTAs, operators, procurers, regional politicians	PTAs	Procurers	Policy makers, partnership organisations, PTAs, local authorities, operators, manufacturers
Cases	Two Swedish transport regions, metropolitan and rural	Ten Swedish transport regions, representing the differences in population density	All tender documents in Sweden over ten years	Two English and two Swedish cities
Renewable fuel	Biodiesel, biogas	Biodiesel, biogas, ethanol, electricity	Biodiesel, biogas, ethanol, electricity	Electricity
Organisational structure	Private concession	Private concession, public management	Private concession	Private concession, delegated management, open market entry
Approach to regional introduction	GPP	GPP	GPP	GPP, test projects, under current contract

4.2 Empirical material and research design

4.2.1 Empirical focus on the public transport sector in Sweden

The main geographical focus of this thesis is on Sweden, with an outlook on English experiences in one of the papers. Like all choices made while designing research, my choice of focusing on the public transport sector in Sweden has both possibilities and delimitations for the conclusions that were made in the thesis. A focus on Sweden gives the opportunity to study a market that has progressed relatively far in the introduction of renewable fuel, thereby offering other countries an opportunity to learn from their experience. The Swedish public transport sector is also an interesting empirical field from the perspective of GPP literature since the majority of the public transport sector is procured and environmental requirements are included in all tenders to some extent.

It is also important to be aware that Sweden differs from many other European countries in terms of geography and population distribution. Measured by land area, Sweden is one of the largest countries in Europe (447,000 km²). However, it has quite a small population, just over 10 million inhabitants in 2020, with a population density of 25.5 inhabitants per square kilometre. Also, the inhabitants are not evenly distributed across the country, with most people living in southern Sweden. Sweden has only three large cities: Stockholm (1.6 million inhabitants), Gothenburg (600,000 inhabitants) and Malmö (300,000 inhabitants) and only nine urban areas with over 100,000 inhabitants (Statistics Sweden, 2021). Apart from the large variations in population density and urban density across Swedish regions, other contextual factors also vary. An important example is the availability of the production and distribution of renewable fuel (biogas production in particular varies across Swedish regions), as well as fuelling and charging infrastructure (this is particularly a concern for biogas and electricity, but can also include the possibility of accessing HVO100). The size and resources of the authorities and the size of the bus fleets also vary across the country.

As a field of research, the Swedish public transport sector is a large empirical area and it has not been possible to go into detail regarding all questions of interest. I have chosen to cover the experience from several regions in order to gain a comprehensive overview of the Swedish introduction. The included papers range in detail. In papers I and IV, the views of stakeholders in different positions were in focus, while the aim of paper II was to cover multiple regions. Paper III was a way to compare all Swedish regions over time. The different research designs in the papers also gave the opportunity to cover the differences in organisational approach, different ways to express requirements and differences in outcome in terms of share and type of renewable fuel. If I had wanted to develop a more detailed analysis of the introduction process, it might have been better to focus all papers on one or two regions with a single or limited case study design (Yin, 2006). However, I would then have missed the width of experience from geographical contexts and organisational approaches that my research design enabled me to cover.

A further perspective on Swedish introduction was achieved by including a comparison with the introduction of electric buses in England, because, at the time of the study, England utilised different ways of organising public transport both on the national and local level. On the national level, funding has been the main way of supporting the introduction of renewable fuel in the public transport sector and on the local level, private operators are primarily responsible for planning a large part of the bus services (van de Velde, 2014), while local authorities are mainly responsible for socially necessary but unprofitable bus services (House of Commons Transport Committee, 2019). At the beginning of my study that compared England and Sweden, the UK had the largest fleet of electric buses in Europe (Bloomberg New Energy Finance, 2018).

Nevertheless, the national level is not the main focus of my papers, but regions in a national Swedish context, instead. In the next section, I review the choice of cases and methods in each separate paper included in the thesis.

4.2.2 Research design of the four papers

All four papers included in the thesis contribute to an enhanced understanding of the challenges and opportunities of the introduction of renewable fuel in the public transport sector. A deliberate choice in this thesis was that the design of the papers should differ in terms of methods, depth and empirical cases in order to complement and strengthen the findings and provide answers to different questions.

> Any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared aspects or impacts of a program. (Patton, 1990, p. 172)

As described in section 4.1, the included papers build on each other by confirming and complimenting the findings identified in previous papers. Below, I describe the research design of each of the included papers. For further details, see each paper.

Paper I is a comparative qualitative case study of two divergent Swedish regions. In the choice of regions, differences in regional size, geography and renewable fuel introduced were central. This study includes interviews with several stakeholders (public procurers, transport operators, public transport strategists, politicians) and aspires the aim of covering different perspectives on the process of public procurement. The study builds on previous GPP literature but is rather exploratory regarding the effects of GPP on introducing fuel in the public transport sector. The interviews together with a document analysis allows for an enhanced understanding of the regional process of introducing renewable fuel in the public transport sector and highlights the importance of contextual differences.

Paper II builds on the findings from paper I by investigating the importance of context and choice of strategy identified in the previous paper. It is a comparison of multiple cases in order to cover the process of introduction in a broad span of regional geographical conditions and types of renewable fuel. Semi-structured interviews were conducted with one respondent with the same responsibility in each region. The aim was to interview the person responsible for strategic environmental decisions in the PTA. Also, in this paper, document analysis is used to further understand the regional process and differences.

Paper III is a content analysis of all tender documents in the Swedish public transport sector between 2008 and 2018. The more quantitative approach compared to the other papers allows for a systematic analysis of trends in procurement and how requirements are set. In order to gain a deeper understanding of the findings

from the content analysis, a complementary workshop was held with public transport practitioners. This study enables a comprehensive understanding of the influence of type of traffic procured and the size of procurements, as well as the influence of the different ways of setting requirements identified in the first two papers.

Paper IV is a comparative case study of the introduction of electric buses in four cities in two countries (Sweden and England). The countries and cities were chosen to represent differences in national regulations and support, as well as local context. Their common denominator is that they are early adopters of electric buses. Interviews were conducted with several stakeholders (local governments, regional PTAs, operators, manufacturers, the national government and partnership organisations) representing the driving stakeholders in each city, as well as actors responsible at the national level. Like the first paper, the more in-depth study allows a deeper understanding of the process of introducing a new technology and has a more exploratory approach.

Table 5 Methods and sources used in the included papers.

	Paper I	Paper II	Paper III	Paper IV
Method	Semi-structured interviews, document analysis	Semi-structured interviews, document analysis	Content analysis of documents – quantitative and qualitative, workshop	Semi-structured interviews, document analysis
Source	Eight interviews, local and regional transport plans, environmental strategies	10 interviews, local and regional transport plans, environmental strategies	Tender documents, workshop	15 interviews, local and regional transport plans, environmental strategies

As seen, the findings build on empirical data conducted through semi-structured interviews, document analysis and workshops. In three of the papers (papers I, II, and IV), the approach is qualitative and semi-structured interviews the main method, while document analysis primarily serves to complement the interviews. However, in paper III, a more quantitative approach is taken through a thorough content analysis of documents, complemented by a workshop. In Table 5, I summarise the methods together with the main empirical sources used in each paper. In the rest of this section, I will focus on the use of interviews and documents in my papers and reflect upon their benefits and limitations.

4.2.3 Interviews

An important part of addressing the aim of this thesis was to understand the stakeholders' perspective on the introduction of renewable fuel. In qualitative interviews, the informants' own perspectives are central and they are a useful ways

of exploring new fields of research or complement existing research in a field (Kvale and Brinkman, 2009; Esaiasson *et al.*, 2017)

Thus, the use of interviews has been an important method in this thesis in order to identify the challenges and opportunities of using GPP (RQ2) and how they differ for different stakeholders depending on their choice of renewable fuel (RQ3). In three of the papers (papers I, II and IV), interviews were used as the main method.

A total of 33 interviews were conducted for this thesis. Most of the focus was on interviewing regional authorities which, in most cases, are PTAs since public transport is organised on the regional level in Sweden and PTAs are responsible for planning public transport and therefore have a lot of influence regarding the type of renewable fuel. However, in papers I and IV, other stakeholders were also interviewed. The interviewees included in the papers can be seen in Table 6. All interviews were recorded and transcribed. The interviews lasted between 40 minutes and two hours and were held in person, with a few exceptions in which telephone interviews were conducted.

The process of identifying the right stakeholders was crucial. This was achieved by identifying key stakeholders through documents and websites. A request was then submitted with a brief description of the project. It was sometimes hard to reach people, it took a lot of time or I was referred to other people who were apparently more knowledgeable. In all the interviews the interviewees were also asked whether there was someone else I should contact. This is called snowball sampling, which results in the most relevant person for the process being interviewed. However, there is also a risk that you will end up with people sharing the same view (Esaiasson *et al.*, 2017), although this was not a major problem in my study. A greater challenge was knowing who the key actors were in relation to the introduction of renewable fuel since, depending on the size and organisational approach in a region, responsibility could lie with different positions, or they simply had different titles.

The overall process, from designing the interview studies to analysing and reporting the results of the interviews, was primarily inspired by Kvale and Brinkman's (2009) seven stages: thematising, designing, interviewing, transcribing, analysing, verifying and reporting.

I chose to use semi-structured interviews since they allow for more open questions at the start of the interview in order to avoid guiding the interviewees' responses as much as possible. The open questions could then be supplemented by more specific questions at the end of the interview to cover all the required information. The use of semi-structured interviews based on topics allowed the interviewees to provide their own experience of the introduction of renewable fuel and an interview guide with topics ensured that the required topics were covered. Semi-structured interviews are also flexible enough to allow for follow-up questions in order to dig deeper into the most relevant aspects of the interview (Kvale and Brinkman, 2009).

Table 6 Position of stakeholders taking part in the interviews for this thesis, a total of 37 (higher total number compared to Table 5 because some of the interviews involved more than one stakeholder).

Organisation	Position	Number of interviewees	Included in paper
Regional authority (PTA)/ Administration under PTA	Environmental and market strategist, Environmental Strategist, Strategist for fuel and energy, Public transport strategist, Strategic planner, Strategist, Manager for strategic development, Development manager/leader, Manager for society and transport, Procurement Manager, CEO, Project leader for the introduction of electric buses	20	Papers I, II and IV
PT Operator	Marketing director, Managing director, Business manager, Technical director, Managing director	5	Paper I and IV
Municipality/City council	Public transport coordinator, Low Emission Officer, Electric Bus Project Manager	3	Paper IV
Bus manufacturer	Commercial Director, City Mobility Director	2	Paper IV
Partnership organisation	The Swedish Public Transport Association, Low CVP	2	Paper IV
National level	Swedish Energy Agency, Department of Transport England	4	Paper IV
Regional politicians	Green Party	1	Paper I

For the analysis, the transcribed material was structured using the data managing programme NVivo or Excel. The interview analysis was conducted by dividing the paragraphs into themes using an abductive method in which some of the categories were predefined, while other categories were created during the analysis. In order to compare and analyse the opinions of the different interviewees, I used meaning condensation, in which the interviewees' responses are reproduced in shorter formulations (Kvale and Brinkman, 2009). However, it was not a linear process from thematising to reporting. It was more of an iterative process, as described by Srivastava and Hopwood (2009), going back and forth between coding the interviews and identifying themes and theory.

Interviews were an effective method to gain knowledge of the stakeholders' perspective on the introduction of renewable fuel and how they experienced challenges and opportunities depending on the organisation of the public transport sector and the context in which the introduction took place. To gain a better understanding of the practical implications, the interviews were also combined with analysis of strategic documents and tender documents. In the next section, the role of document analysis will be further discussed.

4.2.4 Document analysis

Documents were used in two ways in this thesis: as a complement to interviews (papers I, II and IV) and as the main method using content analysis (paper III). The content analysis was based on tender documents from the procurement of public bus transport in all Swedish regions over a ten-year period. This meant we ended up with 84 procurements that covered 95% of all public bus services procured within this time frame (excluding school bus services). The documents were analysed by two researchers with categories based on the guidelines for environmental technical specifications in public bus transport in order to achieve as systematic and objective an analysis as possible. To enable comparison of the findings, they were compared in relation to factors identified as being important in previous literature. Further, in order to understand the properties of the material, the information was transferred from text to numerical data in order to apply statistical analyses. The use of content analysis of documents in one paper was a way of gaining deeper knowledge and new insights by making inferences from specific data to a general context (Krippendorff, 2004). The content analysis was an important part of understanding how contextual factors (size of procurement, type of traffic) influence the introduction of renewable fuel (RQ1).

In papers I, II and IV, documents were mainly used as a complement to the interviews, for example, to validate facts and describe the context in the regions. The main documents used were regional and local transport plans and environmental strategies. Key documents were the regional transport supply programmes as they are mandatory in all Swedish regions and provide an overview of the strategic ambitions for transport in a region, including environmental targets. Tender documents were also important to understanding how the requirements were set. In paper IV, Swedish and English national policy documents and strategies were important in order to understand the context of the two countries, as well as guidance and government funding affecting low emission public transport, along with explanatory briefings produced for policymakers, planners and politicians. EU regulations concerning policy instruments, public procurement and renewable fuel have also been an important part of understanding the limitations of decisions on the local, regional and national level. Complementing the interviews with documents was a way of providing a better understanding of the regulatory and policy context in each case. It also provided additional insight into the ambitions and priorities of stakeholders.

In this section, I have focused on describing how I designed the studies in my research papers and the benefits of using interviews and documents as methods. In the last section of this chapter, I will discuss how I have ensured the validity and reliability of my research.

4.3 Validity and reliability

Validity, reliability and generalisability are important aspects to discuss in relation to the choice of method and research design. In this section I will primarily focus on the measures I used in the papers to increase the validity and reliability. Validity is about whether the findings represent "the truth", which is a complex term in relation to qualitative research. Instead, I tried to address validity in all parts of the research process, for example, by carefully selecting categories for the analysis and data triangulation. Reliability is often regarded as something that ensures that another researcher would be able to replicate a study and draw the same conclusions. However, strictly speaking, this is not possible for a qualitative interview study. Instead, reliability in a qualitative study can be about ensuring that other researchers can connect the empirical material to the conclusions drawn by the researcher by carefully describing the studied case, designing the questions in the interview guide, as well as consistent analysis in which coding is confirmed with other researchers (Kvale and Brinkman, 2009). Below, I will describe the measures taken in the papers to ensure the validity and reliability of the research. The measures include triangulating information through data sources and interviewees, accounting for cases and material, adopting systematic analysis procedures, as well as discussions between the involved researchers. The possibility of generalising my findings will be further discussed in Chapter 6.

One of the main ways of increasing the validity in the papers was through data triangulation. One of the challenges of interviews is whether the interviewees remember information correctly. Thus, in papers I, II and IV, when the interviews were used as the main method, factual information was triangulated with information from documents to ensure accuracy. However, since my main interest was with the stakeholders' view of what was challenging and what worked well in the introduction, their version, based on their position as agents, was my primary interest. Thus, the position of the interviewees and their role in the process became very important. In papers I and IV, the information in the interviews was also validated by interviewing several stakeholders with different perspectives chosen through purposive sampling. This was not the case in paper II, in which only one stakeholder was interviewed in each region. However, this approach was motivated by the aim to verify the information from paper I by covering several regions. Another example of the triangulation of findings can be seen in paper III in which the results of the document study was complemented by a workshop in order to achieve a better understanding of what had led up to the information included in the documents.

Careful descriptions of the studied cases in each paper was an important way of improving the reliability of the studies. This thesis also includes an extensive background section to further show the context in which the research was conducted. In paper III, which used content analysis, it was important to conduct

the analysis in an objective and systematic way in order to achieve the most reliable results possible. Objectivity includes providing a clear motivation for the selection of documents and categories and ensuring the inclusion of the same type of information; meaning that if another researcher used the same categories, the analysis should result in the same outcome (Kassarjian, 1977). It was therefore important to set clear boundaries when the documents were chosen. This was achieved by including the procurement of buses from all Swedish transport regions over a ten-year period. We managed to include 95% of tenders, excluding school bus services.

Another important way to ensure reliability and validity was to adopt a systematic analysis procedure. When interviews were used as the main method, as well as for the content analysis, the choice of categories for the analysis was important. The categories were based on previous research (for example, GPP literature) or official documents (sector guidelines for environmental technical specifications). However, the entire process was important. Analysing interviews is not a process that only takes place in the final stage. It is an ongoing part of the entire research process. Thus, validity and reliability must be ensured throughout the entire research process when choosing interviewees, conducting interviews, adopting a systematic analysis procedure and validating the findings (Kvale and Brinkman, 2009). One challenge during the process of interviewing was, for example, to avoid guiding the interviewees' responses while being influenced by my preconceptions and prior knowledge. This was addressed by designing an interview guide based on topics that started with more open questions.

Lastly, discussions between the involved researchers played an important role in ensuring the validity of the results. In the content analysis in paper III, the documents were partially cross analysed by two researchers and the findings were discussed throughout the data collection process and analysis. The method section in paper III contains a further description of how this was done. Also, in paper I, the analysis was conducted by two researchers, and themes, coding and findings were discussed continuously throughout the process. In paper II, I was the sole author, meaning I conducted the interviews and analysis largely on my own, with supervisors and colleagues functioning mainly as discussion partners and providing feedback.

Finally, all the papers also collectively offer an additional triangulation of the findings. For example, papers I, II and III cover very similar themes but have different research designs. The qualitative interviews used in papers I, II and IV also strongly focused on context-specific issues and I have been careful about making generalisations from the studies. However, Halkier (2011) claims that it is possible to generalise from qualitative studies but that it must be more specific and context bound than quantitative studies and can be seen as producing context bound topicalities. I also believe that, collectively, the papers and their scope will make a good basis for more general discussions about the challenges of introducing

renewable fuel in the public transport sector. The quantitative document analysis in paper III was also a way to help confirm some of the patterns identified in the interviews.

This section has focused on how interviews and document studies have been used in the papers and the possibilities and limitations of my choices of research approach, methods and materials. In the next chapter, I will summarise the aims and results of the four papers included in the thesis.

5 Summary of the papers

5.1 Paper I: Strategic use of green public procurement in the bus sector: Challenges and opportunities

The point of departure in paper I was in five important factors identified in previous research that influenced the success of using GPP: strategies, requirements, costs, size and knowledge. The aim of the paper was to compare and analyse the role these factors played in promoting the introduction of renewable fuel in public transport systems in two Swedish regions, which differed in both fuel choice and geographical contexts. The method comprised a qualitative comparative case study based on interviews and document studies. The paper also addressed the question of the strategic motivations for using public procurement to stimulate the use of renewable fuel.

In the paper, the importance of context when assessing GPP schemes was highlighted by showing the case-specific influence of factors on the outcome of GPP. The variations in strategies showed an important difference between the regions. A regional biogas strategy with regional political backing and the acceptance of increased costs allowed Skåne to develop a local market for biogas. In comparison, Jämtland's focus on introducing renewable fuel in the most cost efficient way resulted in a more direct influence by the national targets on the ambition level of the GPP scheme. The differences in strategy resulted in them using different kinds of requirements in the tender documents. For many years, Skåne set specific requirements on biogas, which had helped the development of a biogas market, but had also resulted in high costs and lack of availability. In Jämtland, these challenges were seen as reasons for using functional requirements in the first place. Also, the operators were seen to prefer functional requirements for the same reasons. The extent to which the cost factor impacted introduction also differed between the regions. In Skåne, increased costs were not perceived as being a main barrier since higher initial costs were politically accepted in order to create a market for biogas, while in Jämtland, keeping costs down was a reason to set functional requirements. In terms of the influence of size, the clearest result was that Skåne, as a large metropolitan area, saw itself as having a greater opportunity to influence the development of the market. Lastly, the need for knowledge seemed to be associated with how the requirements were set. With functional requirements, as in Jämtland, the need for knowledge was shifted to the operators and national guidelines. In

Skåne, on the other hand, the procurers felt that both knowledge of the market and monitoring were important in order to manage the biogas strategy.

Overall, the analysis showed that in one region, procurement was strategically used to create a local market for biofuel. This imposes higher demands on political backing, information and knowledge, the way in which requirements are set, and the acceptance of increased costs. In the other region, procurement was used instrumentally to increase the share of biofuel in a cost effective way that offered scope for more flexibility and reduced the demands on the procurers.

5.2 Paper II: Influence of public bus transport organisation on the introduction of renewable fuel

Paper II developed the conclusion in paper I that the influence of factors on the outcome of GPP is case-specific. Thus, in this paper, the regional challenges of introducing renewable fuel in public transport was analysed in ten further Swedish regions. It also included comparisons with regions organising their bus services through public management instead of competitive tendering. The focus was on understanding the motivation behind the use of different organisational forms and the challenges and opportunities encountered by the authorities in a region during the introduction of renewable fuel. The data were mainly collected through interviews with regional PTAs, in combination with an analysis of their transport supply programmes. The findings largely confirmed the findings from paper I and showed that when functional requirements were used in competitive tendering, it exclusively resulted in the least expensive renewable fuel available on the market. Thus, if the PTAs wanted to introduce other renewable fuel that could not compete with biodiesel in terms of price, the regional authority had to assume responsibility by using either specific requirements or public management.

The motivation for regional PTAs to set functional requirements included lower costs, avoiding being locked into one solution, keeping the number of bids, avoiding investment in new infrastructure, using a tried and tested technology, avoiding uncertainties around availability and technology development, and the possibility of using operators' expertise. However, a challenge of functional requirements was that they only resulted in biodiesel, which has no regional benefits, apart from reducing GHG emissions. In regions that procured bus services, specific requirements were used in municipalities, cities or on a specific bus route when there was a desire to create a market for a fuel such as biogas or electricity, motivate investments in new infrastructure, use regional assets, address local air quality issues or achieve a more diverse bus fleet. Biogas was also more common in urban traffic than in regional traffic. Specific requirements meant increased costs resulting from investments in vehicles and infrastructure and therefore required political

support. This made the regions hesitate regarding whether they wanted to be at the forefront in the future. The availability of the requested fuel was also regarded as a challenge, as well as being locked into the choice of fuel and infrastructure. In regions or cities in which the public authorities did not procure the bus services from private operators but owned and operated the buses themselves, the motivation for introducing renewable fuel was similar to the motivation when specific requirements were set, including creating a market for biogas, improving air quality and using regional assets. Compared to specific requirements, public management allowed for a gradual transition in which the region was not locked into the chosen solution. Nevertheless, public management also faced challenges regarding high costs and a lack of availability of the chosen fuel.

5.3 Paper III: The role of environmental requirements in Swedish public procurement of bus transport

Paper III complemented papers I and II by looking in more detail at how environmental requirements have been expressed in tender documents during the shift from fossil fuel to renewable fuel. The aim of this study was to examine the role PTAs could play in supporting more environmentally sustainable public transport through public procurement. The study was based on a content analysis regarding the historical use of environmental requirements, over a ten-year period, in tender documents in Sweden, combined with a workshop with relevant stakeholders.

The findings showed three ways of expressing environmental criteria in tenders for the Swedish public transport sector: technical specifications, incentives and options. Technical specifications were by far the most common and were either a functional requirement for reducing the share of fossil fuel, CO_2 emissions, energy use, NOx and noise, or as a specific requirement for a type of fuel. However, the stringency of the functional requirements varied between contracts. The findings showed that all the environmental requirements became more stringent during the studied period and showed a tendency for higher use of environmental requirements in larger tenders, as well as in the tendering of public transport in cities. Particularly for fuel requirements, larger tenders and tenders for city traffic included specific requirements to a higher extent. The high use of functional requirements seemed to correspond with a high share of biodiesel in a region, while all regions that used biogas set specific requirements for biogas in their tenders to some degree. However, the subsequent workshop discussions indicated that the use of specific requirements was a reason for lack of consensus among the involved stakeholders; while specific requirements should be avoided according to some stakeholders, other stakeholders claimed they are needed in situations in which new infrastructure

is required. Overall, this study of the Swedish public transport sector showed that PTAs have great potential to support more environmentally sustainable solutions using environmental requirements in public procurement.

5.4 Paper IV: Electric buses in England and Sweden – overcoming barriers to introduction

Paper IV specifically focused on the introduction of electric buses in cities. This paper provided a European perspective on the introduction of electric buses by comparing experiences in England and Sweden, two countries with different institutional settings. In each country, two cities were studied (Nottingham, York, Gothenburg and Eskilstuna). The comparative approach enabled us to investigate the influence of governance context, organisational practices and relationships between stakeholders in the process of introduction. The study aimed to identify the main challenges in each city and the approaches that were taken to overcome such challenges, as well as see whether national context mattered and, if so, in what way. The study was based on interviews with a broad spectrum of stakeholders in these cities.

The paper showed that there were both similarities and differences between the challenges of introducing electric buses in the cities. All the cities encountered challenges associated with charging infrastructure, operation and scheduling, higher and unknown costs, involvement of many (new) stakeholders, and lack of knowledge. However, the significance of the challenges differed across cities and seemed to be associated with context-specific factors such as geography, passenger demand, current bus schedules and route planning, regional introduction strategy and national governance.

Choices and challenges around charging infrastructure were particularly context dependent. The three cities with higher passenger demand had installed top-up charging to address the shorter range of the buses. Top-up charging involved additional challenges for the cities. Rapid charging at end stations created a lock-in to specific bus routes and placed a burden on the local electricity grid, while slower charging required greater modifications to the operational schedule. However, the city with lower passenger demand and shorter bus routes allowed for overnight charging and operation of the current system without the need for major modifications. The procurement of electric buses was also challenging in all cases because of the high initial investment costs and difficulties in accounting for the risks and uncertainties of procurement contracts. In the Swedish cities, this was primarily addressed using test projects and PTAs accounting for more risks. However, in all the studied cities there was an uncertainty around the total cost of ownership. In the English cities, higher national funding partially helped to

overcome high initial costs, although in Nottingham, the electric buses were also owned by the local authorities. It was also interesting to note that the PTAs were responsible for all electric buses in the studied cases, including in England, in which most of the services in the cities were organised based on open market entry.

It was concluded in the paper that most challenges came down to individual cases although some national differences were identified. In England, more national funding made the initial investment costs less of a challenge, while introduction in Sweden relied more on regional politicians accepting increased costs and PTAs taking on more risks. We also concluded that achieving a functioning collaboration between the stakeholders was an important challenge and was key to overcoming challenges in all the cases.

6 Discussion

In this chapter, I will discuss the challenges and opportunities for the introduction of renewable fuel in the public transport sector. The discussion section is based on the knowledge compiled in this thesis. The findings from the four research papers are discussed in relation to each other and in relation to the current literature on the introduction of renewable fuel and the literature on GPP.

Since most of the Swedish public transport sector is procured through competitive tendering, the challenges and opportunities of using GPP to introduce renewable fuel came into focus in this thesis. Different ways of setting environmental requirements were seen to significantly influence the challenges encountered by the involved stakeholders, as well as the outcome in terms of share and type of renewable fuel. Nevertheless, not all public transport in Sweden is procured and there were also examples of regions, municipalities and cities in which the authorities owned and operated the buses themselves. These examples were analysed in relation to procured services in one of the papers (paper II).

In the first section of this discussion, the most common way to use procurement in Sweden by setting technical specifications is discussed and seen in relation to alternative ways of organisation. In the second part of the discussion, the most common factors that influence the introduction of renewable fuel are discussed. These factors have been identified in previous research on GPP, as well as in research on the introduction of renewable fuel in the public transport sector, specifically. Last, in this chapter, the role these factors play depending on which renewable fuel is introduced is discussed.

6.1 Organisation of responsibilities and the use of GPP

The way in which responsibilities are organised between stakeholders in the public transport sector, not least between the public and private sector, was seen to influence the challenges and opportunities faced during the introduction of renewable fuel. In Sweden, responsibility for strategic long-term decisions for regional and local public transport is delegated to regional PTAs. In most cases, the PTAs then tender out the operation and, to varying degrees, tactical planning to private operators – the private operators also commonly own the buses.

Nevertheless, there are also regions and municipalities in Sweden in which public authorities have retained operational management themselves and cases in which buses have been introduced outside normal organisation through test projects. These cases are discussed last in this section in relation to publicly procured public transport.

Since most Swedish public transport is based on public transport being procured by PTAs from private operators, the focus has been on how environmental criteria were set to introduce renewable fuel in the public transport sector – referred to in the literature as GPP. In paper III, technical specifications was identified as the main way of expressing environmental criteria in Swedish tender documents. The most common process was to set functional requirements for the desired share of renewable fuel, reduction in CO_2 emissions, increased energy efficiency or reduction in air and noise pollution. However, specific requirements were also used in some contracts to demand a specific fuel – either instead of functional requirements or to complement a specific part of the bus services such as a specific bus route, city or municipality. The findings showed that the choice of using functional or specific requirements had a significant influence on the outcome for renewable fuel in a region, as well as the challenges and opportunities that were faced during its introduction. Comparing these two ways of expressing environmental technical specifications became an important way to better understand the differences in share and type of renewable fuel between the regions in papers I, II and III of this thesis.

Such comparisons of the use of functional and specific requirements have been barely studied in previous GPP research. However, a critique of specific requirements resulting in increased costs in procured Swedish public transport was seen in the previous literature. Also, in the literature on innovation procurement, there is new research that argues about the benefits of functional procurement (describing problems to be solved or functions to be fulfilled) since it opens up for the innovation and development of products and leaves the responsibility to be innovative to the suppliers, not the procurers (Edquist and Zabala-Iturriagagoitia, 2020). The Swedish public transport sector guidelines also recommend functional requirements for environmental technical specifications, and in the EU procurement Directive 2014/25/EU. However, in my research, both types of requirements were seen to have their own challenges and opportunities for introducing renewable fuel. I will present the most important challenges and opportunities below. However, for further details, I refer to papers I, II and III in this thesis.

My findings showed that functional requirements were often preferred by the involved stakeholders, particularly private operators. Some of the benefits of using functional requirements seen in the previous literature were confirmed by my research, such as being the most cost effective option for PTAs. Functional requirements were also a way for PTAs to address uncertainties, such as the availability of fuel, by leaving the choice of fuel to the operator. Nevertheless, in

papers I, II and III, the results showed that when using functional requirements, the outcome for fuel was biodiesel – which may be because the private sector is often motivated by financial gain and biodiesel is currently the renewable fuel least expensive to introduce.

In all studied cases in which a renewable fuel other than biodiesel had been introduced in the procured bus services, specific requirements for biogas, ethanol or electricity had been used. Some stakeholders therefore argued that specific requirements were necessary if they want to build a market for fuel, when new infrastructure is required, or they wish to address local environmental problems, such as noise or air pollution – which may be because public authorities are more often motivated by achieving broader societal benefits. However, my research also showed that specific requirements can increase the costs for PTAs and therefore require more political support than functional requirements. Specific requirements were also seen to be less flexible if there was a desire to make changes during the contract period, and it was seen to be difficult to stipulate requirements for a technology that is still under development, such as electric buses. Thus, even though most stakeholders agree that functional requirements are preferable in most cases, there seems to be a lack of consensus on how to best set requirements when there is a will to achieve benefits beyond reducing GHG emissions.

As seen in Chapter 2, technical specifications are only one way of describing environmental criteria. However, an option not explored in my papers is the possibility to use or complement the technical specifications with award criteria. This option was brought up as a possibility for the Swedish public transport sector in new research by Lindfors and Ammenberg (2021) and was seen to be used in public transport in some other European countries, as well as for environmental requirements in other sectors. Award criteria are presented by the European Commission (2016b) as an option when an authority is not certain about the costs or market availability of a product – which can be interesting in relation to the discussion seen in my research on how to set requirements for new fuel and technologies.

Since the development of renewable fuel and technologies is happening quickly, long procurement contracts, often eight to ten years, were sometimes seen as a challenge. One option was to change the fuel under the current contract – provided that the contract allows for change. Here, functional requirements can be more beneficial, or special clauses leaving the contract open for development. In paper IV, electric buses were seen to be introduced under current contracts as the next stage following a test project. Introduction under a current contract can be seen as a way for PTAs and operators to collectively develop the best option for the specific circumstances in a city. However, this removes one of the main reason for procuring bus services, to identify the least expensive solution through competitive tendering.

6.1.1 Alternatives to public procurement

Based on experiences from studying the transport sector in Sweden, it seems that GPP could make a positive contribution to the introduction of renewable fuel. From 2010 to 2020, the share of renewable fuel in the Swedish public transport sector has increased from under 20% to over 90%, mainly in publicly procured bus services. Nevertheless, it is difficult to evaluate the effectiveness of GPP since other policy instruments and goals may also have affected the introduction, and similar or even better results could possibly have been achieved under other organisational forms. Also, little research has been conducted on the effectiveness of GPP, and most of this research focuses on its economic effectiveness.

In paper II in this thesis, a few cases of public management were studied in relation to bus services tendered out by PTAs to private operators. It is interesting to note that the share of biogas was high in the regions and municipalities that operated buses through public management. The reasons for choosing biogas in these cases were similar to the reasons for setting specific requirements for biogas – public authorities saw biogas as a way of addressing regional strategies and choose a fuel with local environmental co-benefits, apart from GHG reduction. Compared to procured bus services, one of the benefits was the possibility to try a fuel that was technologically and economically uncertain, since they could introduce it gradually without getting locked into one specific solution.

An alternative solution would be open market entry for private operators. In Sweden, this situation primarily applies to long-distance buses, which were not studied in this thesis. In England, open market entry is common in the cities studied in paper IV. However, an interesting finding was that all electric buses in the two cities that were studied were introduced in services that had been planned, and in one city buses were also owned, by the local public authorities.

To sum up, the Swedish public transport sector represents a case in which GPP seems to have worked well in the introduction of environmental measures. Nevertheless, even though the Swedish public transport sector has achieved the targets it had set out, several challenges needed to be overcome, depending on how the environmental requirements were expressed. What was considered to be the best way of introducing renewable fuel seemed to be related to the PTA's main motivation for introducing renewable fuel, as well as other factors such as regional strategies and political support, acceptance of increased costs, size of the region, procurement contract and type of traffic, as well as knowledge and other resources in the region.

6.2 Factors influencing the introduction of renewable fuel

6.2.1 General remarks

An important conclusion from my research is that the challenges and opportunities of introducing renewable fuel are strongly associated with the specific fuel, but also to the context in which the fuel is introduced. Thus, the findings in this thesis highlight the importance of looking at the individual case in order to understand the challenges and opportunities that the introduction of each renewable fuel entails. Several factors were identified as important in both previous research on GPP and in research on the introduction of renewable fuel. These factors have been further analysed and developed by analysing the role they have played in the introduction of renewable fuel in Swedish public transport. The strategies of goals and top management, cost and knowledge, information and collaboration were frequently mentioned as important in the literature on both GPP and the introduction of renewable fuel. GPP literature also highlighted the environmental criteria and the size of the procuring entity as important factors, while the literature on renewable fuel in the public transport sector focused more on the influence of current operation and availability. In section 6.2.2, I will discuss the challenges and opportunities of the introduction of the three most common renewable fuel (biodiesel, biogas and electricity) in Swedish public bus transport in relation to the identified factors, as well as in terms of their environmental effects. However, I will first summarise each separate factor and how it could influence introduction in general.

Strategies, goals and top management have been identified as the most influential factors affecting the uptake of GPP. Regional strategies and national policies in particular were seen as key factors in the literature on renewable fuel. My papers confirmed this and exemplified how it has influenced introduction of renewable fuel in the public transport sector in different ways. As seen in Chapter 2, most of the strategic responsibilities in Sweden are on the regional level. As a natural consequence, regional strategies and regional political support were seen to influence the type of renewable fuel by affecting how the requirements were set and the extent to which increased costs were accepted. However, the national level was also seen to have an effect through targets and policy instruments that could help overcome high investment costs, as seen in England, or decrease fuel prices, as in the case of tax exemptions for biofuel in Sweden. In Sweden, the guidelines for environmental technical specifications created by the partner co-operation in the public transport sector also played an important role. For example, the proposed way of setting functional requirements for fuel, in terms of share of vehicle kilometre or in later years in terms of reduction in CO_2 emissions, seems to have inspired how the requirements were expressed in many regions. See paper III for further details.

Another important barrier to the uptake of GPP discussed in the literature is *cost*. This is not surprising since, as can be seen in Chapter 2, the main purpose of competitive tendering is to identify the most cost effective solution. However, it was often the fear of increased costs that was seen to be the greatest challenge. Also, in the literature on renewable fuel, costs were often compared between renewable fuel and in relation to diesel regarding both fuel prices and investments in vehicles and infrastructure. However, the total cost of ownership is still uncertain for many renewable fuel. Also, in my research, cost was an important factor discussed in all the papers. However, for which stakeholder it was a challenge and how it influenced the introduction of renewable fuel varied between the cases depending on, for example, national support, regional political backing and which renewable fuel was discussed. For example, one important reason for setting functional requirements stated by the respondents was to introduce renewable fuel in the most cost efficient way (papers I, II). Many different types of costs were also noted – for example, initial investment costs for buses, need for infrastructure, and operational costs.

A lack of *knowledge and information* is also a general challenge regarding choosing environmental products. Previous GPP research has identified a lack of knowledge among procurers for setting environmental requirements. At the same time, the literature on renewable fuel has identified a need to improve environmental awareness in local authorities in Europe, as well as a lack of knowledge among operators regarding choice of technology and fuel for buses. In papers I and II in this thesis, a lack of knowledge among procurers was often seen to be a reason to set functional requirements, leaving the choice of technology to the operators. Thus, if the regions wanted to set specific requirements for a fuel, it demanded great knowledge of the fuel market by the public authorities. Recently, research has been published that attempts to address the lack of knowledge on how to set environmental requirements in the Swedish public transport sector by providing tools to compare fuel and set requirements depending on what the procurers want to achieve (Ammenberg and Dahlgren, 2021a; Lindfors and Ammenberg, 2021).

One way to address the lack of knowledge is through more *collaboration* between the involved stakeholders. For example, previous research has shown that networks played an important role in the development of biogas markets. In GPP literature, increased collaboration was a way of increasing the amount of procured goods to allow for a more ambitious use of GPP. In this thesis, collaboration was particularly seen to be important when introducing a new fuel that had many uncertainties. Nevertheless, achieving a functioning collaboration was also seen as a challenge in itself since it is time consuming and requires common goals among the involved stakeholders. In the interviews and workshops with the stakeholders (papers I, II and III), collaboration across regions was often proposed as a way of overcoming the challenges of a lack of knowledge and small procurement volumes. However, few specific examples of these regional collaborations were identified in this thesis.

Environmental criteria were often mentioned in the literature on GPP and environmental criteria (often technical specifications or award criteria) were often used to evaluate the uptake of GPP. However, little detailed research has been conducted that compares what motivates the different ways of setting requirements and what this means for challenges and opportunities. This was an important focus of papers I, II, and III, in which the different ways of expressing technical specifications as functional or specific requirements were compared and analysed. A more extensive discussion of the challenges and opportunities of different ways to express requirements was presented in section 6.1.

Size was a factor that was sometimes found to influence the uptake of GPP in previous literature, both the size of the procuring entity and the amount of procured goods. As seen in Chapter 2, Swedish regions significantly vary in size and there have been large differences in both share and type of renewable fuel in the regions. In this thesis, the findings in paper I indicated that larger regional size gave the PTAs the sense that they had more influence over the development of the market which, in turn, influenced how they set the requirements. The influence of size was further analysed in terms of regional size (population density and bus fleet) in paper II, and in terms of size of procurement (vehicle kilometre procured), in paper III. The results indicated a tendency for higher functional requirements and more specific requirements in larger tenders, and in city traffic compared to regional traffic. A potential explanation, apart from the possibility of influencing the market, was that larger procurement entities often have more resources in terms of finance, knowledge and expertise.

Some identified factors were specifically associated with research on the introduction of renewable fuel. In previous research on electric buses, the impact of *current operation* such as design of bus routes regarding length and bus stops, scheduling of breaks and shifts, and passenger demand, were important factors. *Availability* was another important factor, primarily in the literature on the introduction of biogas, but also for electric buses. For biogas it often concerned fuel production, distribution of fuel and charging infrastructure, while for electric buses, availability of space and connection for top-up charging were identified as important. These factors were also discussed in my papers, but will be described further under each fuel in the next section.

6.2.2 Differences between fuel

Since renewable fuels have different characteristics, the above-described contextual factors and how the public transport sector is organised will influence them differently. Below, I reflect on how the introduction of biodiesel, biogas and electric buses is affected by context and organisation depending on their specific characteristics. A comparative overview of the three fuels can be seen in Table 7, at the end of this chapter.

6.2.2.1 Biodiesel

The use of biodiesel in buses is closest resembling operation of conventional diesel buses and has played an important role in the introduction of renewable fuel in Sweden. Biodiesel can be used in existing diesel buses (some engine modifications for RME/FAME) and can use the existing infrastructure for fossil diesel. Buses running on biodiesel can also be operated under the same conditions as diesel buses in all types of traffic. The lower investment costs for vehicles and infrastructure, lower risk and low need for adjustments of operation seemed to have led to a rapid introduction in procured bus services in Sweden. Biodiesel also seems to have benefited from the functional requirements for share of renewable fuel that are commonly set in procured bus services by Swedish PTAs, since biodiesel have often won bids that were evaluated based on the lowest price. Biodiesel was the most common fuel in Swedish regional traffic and small procurements and was not seen to demand a high level of specialised knowledge from neither procurers nor operators. However, there are no local environmental benefits in the operational phase compared to fossil diesel and GHG reduction depends on which feedstock is used and how it is processed. Future availability for use in the public transport sector is also being debated and it is uncertain what role it will play in future bus fleets, both in Sweden and the rest of Europe.

6.2.2.2 Biogas

Biogas is the second most common renewable fuel in the Swedish public transport sector and Sweden is exceptional in the use of biogas in the transport sector compared to other countries. The unique use of biogas in Sweden can partly be related to policy instruments, since its use in the transport sector is supported through tax exemptions, which is not the case in many other countries, in which support for biogas is directed towards production instead. However, there have been many uncertainties about the policies for biogas in Sweden, which were seen to influence investments and the requirements set for biogas in many regions in my study. The important influence of national policy instruments for the introduction of biogas was also seen in other biogas studies in Sweden in which national support was seen as necessary to compensate for the higher costs.

Even though national support seems to have played a role in the introduction, my research showed that regional political backing and strategies were at least as important to the introduction of biogas. Biogas was not identified in all Swedish regions and only a few regions have a high share of biogas. This is partly dependent on the differences regarding the availability of biogas production and infrastructure for distribution and fuelling. However, differences in regional political backing for increased procurement costs also seemed to be important. Gas buses are still more costly than diesel buses and investments in new fuelling infrastructure may be necessary. Another factor was whether there was a broader regional biogas strategy for supporting the development of a biogas market. For example, in papers I and II

in the study, investment in biogas buses was seen as a way of increasing biogas production in the region and motivating investment in biogas infrastructure that could also be used by other modes of transport. The fact that biogas concerns more stakeholders than those strictly in the public transport sector was identified in research on biogas introduction and collaboration in networks was seen as important.

Biogas was found in both procured bus services and in public transport owned and operated by a regional PTA. However, in all cases in which bus services were procured, it had happened through the use of specific requirements. It is therefore interesting to note that the introduction of biogas in Sweden has always been a public authority initiative. This corresponds well with research on the organisation of public transport, which states that public authorities are often motivated by wider societal benefits. Thus, biogas could possibly be more difficult to introduce to a market based on open market entry. Biogas also requires a high knowledge of the market and the availability of fuel by the PTA.

Climate and environmental benefits are dependent on the feedstock. However, some research showed that biogas has a great potential to reduce GHG emissions and also contribute to other aspects of sustainability. Most beneficial is the use of local waste, manure and sludge since it can then be seen to have local co-benefits for the region, which was seen to be a common motivation for regional public authorities to choose biogas over other fuels. Compared to diesel buses, gas buses also contribute less to particle and noise pollution, but not to the same extent as electric buses. Gas engines are less efficient than diesel engines, which has been seen as being disadvantageous to biogas, although there have been improvements in recent years. It is also worth noting that biogas is highly dependent on regional circumstances regarding availability and might not be the right choice in all regions.

6.2.2.3 Electric buses

Even though electric buses are not a new invention, it is only in recent years that full battery electric buses have started to be introduced on a larger scale. While biofuels are more common in Sweden than in most other countries, Sweden has not been a forerunner when you consider the number of electric buses in service. Nevertheless, many test projects have been running in different cities and in recent years, Swedish cities have started to procure electric buses on a large scale.

Compared to biofuels, the introduction of electric buses is more dependent on the context of a city and the current operational planning – primarily because of the range limitations. Several solutions have been developed to overcome the short range of electric buses, including different kinds of top-up charging during the day, larger batteries and modifications to services and schedules. The most favourable solution in a city is dependent on both contextual factors in the city such as its size, passenger demand, available space for the installation of charging stations, and grid

connections, as well as on how responsibilities are organised between the involved stakeholders. Since so many factors influence which solution is most suitable, test projects can be a useful measure before large scale introduction. This was seen in my study in paper IV and in previous research.

The introduction of electric buses, like biogas, struggles with the challenge of high investment costs for vehicles and charging infrastructure. The way in which the challenge of increased costs was overcome was one of the main differences seen in the comparison between Sweden and England in paper IV. In England, rapid, early introduction took place with support from national government funding, an important measure also identified in the literature. However, in Sweden, where less funding was available, early strategies built on test projects and collaboration between multiple stakeholders instead.

The many new stakeholders involved and the many uncertainties around technology development, charging solutions and total cost of ownership was seen to make it difficult to set requirements in tenders. In my studies, this was exemplified in both the Swedish and English cities. In Sweden, the cities had chosen to run test projects followed by introduction under current procurement contracts to learn more about the introduction. In England, a quite rapid introduction of electric buses took place in the bus services that were procured by local authorities. However, in one case, the public authorities owned the buses themselves and, in both cases, national funding was important to overcome the high investment costs. The introduction also faced many challenges concerning uncertainties surrounding contractual responsibilities.

Two general ways of successfully introducing electric buses seemed to be to run test projects in order to identify an optimal solution for the specific case and to achieve a functioning collaboration early in the process. Regarding the cost challenge, some studies point out that under the right circumstances, operational costs can compensate for high investment costs and make the total cost of ownership less expensive than for other fuel. This belief was shared by some stakeholders interviewed in my papers, although the uncertainties are still high. Thus, national government funding might also be helpful to early introduction.

Electric buses are seen as a desirable solution in cities since they have zero emissions or noise in the operational phase. They are also more energy efficiency than other buses. However, emission of GHG are dependent on the source of electricity. If the electricity stems from renewable sources, it can result in very low emissions. However, if the source of electricity is fossil, GHG emissions can be higher than the emissions produced by a conventional diesel bus. Battery production is also a challenge for both environmental and social sustainability.

Table 7 provides a summarising comparison of the main ways that the introduction of biodiesel, biogas and electricity are affected by factors identified as influential in this thesis. It also includes a comparison of the environmental and climate effect from the fuel.

	Biodiesel	Biogas	Electric buses
Strategies, goals and top management	Sector recommendation to increase the share of renewable fuel has benefited biodiesel in procurement contracts	Needs regional political support. Often part of regional biogas strategies.	National funding can help overcome high investment costs
Cost	Lowest investment costs	Increased investment costs for gas buses and possibly infrastructure	Increased investment costs for electric buses, batteries and possibly infrastructure. Possible lower TCO due to low operational costs.
Knowledge, information and collaboration	Low need for specialised knowledge	Requires knowledge of the biogas market and availability. Collaborations with stakeholders in biogas market needed	Many uncertainties and new stakeholders, test projects and collaboration between stakeholders have been necessary
Environmental criteria	Functional requirements for share of renewable fuel has resulted in biodiesel	Has been introduced through specific requirements	Has been introduced through specific requirements. Difficult to set requirements due to many unknown factors
Size	Found in all regions, all traffic and all procurement contract sizes	Most common in large procurement contracts in city and local traffic, although all regional sizes	Only in local and city traffic.
Current operation	No modifications	No modifications	Shorter range challenges for current lengths of bus routes, scheduling and high passenger demand in some cities.
Availability	Uncertainty of future availability of biodiesel for public transport	Availability of biogas production and distribution and fuelling infrastructure varies across regions	Availability of space and connection for top-up charging differ between cities
Climate impact	Small to large positve effect dependent on feedstock and how it is processed	Medium to large positve effect depending on feedstock	Zero to large positive effect depending on source
Local environmental effects from exhaust emissions	Negligible effect	Medium positive effect	Large positive effect for air and noise pollution
Other environmental effects	Negative effect on land use and biodiversity	Dependent on feedstock. Can negatively affect land use and biodiversity. Can also have positive effects when regional waste, sludge and manure is used	Dependent on the source of electricity. Battery production can have negative environmental and social effects

7 Conclusions and further research

The shift away from fossil fuel in the public transport sector in Sweden is interesting to study due to the unusually high share of renewable fuel. The introduction has happened more quickly and without any additional pressure from the EU or the national level compared to the rest of the transport sector. High targets have been set by a partnership organisation for the public transport sector in Sweden and most regional public transport authorities have their own strategies and targets. The aim of this thesis has been to analyse the introduction of renewable fuel from the perspective of the stakeholders involved on the regional and local levels. Through my papers, I have contributed to this aim by studying: 1) how organisational and local and regional contextual factors influence the introduction of renewable fuel, 2) the challenges and opportunities of using green public procurement as a policy tool to introduce renewable fuel in the public transport sector, and 3) how the challenges and opportunities for introduction differ depending on the choice of renewable fuel.

The way in which the public transport sector is organised regarding who is responsible for strategic and tactical planning and operation significantly impacts the introduction of renewable fuel. Depending on the organisation responsible for the introduction, the motivation to introduce renewable fuel varies, which leads to different strategic decisions being made. It has been noted that the more that responsibility is left to the private sector, the more focus is on finding the most cost effective solution, while public authorities tend to take the wider societal gains into consideration to a higher extent. For example, when public transport authorities own and operate buses themselves, or choose to set specific requirements in tender documents, the motivation is often to develop a biogas market or address air and noise pollution by introducing electric buses. However, when the choice of renewable fuel is left to private operators, the most cost effective solution is chosen. In the cases studied in this thesis, this meant that biodiesel was introduced, which has no wider benefits for a region in terms of addressing local environmental issues or using regional resources.

Apart from the influence of organisation, local and regional contextual factors also influence the challenges and opportunities to introduce renewable fuel. Depending on the type of traffic in which the fuel are to be introduced - regional or urban traffic - the various kinds of renewable fuel are more or less beneficial. The size of a region, city or procuring entity can influence the resources available, such as finances and

knowledge, but also the perceived possibilities of influencing the market. What is available in terms of fuel production, distribution of fuel, charging and fuelling infrastructure from before can also influence the choice of fuel. For the introduction of electric buses in particular, current operational factors can influence the introduction. For example, shorter range could be a challenge depending on the length of bus routes, and top-up charging could be difficult to incorporate into current scheduling. Political support, particularly regional strategies and the acceptance of increased costs, but also national policy instruments, also influence the decisions that are made regarding the type of fuel in the regions. It is therefore important to note that there is not one right solution for introducing renewable fuel; instead, the organisational and contextual prerequisites must be considered regarding the introduction in each case.

The main way to organise the public transport sector in Sweden is by giving responsibility to the regional public transport authorities which, in most cases, contract out the operational responsibilities to private operators. This creates challenges and opportunities for green public procurement to be a highly relevant focus area when studying the introduction of renewable fuel. In Sweden, technical specifications in tender documents are the main way that regional PTAs have chosen to influence the type of fuel and almost all tender documents include environmental technical specifications. Nevertheless, the share and type of renewable fuel still differs across Swedish regions and across regional and urban bus services. A main difference seems to be the choice between setting functional or specific requirements. Functional requirements are seen as a cost effective solution, in which more responsibility is left to operators to find the best solution to achieve goals for the share of renewable fuel or reduction in emissions. This has exclusively led to the introduction of biodiesel in the studied cases. Through specific requirements, on the other hand, the PTAs retain more of the responsibility by requesting a specific fuel, such as biogas or electricity, with the aim of creating a market or achieving wider societal and environmental benefits in the region.

Another conclusion drawn in my paper is that organisational and contextual factors affect the introduction of renewable fuel differently depending on their individual characteristics. The motivation for introducing renewable fuel also differs. Biofuel comprises a large share of renewable fuel in the Swedish public transport sector. Whereas biodiesel is seen as a cost efficient and easy way to replace diesel as a fuel, the introduction of biogas is an important way for regional authorities to contribute to the development of a biogas market. Increased interest in electric buses for addressing local pollution problems is primarily seen in urban areas. However, electric buses still comprise a small share of the Swedish bus fleet. Nevertheless, a rapid increase has been noted in which the introduction in recent years has moved from test projects to introduction under current procurement contracts, to large scale procurements. A further increase in electric buses is likely because of increasing pressure from the EU (Directive 2019/1161) to increase the share of zero- emission

buses in procured bus services, as well as uncertainties around the share of high blend biofuel being available for public transport in the future.

This thesis contributes to addressing research gaps for both the introduction of renewable fuel, as well as in the literature on GPP. For the introduction of renewable fuel, it contributes with comparisons of different renewable fuel, instead of treating renewable fuel as a single entity or focusing only on one fuel. It also provides experience from a best practise case by studying a country that has progressed far in the introduction. However, it is worth noting that the high share of biofuel in transport is rather unique for Sweden and might not be an option in all countries. Even if the present Swedish public transport sector has reached a level of over 90% renewable fuel, this does not mean that the introduction of renewable fuel has been accomplished. The use of electric buses has just started to increase in urban areas and is likely to replace some of the biofuel. It is also reasonable to assume that the environmental requirements in public procurement will keep developing and, for example, more focus on energy-efficiency requirements could benefit different fuel than is the case today. This thesis also contributes with best practice experience of the uptake of GPP by further analysing how common factors such as strategies, cost, size, knowledge and requirements influence the use of GPP in the public transport sector. Further, this thesis provides detailed comparisons of how technical specifications can be expressed and the challenges and opportunities this entails. It also highlights the importance of not just looking at the uptake of GPP, but also at the differences depending on the type of requirements, such as functional requirements, compared to specific requirements. This is an important concern for the involved stakeholders, but is lacking in the academic literature.

Based on the findings in the thesis a few general recommendations for introduction of renewable fuel in the public transport sector can be provided. These recommendations includes to carefully reflect over what the main goal for introducing renewable fuel in the specific case is and which resources are available. Depending on the motivation and recourses available different implementation strategies can be more suitable. If the goal of introducing renewable fuel is to contribute to general climate targets in the most cost efficient way for the public transport sector, setting functional requirements for share of renewable fuel or decrease of GHG emissions can be a good option. Functional requirements allow for competition and leave the choice of fuel to the private operator. If the goal is to also contribute to environmental and societal sustainability measures locally, such as air and noise pollution or support of market development of a specific fuel, it might be necessary for the public authority to keep more of the control over the type of fuel. This can be done by setting more ambitious functional requirements and by describing the wished function in more detail by for example setting ambitious requirements for air or noise pollution. Another option is to set specific requirements for a fuel. However, steering towards a specific fuel requires high knowledge of the requested fuel (for example availability of production, distribution,

fuelling/charging and technical capacity). Ways to gain knowledge often include collaboration, for example by running test projects before procuring or by introducing the first buses under the current contract in collaboration with the operators. In case the type of fuel leads to higher costs, financial resources must also be available. It is therefore important to be aware of available national funding or having regional political acceptance of increased costs, for example as part of achieving broader regional strategies.

Even though the research in this thesis has contributed to interesting learning experiences there is much further research to be conducted on similar topics. Since the focus in this thesis was on introducing renewable fuel by using public procurement through technical specifications in the Swedish context, it would also be interesting to compare the findings from this study with the introduction in other countries. This could be accomplished through a comparison of countries that procure their transport using different kinds of environmental criteria such as award criteria. Also, comparisons with countries in which most public transport services are organised either based on open market entry or public management would be interesting for future research. Regarding GPP research, it would be relevant to further compare the motivations and outcomes of setting functional or specific requirements to establish whether the findings from the public transport sector also apply to other sectors.

References

ACEA (2021a) *Medium and heavy buses (over 3.5 T) New registrations by fuel type in the European Union*.

ACEA (2021b) *Vehicles in use Europe*.

Aldenius, M. *et al.* (2016) *Elektrifiering av stadsbussar - En genomgång av erfarenheter i Sverige och Europa*. Lund. Available at: https://www.k2centrum.se/elektrifiering-av-stadsbussar.

Ammenberg, J. *et al.* (2018) 'Biogas in the transport sector—actor and policy analysis focusing on the demand side in the Stockholm region', *Resources, Conservation and Recycling*. Elsevier, 129, pp. 70–80. doi: 10.1016/j.resconrec.2017.10.010.

Ammenberg, J. and Dahlgren, S. (2021a) 'Sustainability assessment of public transport, part I - A Multi-Criteria Assessment Method to Compare Different Bus Technologies', *Sustainability (Switzerland)*, 13(825), pp. 1–32. doi: 10.3390/su13031273.

Ammenberg, J. and Dahlgren, S. (2021b) 'Sustainability assessment of public transport, part II -applying a multi-criteria assessment method to compare different bus technologies', *Sustainability (Switzerland)*, 13(3), pp. 1–32. doi: 10.3390/su13031273.

Bakker, S. and Konings, R. (2018) 'The transition to zero-emission buses in public transport – The need for institutional innovation', *Transportation Research Part D: Transport and Environment*. Elsevier, 64(August 2017), pp. 204–215. doi: 10.1016/j.trd.2017.08.023.

Banister, D. (2008) 'The sustainable mobility paradigm', *Transport Policy*. Elsevier, 15(2), pp. 73–80. doi: 10.1016/j.tranpol.2007.10.005.

Bloomberg New Energy Finance (2018) *Electric Buses in Cities - Driving Towards Cleaner Air and Lower CO2*.

Borén, S. and Grauers, A. (2019) 'Stakeholder Collaboration Models for Public Transport Procurement of Electric Bus Systems', *The International Journal of Sustainability Policy and Practice*, 15(1), pp. 19–29. doi: 10.18848/2325-1166/CGP/v08i01/55360.

Brammer, S. and Walker, H. (2011) 'Sustainable Procurement in the Public Sector: An International Comparative Study', *International Journal of Operations & Product Management*, 31(4), pp. 452–476.

Bratt, C. *et al.* (2013) 'Assessment of criteria development for public procurement from a strategic sustainability perspective', *Journal of Cleaner Production*. Elsevier Ltd, 52, pp. 309–316. doi: 10.1016/j.jclepro.2013.02.007.

Butcher, L. and Dempsey, N. (2018) *Bus Services Act 2017, Briefing paper*. Available at: https://researchbriefings.files.parliament.uk/documents/CBP-7545/CBP-7545.pdf.

Cheng, W. *et al.* (2018) 'Green Public Procurement, missing concepts and future trends – A critical review', *Journal of Cleaner Production*. Elsevier Ltd, 176(December), pp. 770–784. doi: 10.1016/j.jclepro.2017.12.027.

Chersan, I. C. *et al.* (2020) 'Green Public Procurement in the Academic Literature', *Amfiteatru Economic*, 22(53), pp. 82–101. doi: 10.24818/ea/2020/53/82.

Clean Fleets (2014) *Clean Buses – Experiences with Fuel and Technology Options*. Available at: www.clean-fleets.eu.

Corazza, M. V. *et al.* (2016) 'A new generation of buses to support more sustainable urban transport policies: A path towards "greener" awareness among bus stakeholders in Europe', *Research in Transportation Economics*. Elsevier Ltd, 55, pp. 20–29. doi: 10.1016/j.retrec.2016.04.007.

Dahlgren, S. and Ammenberg, J. (2021) 'Sustainability assessment of public transport, part II -applying a multi-criteria assessment method to compare different bus technologies', *Sustainability (Switzerland)*, 13(3), pp. 1–32. doi: 10.3390/su13031273.

Dickinson, J. and Wretstrand, A. (2015) *Att styra mot ökad kollektivtrafikandel*. Lund. Available at: https://www.k2centrum.se/att-styra-mot-ökad-kollektivtrafikandel.

Edquist, C. and Zabala-Iturriagagoitia, J. M. (2020) 'Functional procurement for innovation, welfare, and the environment', *Science and Public Policy*, pp. 1–9. doi: 10.1093/scipol/scaa046.

Esaiasson, P. *et al.* (2017) *Metodpraktikan. Konsten att studera samhälle, individ och marknad*. 5th edn. Stockholm: Wolters KluwerSverige AB.

European Commission (2004) *Buying Green! A handbook on environmental public procurement*. Brussels.

European Commission (2011) *White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*. Brussels.

European Commission (2016a) *A European Strategy for low- emission mobility*. Brussels.

European Commission (2016b) *Buying green! A handbook on green public procurement*, *Planning*. Luxembourg. doi: 10.1038/scientificamericanearth1208-80.

European Commission (2019) *EU green public procurement criteria for road transport*. Brussels.

European Commission (2020a) *State aid: Commission approves prolongation of tax exemption for non food-based biogas and bio propane used for heating or as motor fuel in Sweden*. Available at: https://ec.europa.eu/info/news/state-aid-commission-approves-prolongation-tax-exemption-non-food-based-biogas-and-bio-propane-used-heating-or-motor-fuel-sweden-2020-jun-29_en (Accessed: 12 August 2021).

European Commission (2020b) *State of the Art on Alternative Fuels Transport Systems in the European Union*. Brussels.

European Council (2014) *2030 climate and energy policy framework*. Brussels.

Fallde, M. and Eklund, M. (2015) 'Towards a sustainable socio-technical system of biogas for transport: The case of the city of Linköping in Sweden', *Journal of Cleaner Production*. Elsevier Ltd, 98, pp. 17–28. doi: 10.1016/j.jclepro.2014.05.089.

Fenton, P. and Kanda, W. (2017) 'Barriers to the diffusion of renewable energy: studies of biogas for transport in two European cities', *Journal of Environmental Planning and Management*. Taylor & Francis, 60(4), pp. 725–742. doi: 10.1080/09640568.2016.1176557.

Forbord, M. and Hansen, L. (2020) 'Enacting sustainable transitions: A case of biogas production and public transport in Trøndelag, Norway', *Journal of Cleaner Production*. Elsevier Ltd, 254, p. 120156. doi: 10.1016/j.jclepro.2020.120156.

Fuel Cell Electric Buses (2021) *Towards Clean Public Transport with Hydrogen*. Available at: https://fuelcellbuses.eu/ (Accessed: 17 August 2021).

Fuentes-Bargues, J. L. *et al.* (2019) 'Green public procurement at a regional level. Case study: The valencia region of Spain', *International Journal of Environmental Research and Public Health*, 16(16). doi: 10.3390/ijerph16162936.

Glotz-Richter, M. and Koch, H. (2016) 'Electrification of Public Transport in Cities (Horizon 2020 ELIPTIC Project)', *Transportation Research Procedia*. Elsevier B.V., 14, pp. 2614–2619. doi: 10.1016/j.trpro.2016.05.416.

Government Offices (2017) *Det klimatpolitiska ramverket*. Available at: https://www.regeringen.se/artiklar/2017/06/det-klimatpolitiska-ramverket/ (Accessed: 7 May 2021).

Grauers, A., Bor, S. and Enerbäck, O. (2020) 'Total Cost of Ownership Model and Significant Cost Parameters for the Design of Electric Bus Systems', *Energies*, 13(12).

Günther, E. *et al.* (2013) 'The "why not"–perspective of green purchasing: a multilevel case study analysis', *Journal of Change Management*, 13(4), pp. 407–423.

Halkier, B. (2011) 'Methodological practicalities in analytical generalization', *Qualitative Inquiry*, 17(9), pp. 787–797. doi: 10.1177/1077800411423194.

Häll, C. H. *et al.* (2019) 'Adjustments of public transit operations planning process for the use of electric buses', *Journal of Intelligent Transportation Systems*. Taylor & Francis, 23(3), pp. 216–230. doi: 10.1080/15472450.2018.1488131.

Hickman, R. and Banister, D. (2015) *Transport, Climate Change and the City*. 1st edn. London: Routledge.

Holmberg, B. (2013) *Ökad andel kollektivtrafik - hur? : en kunskapssammanställning*. Lund.

House of Commons Transport Committee (2019) *Bus services in England outside London, Ninth Report of Session 2017–19*. London. Available at: https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/1425/1425.pdf.

IEA (2020) *Tracking Transport 2020*. Paris. Available at: https://www.iea.org/reports/tracking-transport-2020.

International Transport Forum (2020) *Reforming public transport planning and delivery*. Available at: https://www.itf-oecd.org/reforming-public-transport-planning-and-delivery%0Ahttps://trid.trb.org/view/1696179.

Johansson, B. (2021) *Utfasning av fossila drivmedel. En analys av hur skatter, utsläppsrätter och reduktionsplikt kan bidra.* Lund.

Kassarjian, H. H. (1977) 'Content Analysis in Consumer Research', *Journal of Consumer Research*, 4(1), pp. 8–18. doi: 10.1086/208674.

Krawiec, S. *et al.* (2016) 'Urban public transport with the use of electric buses - Development tendencies', *Transport Problems*, 11(4), pp. 127–137. doi: 10.20858/tp.2016.11.4.12.

Krippendorff, K. (2004) *Content Analysis: An Introduction to its Methodology.* Second, *SAGE Publications*. Second. Thousand Oaks. doi: 10.2307/2288384.

Kvale, S. and Brinkman, S. (2009) *InterViews: Learning the Craft of Qualitative Research Interviewing*. London: Sage Publications, Inc.

Lajunen, A. (2018) 'Lifecycle costs and charging requirements of electric buses with different charging methods', *Journal of Cleaner Production*. Elsevier Ltd, 172, pp. 56–67. doi: 10.1016/j.jclepro.2017.10.066.

Li, X., Castellanos, S. and Maassen, A. (2018) 'Emerging trends and innovations for electric bus adoption — a comparative case study of contracting and financing of 22 cities in the Americas , Asia- Pacific , and Europe', *Research in Transportation Economics*. Elsevier, 69, pp. 470–481. doi: 10.1016/j.retrec.2018.06.016.

Lidestam, H., Johansson, A. and Pydokke, R. (2016) *Kontraktsformer och deras inverkan på svensk kollektivtrafik - En kunskapsöversikt*. Lund.

Lindfors, A. and Ammenberg, J. (2021) 'Using national environmental objectives in green public procurement: Method development and application on transport procurement in Sweden', *Journal of Cleaner Production*. Elsevier Ltd, 280, p. 124821. doi: 10.1016/j.jclepro.2020.124821.

Lindström, V. *et al.* (2017) *En studie om förnybara drivmedel och dess förutsättningar i norra Sverige*. Umeå.

Lundberg, S. and Marklund, P.-O. (2013) 'Green Public Procurement as an Environmental Policy Instrument: cost effectivness', *Environmental Economics*, 4(4), pp. 85–119.

Lundberg, S. and Marklund, P. O. (2018) 'Green public procurement and multiple environmental objectives', *Economia e Politica Industriale*, 45(1). doi: 10.1007/s40812-017-0085-6.

Lundberg, S., Marklund, P. O. and Strömbäck, E. (2016) 'Is Environmental Policy by Public Procurement Effective?', *Public Finance Review*, 44(4), pp. 478–499. doi: 10.1177/1091142115588977.

Lundmark, R. *et al.* (2021) 'Establishing local biogas transport systems: Policy incentives and actor networks in Swedish regions', *Biomass and Bioenergy*, 145, p. 105953. doi: 10.1016/j.biombioe.2020.105953.

Lundström, A. *et al.* (2019) *Elbussar i Sveriges kollektivtrafik - En kartläggning av Trafikförvaltningen Stockholm, Skånetrafiken och Västtrafik utifrån fyra perspektiv*. Solna.

Marron, D. (2003) 'Greener Public Purchasing as an Environmental Policy Instrument', *Journal on Budgeting*, 3(4), pp. 71–105.

Marron, D. B. (1997) 'Buying green: Government procurement as an instrument of environmental policy', *Public Finance Review*, 25(3), pp. 285–305.

McKenzie, E. C. and Durango-Cohen, P. L. (2012) 'Environmental life-cycle assessment of transit buses with alternative fuel technology', *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 17(1), pp. 39–47. doi: 10.1016/j.trd.2011.09.008.

Michelsen, O. and de Boer, L. (2009) 'Green procurement in Norway; a survey of practices at the municipal and county level', *Journal of Environmental Management*. Elsevier Ltd, 91(1), pp. 160–167. doi: 10.1016/j.jenvman.2009.08.001.

Mohamed, M., Ferguson, M. and Kanaroglou, P. (2018) 'What hinders adoption of the electric bus in Canadian transit? Perspectives of transit providers', *Transportation Research Part D: Transport and Environment*. Elsevier, (Article in press). doi: 10.1016/j.trd.2017.09.019.

Mutter, A. (2019) 'Obduracy and change in urban transport-understanding competition between sustainable fuels in swedish municipalities', *Sustainability (Switzerland)*, 11(21). doi: 10.3390/su11216092.

Nordelöf, A., Romare, M. and Tivander, J. (2017) *Miljöpåverkan från elektriska stadsbussar - Livscykelanalys av kollektivtrafikbussar drivna med elektricitet, biobränslen och diesel baserat på ElectriCity-linjen*. Gothenburg. Available at: http://publications.lib.chalmers.se/records/fulltext/254814/254814.pdf.

von Oelreich, K. and Philp, M. (2013) *Green public procurement - A tool for achieving national environmental quality objectives*. Stockholm. doi: 10.2779/93178.

Partnership for improved public transport (2010a) *Branschgemensamt miljöprogram 2010*.

Partnership for improved public transport (2010b) *Miljökrav vid trafikupphandling 2010*.

Partnership for improved public transport (2011) *Miljökrav vid trafikupphandling 2011*.

Partnership for improved public transport (2013) *Branschgemensamt miljöprogram 2013*.

Partnership for improved public transport (2014) *Miljökrav vid trafikupphandling - buss 2014*.

Partnership for improved public transport (2018a) *Branschgemensamt miljöprogram 2018*.

Partnership for improved public transport (2018b) *Miljökrav vid trafikupphandling - buss 2018*.

Partnership for improved public transport (no date) *Miljösatsningar för ett långsiktigt miljöarbete*. Available at: https://www.svenskkollektivtrafik.se/partnersamverkan/miljo/ (Accessed: 19 August 2021).

Patil, A., Herder, P. and Brown, K. (2010) 'Investment Decision Making for Alternative Fuel Public Transport Buses: The Case of Brisbane Transport', *Journal of Public Transportation*, 13(2), pp. 115–133. doi: 10.5038/2375-0901.13.2.6.

Patton, M. (1990) *Qualitaive evaluation and research methods*. Beverly Hills: Sage.

Preuss, L. (2007) 'Buying into our future: Sustainability initiatives in local government procurement', *Business Strategy and the Environment*, 16(5), pp. 354–365. doi: 10.1002/bse.578.

Preuss, L. (2009) 'Addressing sustainable development through public procurement: The case of local government', *Supply Chain Management*, 14(3), pp. 213–223. doi: 10.1108/13598540910954557.

Quintero, R. R. *et al.* (2019) *Revision of the EU Green Public Procurement Criteria for Transport*. Luxembourg. doi: 10.2760/700836.

Riksdagsskrivelse (no date) *Nationell strategi för hållbar regional utveckling i hela landet 2021–2030*. Available at: https://www.riksdagen.se/sv/dokument-lagar/dokument/riksdagsskrivelse/riksdagsskrivelse-202021133_H80K133.

Ringqvist, S. (2016) *Kollektivtrafikens styrning och organisering: Utveckling och erfarenheter av lokal och regional kollektivtrafik 1970 - 2015*. Lund.

Rosell, J. (2021) 'Getting the green light on green public procurement: Macro and meso determinants', *Journal of Cleaner Production*. Elsevier Ltd, 279, p. 123710. doi: 10.1016/j.jclepro.2020.123710.

Rye, T. *et al.* (2018) 'The relationship between formal and informal institutions for governance of public transport', *Journal of Transport Geography*. Elsevier, 69, pp. 196–206. doi: 10.1016/j.jtrangeo.2018.04.025.

Srivastava, P. and Hopwood, N. (2009) 'A Practical Iterative Framework for Qualitative Data Analysis', *International Journal of Qualitative Methods*, 8(1), pp. 76–84. doi: 10.1177/160940690900800107.

Statistics Sweden (2021) *Statistikdatabasen*. Available at: https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/ (Accessed: 12 July 2021).

Swedish Association of Local Authorities and Regions (2021) *Fakta om kommuner och regioner*. Available at: https://skr.se/skr/tjanster/kommunerochregioner/faktakommunerochregioner.1022.html (Accessed: 28 June 2021).

Testa, F. *et al.* (2012) 'What factors influence the uptake of GPP (green public procurement) practices? New evidence from an Italian survey', *Ecological Economics*. Elsevier B.V., 82, pp. 88–96. doi: 10.1016/j.ecolecon.2012.07.011.

Testa, F. *et al.* (2016) ‘Drawbacks and opportunities of green public procurement: An effective tool for sustainable production’, *Journal of Cleaner Production*. Elsevier Ltd, 112, pp. 1893–1900. doi: 10.1016/j.jclepro.2014.09.092.

The Swedish Bus and Coach Federation (2019a) *Goda exempel kan bana väg för bättre offentliga upphandlingar av busstrafik*. Stockholm.

The Swedish Bus and Coach Federation (2019b) *Statistik om bussbranchen*. Stockholm.

The Swedish Bus and Coach Federation (2020) *Statistik om bussbranschen*. Stockholm.

The Swedish Confederation of Transport Enterprises (no date) *Om förbundet*. Available at: https://www.transportforetagen.se/om-oss/vara-branscher/sveriges-bussforetag/forbundets-verksamhet/om-forbundet/ (Accessed: 19 August 2021).

The Swedish Energy Agency (2016) *Marknaderna för biodrivmedel 2016*. Eskilstuna.

The Swedish Energy Agency (2019) *Informationsstöd om elbussupplägg till kollektivtrafikhuvudmän - Åtagande i den strategiska planen för omställning av transportsektorn till fossilfrihet (SOFT)*. Bromma.

The Swedish Environmental Protection Agency (2021) *Om Klimatklivet*. Available at: https://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Uppdelat-efter-omrade/Klimat/Om-Klimatklivet/ (Accessed: 29 June 2021).

The Swedish Public Transport Association (2009) ‘Miljökrav vid trafikupphandling 2009’, pp. 1–34.

The Swedish Public Transport Association (2021) *FRIDA miljö- och fordonsdatabas*. Available at: http://www.frida.port.se/hemsidan/default.cfm (Accessed: 28 June 2021).

The Swedish Public Transport Association (no date) *Miljökrav vid trafikupphandling*. Available at: https://www.svenskkollektivtrafik.se/partnersamverkan/modellavtal--kravbilagor/miljokrav-vid-trafikupphandling/ (Accessed: 8 August 2019).

The Swedish Tax Agency (2021) *Energiskatter*. Available at: https://skatteverket.se/foretag/skatterochavdrag/punktskatter/energiskatter.4.18e1b10334ebe8bc8000843.html (Accessed: 20 August 2021).

Transport Analysis (2015) *Lokal och regional kollektivtrafik 2014*. Stockholm.

Transport Analysis (2018) *Avtal för upphandlad Rapport kollektivtrafik 2015*. Stockholm.

Transport Analysis (2020) *Regional linjetrafik 2019*. Available at: https://www.trafa.se/kollektivtrafik/kollektivtrafik/.

United Nations (no date) *The 17 goals*. Available at: https://sdgs.un.org/goals (Accessed: 28 June 2021).

USDA Foreign Agricultural Services (2019) *EU Biofuels Annual 2019*. Available at: http://gain.fas.usda.gov/Recent GAIN Publications/Biofuels Annual_The Hague_EU-28_7-3-2014.pdf.

Varga, B. O. and Iclodean, C. (2015) 'Electric buses for urban transportation: assessments on cost, infrastructure and exploitation', *Fascicle of Management and Technological Engineering*, (1), pp. 253–258.

Van De Velde, D. M. (1999) 'Organisational forms and entrepreneurship in public transport. Part 1: Classifying organisational forms', *Transport Policy*, 6(3), pp. 147–157. doi: 10.1016/S0967-070X(99)00016-5.

van de Velde, D. (2008) 'A new regulation for the European public transport', *Research in Transportation Economics*, 22(1), pp. 78–84. doi: 10.1016/j.retrec.2008.05.011.

van de Velde, D. (2014) 'Market initiative regimes in public transport in Europe: Recent developments', *Research in Transportation Economics*. Elsevier Ltd, 48, pp. 33–40. doi: 10.1016/j.retrec.2014.09.029.

van de Velde, D. and Wallis, I. (2013) '"Regulated deregulation" of local bus services-An appraisal of international developments', *Research in Transportation Economics*. Elsevier Ltd, 39(1), pp. 21–33. doi: 10.1016/j.retrec.2012.05.020.

Vigren, A. (2015) *Costs in Swedish Public Transport*. KTH Royal Institute of Technology. Available at: http://www.diva-portal.org/smash/get/diva2:860480/FULLTEXT01.pdf.

Walker, H. and Brammer, S. (2009) 'Sustainable procurement in the United Kingdom public sector', *Supply Chain Management*, 14(2), pp. 128–137. doi: 10.1108/13598540910941993.

Wendt-Rasch, L. *et al.* (2021) 'Chemical requirements in Swedish municipal green public procurement: Challenges and opportunities', *Journal of Cleaner Production*, 299. doi: 10.1016/j.jclepro.2021.126701.

Witjes, S. and Lozano, R. (2016) 'Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models', *Resources, Conservation and Recycling*. Elsevier B.V., 112, pp. 37–44. doi: 10.1016/j.resconrec.2016.04.015.

WSP (2014) *Särkravens betydelse för busstrafikens kostnader*. Stockholm.

Xu, Y. *et al.* (2015) 'Assessment of alternative fuel and powertrain transit bus options using real-world operations data: Life-cycle fuel and emissions modeling', *Applied Energy*, 154, pp. 143–159. doi: 10.1016/j.apenergy.2015.04.112.

Xylia, M. and Silveira, S. (2017) 'On the road to fossil-free public transport: The case of Swedish bus fleets', *Energy Policy*, 100, pp. 397–412. doi: 10.1016/j.enpol.2016.02.024.

Yin, R. K. (2006) *Case Study Research*. 1st edn. Malmö: Liber AB.

Yu, C., Morotomi, T. and Yu, H. (2020) 'What influences adoption of green award criteria in a public contract? An empirical analysis of 2018 european public procurement contract award notices', *Sustainability (Switzerland)*, 12(3). doi: 10.3390/su12031261.

Zeeus (2017) *Analysis of Existing Legislation and Funding Applicable to Urban Electric Buses*.

Zeeus (2018) *Tender Structure for Urban Electric Bus Procurement*.