REPORT f3 2019:02

BIOGAS IN THE TRANSPORT SECTOR – AN ACTOR AND POLICY ANALYSIS OF STOCKHOLM COUNTY

Report from a project within the collaborative research program *Renewable transportation fuels* and systems (Förnybara drivmedel och system)

March 2019

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THE SWEDISH KNOWLEDGE CENTRE
FOR RENEWABLE TRANSPORTATION FUELS

PREFACE

This project has been carried out within the collaborative research program *Renewable transportation fuels and systems* (Förnybara drivmedel och system), Project no. 39595-1. The project has been financed by the Swedish Energy Agency and f3 – Swedish Knowledge Centre for Renewable Transportation Fuels.

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- Provides a broad, scientifically based and trustworthy source of knowledge for industry, governments and public authorities
- Carries through system oriented research related to the entire renewable fuels value chain
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The work resulting in this report has been conducted at KTH (Division of Energy Processes, Department of Chemical Engineering and Technology as well as Department of Industrial Economics and Management) and Linköping University (Department of Management and Engineering) by the authors stated on the front page. Linda Olsson was also part of the project and conducted several of the interviews on which the analysis builds. She also contributed to the design of the interview study. Stockholm Gas has also been a project partner and provided valuable input.

This report should be cited as:

Lönnqvist, T. Ammenberg, J., Grönkvist, S., Anderberg, S., Sandberg, T. (2019) *Biogas in the transport sector – an actor and policy analysis of Stockholm county.* Report No 2019:02, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden. Available at www.f3centre.se.

SUMMARY FOR POLICY MAKERS

Biogas has been used as a transportation fuel in Sweden for over two decades and the technology for production, distribution and use is now established at a commercial scale in the more heavily populated areas of the country. Despite this and an underutilized domestic feedstock potential from waste and energy crops, the use is still limited in comparison to other established renewable transportation fuels such as hydrotreated vegetable oils (HVO) or fatty acid methyl esters (FAME).

This project has investigated the conditions for production, distribution and use of biogas in transport in a Swedish region – Stockholm County – from a bottom-up perspective. The region differs in some respects to other Swedish regions with a developed use of biogas regarding the conditions for biogas in transport. Stockholm County does not have access to a natural gas pipeline and the potential feedstock composition is somewhat different. Stockholm has a larger share of urban waste and a smaller share of industrial residues suitable for biogas production. However, the individual actors involved in production and use of biogas are often comparable with actors in other parts of the country and the results may thus be generalized. Information was gathered in 21 interviews performed with actors representing production, distribution and use of biogas.

The main aim of the project has been to increase the knowledge about the conditions for biogas development in the transport sector by presenting, discussing, and analyzing the views from actors involved in biogas production and use of biogas in transport. Another objective is to provide insights about policy instrument that promote and may promote biogas development, considering – but not limited to – the actors' perspective. This report is thus intended to support policy decision makers.

The interviews were semi-structured in the sense that the actors had the possibilities to describe their position or view on topics not covered by the interview guideline that was sent to the interviewee prior to the interview. The interview guidelines were adapted to the individual actor and the focus was to get a bottom-up perspective, even concerning factors that affect other, or all, parts of the chain from supply to use of biogas in transport.

The use of biogas in the Swedish transport sector has experienced a slow but steady increase since the start in the end of the 1990s. However, during recent years, the demand for vehicle gas has stagnated, while the production of upgraded biogas has continued to increase. As a result, the share of biogas in vehicle gas[1] has increased in the country. The development is similar in Stockholm County, but the stagnating trend for vehicle gas started earlier here – in 2013 instead of in 2014 for Sweden as a whole. The use of upgraded biogas in the region is mainly found in public bus transport and taxi services and the users are part of a system that may be considered as a Large Technical System (LTS) at a relatively early stage of development. The studies of LTSs is a theoretical framework used to understand the development of huge and complex technical networks such as the electricity system or the internet.

Even with the stagnated demand for vehicle gas, the interviewees identified opportunities that may help in the continued development and growth of biogas production. Examples of such opportunities were:

[1] A term used in Sweden to describe a blend of biogas and natural gas.

- improved and increased sorting of household wastes would make more feedstock available,
- improved yield in biogas production,
- improved and expanded use of the digestate from anaerobic fermentation as a way of improving the profitability and nutrients recycling as part of a circular economy, and
- possibilities to reduce risks on the supply side through a more extensive use of short and long term contracts along the value chain in combination with improved cooperation.

However, societal benefits that biogas can bring, e.g. nutrients recycling and contribution to the circular economy, are not transmitted into economic incentives for the biogas producer.

The demand side does not have the same focus on biogas and may consider other renewable energy carriers to fulfill ambitions to become less dependent on fossil fuels or fossil-free in transport. Thus the focus among the interviewees – which commonly had an environmental responsibility for transports – was not on opportunities to develop biogas, but rather to develop the environmental ambitions of the public or private organization that use the biogas vehicles. It also became clear that the ambitions among the three interviewed municipalities were very different concerning the use of renewables in transport. Hence, the municipalities were also at different development stages regarding their shares of vehicles fueled by renewables.

The large taxi company Taxi Stockholm currently operates 1 600 taxis of which 70 % are gas-fueled, mainly due to the regulations at airports, which give priority to taxis with low estimated emissions. The vehicle choice of taxi companies is also affected by the definition of environmental cars, which has changed over time. The taxi fleet is renewed every three years and the share of gas vehicles may quickly change.

Another influential public actor is the public transport company SL that influence the fuel used by private transport operators in the county through public procurement. The bus fleet used for public transport in the county is 100 % fossil free since early 2017. SL demands that private operators use renewable transport fuels without directly specifying which one. However, biogas has a special position and SL demands that one of the operators should use a specified volume. As a consequence, 15 % of the 2 200 buses currently are fueled by biogas. Contracts between SL and private operators are long term and this has created stability and predictability for biogas development.

The interviews revealed a number of obstacles for a continued development of biogas in transport of which most were found on the demand side. The production side was awaiting clear positive signals from the market before deciding about further investments and such signals are hard to find when the market for vehicle gas is stagnating. The bottleneck of the biogas development may change over time. During 2010 and 2011, prior to the commissioning of a liquefied natural gas harbor in the region, the vehicle gas supply was insufficient at times. The supply problems have been solved, but they have caused a mistrust among the users that has been hard to repair. Another possible obstacle is the widespread interest for electricity in transport that is found among both public organizations and other users. The public organizations have acted as forerunners regarding renewables in transport and the signals from these users may very well be transferred to other users, not least through the second hand market for vehicles. The interviewees perceive that decision makers are easily distracted and have demonstrated a tendency to jump onto the latest ‘attractive option’ and thus only focus on one solution at a time, which currently is electric vehicles.

However, the major identified obstacle for a continued development of biogas in the transport sector is the unstable policy instruments that affect biogas. The policy instruments are directed towards all parts of the value chain from production and distribution to use, but currently, the interviewees see the policy instruments directed toward the demand side as the most crucial. Examples of policy instruments that are seen as unpredictable have been the premiums on new cars and vehicle tax reductions that are decided about in accordance with the current definition about what will be qualify as an environmental car. Another example is the reduced fringe benefit taxes provided for environmental cars for which the decisions have been taken every second year.

The late approval of the tax exemption for biogas in transport was also mentioned as an example of the low predictability of Swedish policy instruments. The tax exemption was approved in mid-December 2015, only two weeks before the previous period would have expired. The interviewees on the supply side emphasized that they cannot make any investment decisions under such circumstances.

The different proposals for a bonus-malus system[2] for cars have also sent confusing signals to the market and increased the uncertainty of Swedish policy instruments. The initial proposal from 2016 would have given disincentives to gas vehicles through an increased vehicle tax. This is a negative signal to the market, if the intention is to promote biogas development. The latest proposal for the bonus-malus system in 2017 would instead give incentives to gas vehicles. Nevertheless, the premium that would be granted to gas vehicles is relatively small. The low predictability of Swedish policy instruments and the stagnated demand side are related, but it is clear that policy instruments have supported biogas development. This development started in technological niches[3] and biogas in transport has started to become established as a commercial option. This development would not have taken place without policy support. It is also clear that further policy support is needed to increase the stagnated demand and for the use of biogas to spread from public actors to new user groups. Such user groups could be private owners of personal vehicles as well as haulage contractors.

Biogas is a young and developing sociotechnical system and the fronts of this system develop at different pace. System fronts is a term used within the aforementioned studies of LTS to represent parts of a system that are vital for the development and where the development has reached the furthest. In this case the system fronts may represent links in value chain from supply to use or actor networks. Currently the demand side is a front that lags. The policy framework is another front that lags and one indication of this is the recognized low predictability of Swedish policy instruments. This perception in itself may compromise the efficiency and effectiveness of policy instruments. Given this, it is likely that predictable policy support could stimulate the demand side and thereby create incentives for investments in increased production and an expanded distribution infrastructure.

[2] The bonus-malus system is a policy instrument that would support less environmentally harmful cars and disincentivize more environmentally harmful cars.
[3] A niche is a term used within the theoretical framework Multi Level Perspective (MLP) to describe a place where a technological innovation may develop without interference or pressure from the market at large. MLP is used to describe technological transitions.

Although the demand side is stagnating and is in immediate need of more support, it is also necessary to provide predictable policy support to the entire biogas value chain if biogas in transport should develop. This is because the system front(s) that lag(s) may vary over time. Stockholm County has for example experienced a period when the supply side was lagging. Policy decision makers may benefit from considering this dynamic in order to support the development of biogas in transport in an efficient manner.

SAMMANFATTNING

I Sverige har biogas använts som drivmedel i över två decennier och teknologin för produktion, distribution och användning är nu kommersiellt etablerad i landets mer tätbefolkade områden. Trots att biogas nu är ett etablerat drivmedel och att råvaror i form av avfall och energigrödor inte är fullt utnyttjade för biogasproduktion, så är användningen av biogas väldigt begränsad i jämförelse med andra drivmedel som hydrerade vegetabiliska oljor (HVO) eller fettsyrametylestrar (FAME).

I föreliggande projekt har förutsättningarna för produktion, distribution och användning av biogas för transportändamål i en svensk region - Stockholms län – studerats utifrån ett nedifrånperspektiv. Regionen skiljer sig från andra svenska regioner med en välutvecklad användning av biogas gällande tillgången till ett naturgasnät, där det inte finns något i Stockholmsregionen. Tillgången på, och fördelningen av, potentiella råvaror för biogasproduktion skiljer sig också i viss mån från andra svenska regioner. De enskilda aktörerna inom respektive del av värdekedjan för biogas är däremot ofta jämförbara med motsvarande aktörer i andra delar av landet och resultaten kan på så sätt vara generaliserbara. Information inhämtades genom 21 intervjuer med aktörer som representerade produktion, distribution och användning av biogas som drivmedel.

Projektets huvudsakliga syfte har varit att bidra till ökad kunskap om förutsättningarna för utveckling av biogas i transportsektorn genom att presentera, diskutera och analysera uppfattningar som aktörer från olika delar av biogasens värdekedja har. Ett annat syfte är att förmedla insikter om de styrmedel som stöttar eller kan tänkas stötta biogasens utveckling och perspektivet är här huvudsakligen aktörernas. En av intentionerna med den här rapporten är därför att vara ett stöd för politiska beslutsfattare.

Intervjuerna utformades så att de intervjuade aktörerna hade möjligheten att själva även beskriva sin hållning och synpunkter gällande områden som inte täcktes av den intervjuguide som skickades till intervjupersonerna innan intervjun. Intervjuguiderna var anpassade till den enskilde aktören och intervjuerna utformades så att nedifrånperspektivet blev tydligt, och det gällde även frågeställningar som berörde andra eller alla delar av värdekedjan för biogas som drivmedel.

Användandet av biogas i den svenska transportsektorn har långsamt men stadigt ökat sedan användningen av biogas som drivmedel startade i början av 1990-talet. Under de senaste åren har efterfrågan på fordonsgas stagnerat medan produktionen av uppgraderad biogas har fortsatt att öka, vilket har lett till att andelen biogas i fordonsgas har ökat i landet. Utvecklingen har varit liknande i Stockholms län men stagnationen började tidigare här – under 2013 istället för under 2014 för landet som helhet. I länet används uppgraderad biogas huvudsakligen i kollektivtrafik och i taxinäringen och användarna är del av ett system som kan betraktas som ett stort tekniskt system (large technical system, LTS) i ett tidigt skede av utvecklingen. Forskningsfältet stora tekniska system handlar om förståelsen av utvecklingen av omfattande och komplexa tekniska nätverk som elsystem eller internet.

De intervjuade kunde trots den stagnerade efterfrågan på fordonsgas hitta möjligheter till fortsatt utveckling och tillväxt av biogasproduktion. Exempel på sådana möjligheter var: ökad tillgång till råvaror för biogasproduktion genom förbättrad och ökad sortering av hushållsavfall, ökat utbyte i produktionsprocessen, förbättrad och ökad användning av rötrester som ett sätt att förbättra lönsamheten och återvinningen av näringsämnen i en cirkulär ekonomi samt möjligheter att minska risker på tillförselsidan genom en mer omfattande användning av kort- och långtidskontrakt mellan

parter längs värdekedjan i kombination med förbättrade samarbetsmöjligheter. Det framkom däremot att de övriga samhällsvinster som biogas kan medföra, exempelvis återvinning av näringsämnen och bidrag till en cirkulär ekonomi, inte genererade några ekonomiska incitament för biogasproducenten.

Användarsidan har inte samma fokus på biogas som tillförselsidan utan kan tänka sig andra förnybara energibärare för att tillfredsställa strävanden mot att bli mindre beroende eller oberoende av fossila drivmedel. De intervjuade, som ofta hade någon form av miljöansvar för transporter, hade därför inte som huvudsakliga målsättning att utveckla biogassystem som sådant utan att utveckla miljöambitionerna hos de offentliga och privata organisationer som använder biogasfordon. Intervjuerna visade också att de tre intervjuade kommunerna hade väldigt olika ambitioner gällande förnybara drivmedel och att de därför var i olika skeden av utvecklingen gällande andelen fordon som drivs med förnybara drivmedel.

Det stora taxibolaget Taxi Stockholm har en flotta på 1 600 taxibilar och 70 % av dessa är gasdrivna, vilket huvudsakligen beror på regler vid flygplatser som ger en form av förtur för taxibilar med låga utsläpp. Taxibolagens val av bilar beror också på definitionen av miljöbilar och den har varierat över tid. Eftersom taxiflottan förnyas vart tredje år kan andelen gasbilar komma att ändras fort vid förändrade förutsättningar.

En annan betydelsefull offentlig aktör är kollektivtrafiksoperatören SL som påverkar användningen av förnybara drivmedel hos olika transportbolag genom offentlig upphandling. På så sätt är den bussflotta som används för kollektivtrafik i Stockholms län helt fossilfri sedan början av 2017. Kraven från SL är generellt att de olika transportleverantörerna använder förnybara drivmedel utan att specificera vilka men biogas har en särställning för vilken SL har krävt att en av tranportleverantörerna ska använda en specificerad mängd. Som en följd av detta är 15 % av de 2 200 bussarna som SL har kontroll över biogasdrivna. De kontrakt som SL har med olika transportleverantörer är långsiktiga, vilket har skapat stabilitet och förutsägbarhet för utveckling av biogas i flera led.

Under intervjuerna framkom också flera hinder för fortsatt utveckling av biogas som drivmedel och flertalet av dessa återfinns på användarsidan. Tillförselsidan väntade på tydliga positiva signaler från marknaden innan nya investeringsbeslut och sådana signaler är svåra att få när marknaden för fordonsgas har stagnerat. Flaskhalsen för biogasens utveckling kan däremot förflyttas över tid och under 2010 och 2011, före etableringen av en mottagningshamn för förvätskad naturgas i regionen, så var tillförseln av fordonsgas stundtals otillräcklig. Tillförselproblematiken löstes men den misstro som tillförselproblemen skapade har varit svår att åtgärda. Ett annat möjligt problem är det omfattande intresset för olika former av eldrivna transporter som återfinns hos både offentliga och privata användare. De offentliga aktörerna har fungerat som draghjälp för förnybara drivmedel och de signaler som dessa användare har sänt kan på flera sätt överföras till andra användare, inte minst genom andrahandsmarknaden för fordon. De intervjuade beskriver emellertid att beslutsfattare lätt kan bli distraherade och endast fokusera på en lösning i taget. Följden av det blir att beslut kan fattas i riktning mot det som uppfattas som det mest attraktiva för tillfället, vilket just nu är olika typer av elfordon.

Det hinder som i studien identifierats som det mest betydelsefulla för en fortsatt utveckling av biogas som drivmedel är de instabila styrmedel som påverkar biogas. Det finns styrmedel som påverkar alla länkar i värdekedjan från produktion till användning men i nuläget bedömde de intervjuade de styrmedel som riktas mot användarsidan som de mest avgörande. Exempel på styrmedel som

sågs som oförutsägbara är investeringsbidragen och skatterabatterna på miljöbilar, eftersom miljöbilsdefinitionerna har ändrats flera gånger. Ett annat liknande exempel är förmånsvärden på miljöbilar, där besluten om dessa har tagits vartannat år.

Det sena beslutet om fortsatt skattebefrielse för biogas som drivmedel nämndes också som ett exempel på dålig förutsägbarhet för svenska styrmedel. Det senaste beslutet om fortsatt skattebefrielse togs i mitten av december 2015, bara två veckor innan den tidigare perioden för skattebefrielse löpte ut. Användarsidans intervjupersoner påtalade att de inte kunde ta några investeringsbeslut under de förutsättningarna.

Förändringen av förslagen om ett bonus-malus-system[4] för bilar har också sänt förvirrande signaler till marknaden och ökat osäkerheten om svenska styrmedel. Det ursprungliga förslaget från 2016 skulle ha satt gasbilar en bit in på malus-sidan och därmed missgynnat och medfört en ökad fordonsskatt för dessa. Det skulle därför ha skickat en negativ signal till marknaden, om syftet är att stödja utvecklingen av biogas. Det senaste förslaget till bonus-malus-system från 2017 skulle däremot ge incitament för gasbilar men investeringsbidraget som skulle ges för gasbilar med det senaste förslaget är relativt litet.

Den låga förutsägbarheten för svenska styrmedel och den stagnerande efterfrågan hör samman men det är tydligt att styrmedlen också har stöttat utvecklingen av biogas. Utvecklingen startade i tekniska nischer[5] men biogas som drivmedel har nu etablerats kommersiellt. Den utvecklingen hade inte skett utan politiskt understöd i form av styrmedel och fortsatt politiskt stöd behövs för att vända trenden med en stagnerande efterfrågan och för att användningen ska kunna spridas från offentliga aktörer till nya grupper av användare. Exempel på sådana nya grupper är privatbilister och åkerier.

Biogas är ett ungt sociotekniskt system under utveckling där olika fronter utvecklas i olika takt. Fronter är ett begrepp som används inom den tidigare nämnda LTS för att representera delar av ett system som är betydelsefulla för hela systemets utveckling och där utvecklingen har nått som längst. I fallet med biogas som drivmedel så kan systemets fronter vara länkar i värdekedjan från produktion till användning eller aktörsnätverk. För närvarande är det användarsidan som halkar efter men en annan front som är halkar efter är det politiska ramverk som påverkar utvecklingen och en indikation på detta är den påtalade otillräckliga förutsägbarheten för styrmedel i Sverige. Den uppfattningen i sig själv kan minska både effektiviteten och den faktiska verkan av svenska styrmedel. Mot den bakgrunden är det också troligt att förutsägbara stödåtgärder skulle kunna stimulera efterfrågan på biogas och därigenom skapa incitament för investeringar i ökad produktion och en mer välutvecklad distributionsinfrastruktur.

Även om efterfrågan på fordonsgas har stagnerat och är i större behov av stöd än andra delar av värdekedjan, så är det också nödvändigt med mer förutsägbara styrmedel för hela värdekedjan om biogas som drivmedel ska kunna utvecklas. Det beror på att den eller de av systemets fronter som

[4] Bonus-malus-systemet ska stödja bilar som är mindre miljöbelastande och missgynna mer miljöbelastande bilar.

[5] Termen nisch används inom det teoretiska ramverket flernivåperspektivet (Multi Level Perspctive, MLP) för att beskriva en plats där en teknisk innovation kan utvecklas utan att störas av påverkan eller tryck från marknaden i stort. MLP används för att beskriva tekniska övergångar mellan olika utvecklingsfaser.

släpar efter kan förändras över tid. I Stockholms län släpade exempelvis tillförselsidan efter under 2010 och 2011. Politiska beslutsfattare kan dra fördel av att reflektera över den dynamiken om utvecklingen av biogas som drivmedel ska understödjas på ett effektivt sätt.

CONTENTS

LIST OF ABBREVIATIONS

CNG – Compressed natural gas

FAME – Fatty acid methyl esters

GHG – Greenhouse gas

HVO – Hydrotreated vegetable oils

LBG – Liquified biogas

LNG – Liquified natural gas

LTS – Large technical system

MLP – Multilevel perspective

MS – Member State of the European Union

RD&D – Research, development and demonstration

RES – European Union Renewable Energy Source Directive

RME – Rapeseed methyl ester

VAT – Value added tax

1 INTRODUCTION

In March 2017 the Swedish government proposed a new climate policy framework and ambitious goals for climate change mitigation: zero net greenhouse gas (GHG) emissions by 2045 (Government of Sweden, 2017a). As a partial target, emissions from transport should reduce with 70 % by 2030 (ibid). Thus, the bar is raised compared to the current goals: zero net GHG emissions by 2050 and a vehicle fleet independent of fossil fuels by 2030 (Government of Sweden, 2009a).

To achieve these goals, the use of transport biofuels and electric cars is supported with policy instruments. The domestic transport sector amounted 87 TWh in 2015 and the share of renewables reached 17.0 % measured by energy content (Swedish Energy Agency, 2017). Transport biofuels such as biodiesel, ethanol, and biogas amounted 13.2 TWh or 15.1 % of the total use in domestic transport (ibid). Rail transport used 2.6 TWh electricity the same year (ibid). Considering the share of renewables in electricity, 63 %, this corresponds to 1.6 TWh or 1.9 % of the energy use in domestic transport (ibid). The transport biofuel development is illustrated in Figure 1.

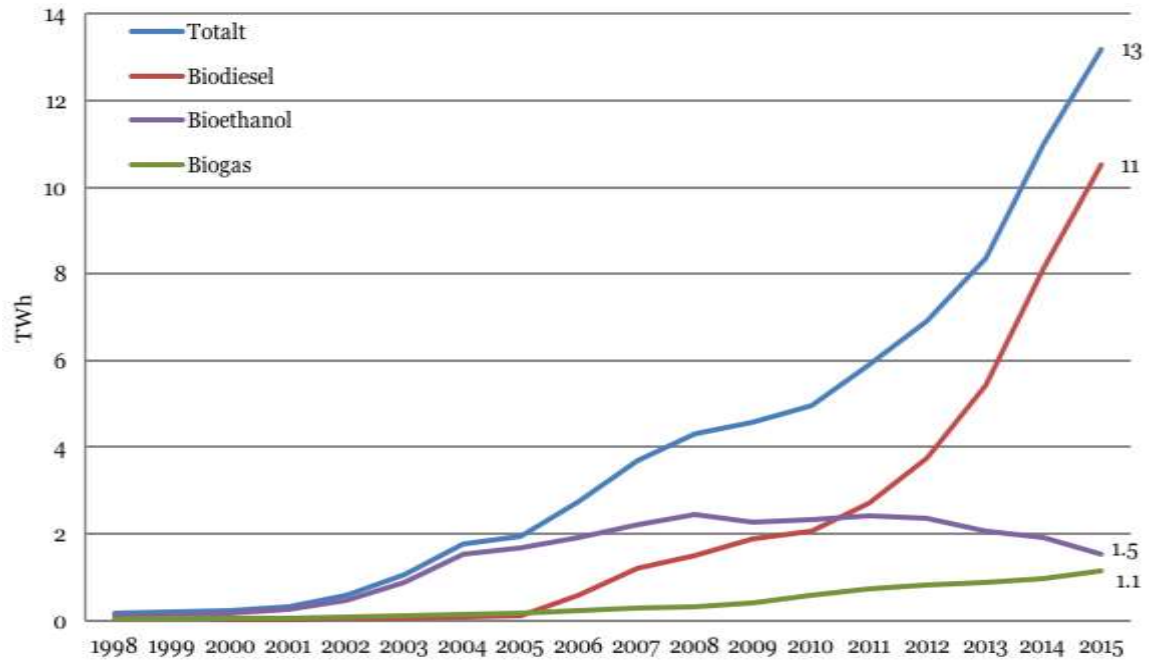

Figure 1: Transport biofuel development 1998 – 2015 (Swedish Energy Agency, 2017).

The number of electric cars is increasing rapidly. The electricity use by these vehicles is not included in the official statistics of transport fuels. Nevertheless, electric cars can replace fossil fuel vehicles and contribute to the achievement of policy goals. The number of electric cars has increased by 73 % during a 12-month period between March 2016 and March 2017 and there were more than 31 000 chargeable cars in Sweden by March 2017 (Power Circle, 2017).

Figure 1 illustrates the use of biodiesel has increased quickly since 2010 and that the use of ethanol has decreased since 2008 (Swedish Energy Agency, 2016a). The use of biogas in transport has grown slowly but steadily and it reached 1.0 TWh in 2014. Studies of the practical production potential indicate that biogas production could increase more than fourfold in Sweden, although there are regional differences (Lönnqvist et al., 2015a, 2013). The production in Stockholm County e.g. could more than double compared to the production level 2015 (Lönnqvist et al., 2015a; Swedish Energy Agency, 2016b).

The biogas development has been supported with policy instruments directed at different parts of the value chain, i.e. biogas production, distribution and end-use. The main use of biogas is in transport; 66 % of the produced biogas was upgraded and used as a transport fuel (Swedish Energy Agency, 2017, 2016b). Biogas is exempted from the energy and CO_2 taxes that apply on fossil transport fuels, increasing its economic attractiveness. In addition, premiums and vehicle tax exemptions have been granted to gas vehicles. Public actors have also supported biogas as a transport fuel and e.g. public transport is an important end-user. Biogas is complemented with natural gas to meet the vehicle gas demand. Figure 2 illustrates the vehicle gas development from 1995 until 2016.

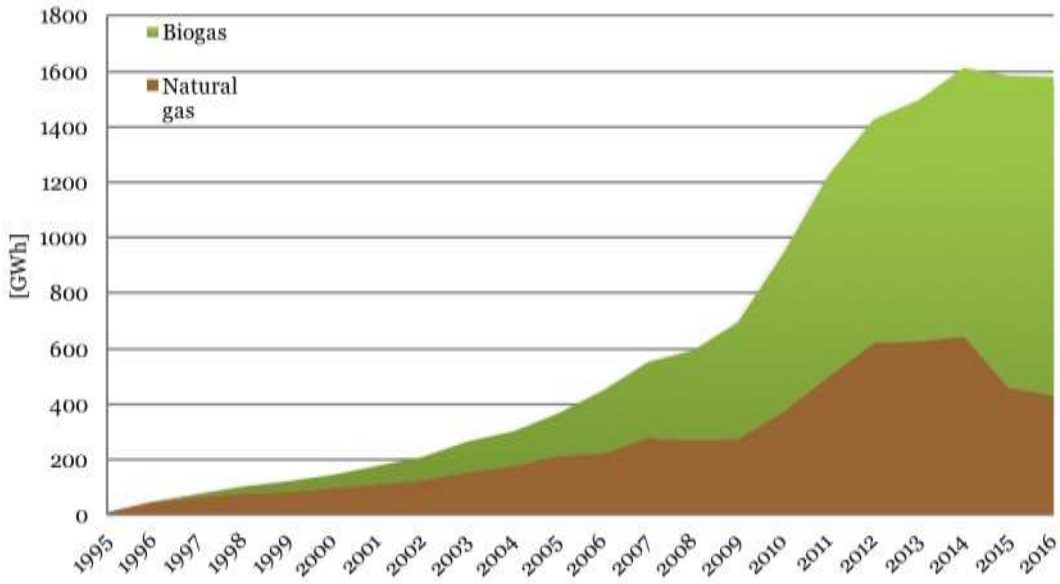

Figure 2: Vehicle gas development in Sweden, 1995-2015 (Gasbilen, 2016)

It can be seen from Figure 2 that the use vehicle gas in Sweden has grown strongly until 2014 when it appears to have stagnated. At the same time, the production of upgraded biogas has continued to increase. As a result the share of biogas in vehicle gas increased to 75 % measured by volume in 2016 (Statistics Sweden, 2017). Figure 3 illustrates the vehicle gas development in Stockholm County between 2009 and 2015.

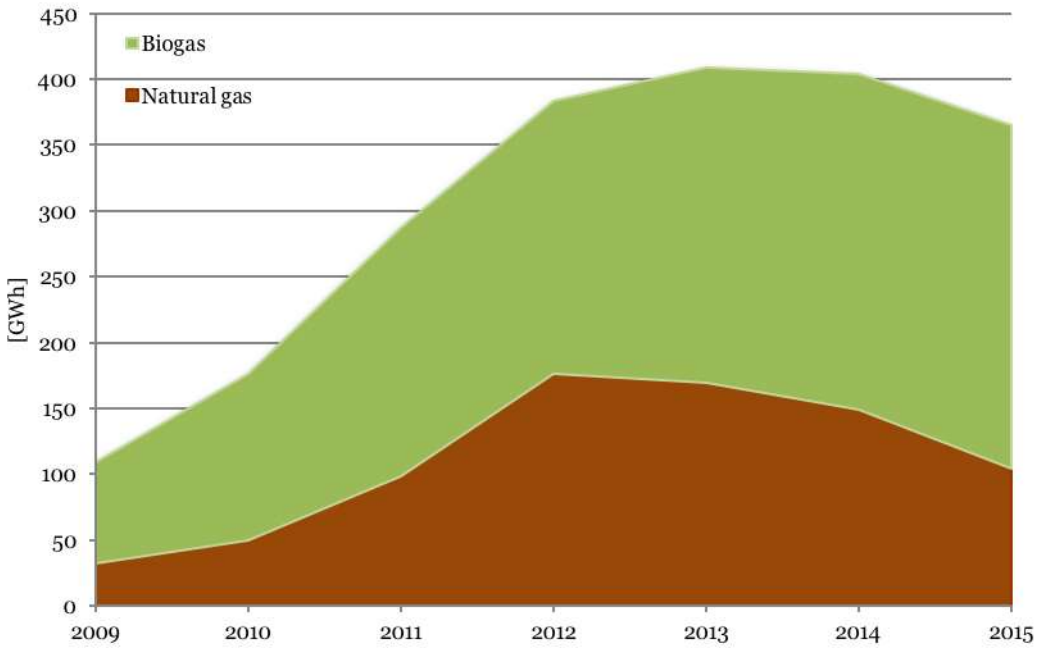

Figure 3: Vehicle gas development in Stockholm County 2009 – 2015 (Statistics Sweden, 2017)

Figure 3 illustrates that the vehicle gas demand in Stockholm County grew until 2013, when it stagnated at approximately 400 GWh (Statistics Sweden, 2017). It decreased to 370 GWh in 2015 and increased again to 400 GWh in 2016 (ibid). The data for 2016 are not illustrated in the figure. This is because Statistics Sweden has not published the share of biogas and natural gas for that year (ibid). During 2015, the share of biogas in vehicle gas was 74 % in Stockholm County, representing the national average the same year (ibid). The vehicle gas development in Stockholm County thus reflects the national development in this regard. However, there are other specific conditions for the region, e.g. the lack of access to a natural gas pipeline, as opposed to the southwestern part of Sweden. In general, the region of Stockholm County that is used as a case study in this work shows more similarities than differences with the rest of Sweden regarding the conditions for biogas development (Section 2 and 3.1).

1.1 AIM

The primary aim of this project is to increase the knowledge about the conditions for biogas development in the transport sector. This aim is detailed in three objectives:

1) Increase the knowledge of biogas supply, present and potential actors in Stockholm County that generate feedstock, as well as interest among actors to cooperate.

2) Increase the knowledge of present and potential end-users of biogas in transport in the region and how biogas fits into their core activities.

3) Increase the knowledge about how policy instruments at different levels can promote biogas development, i.e. incentivize increased biogas production and use in transport, based on (but not limited to) the actors' perception of policy instruments.

2 METHODOLOGY

This project builds on information retrieved through interviews with actors along the biogas value chain, from biogas production and distribution to end-use in transport. In total 17 actors in Stockholm County were interviewed. We contacted 18 actors, but one (a small municipality) chose not to participate. Altogether, 21 interviews were performed. This is because we interviewed different actors within the same organization to capture that some organizations are active in several parts of the value chain, e.g. large municipalities that are engaged in both waste collection procurement and biogas end-use. All the interviewed actors are described in section 3.2 and their position in the biogas value chain is illustrated in Figure 5.

Stockholm County is used as a case study that permits a bottom-up approach considering local actors and conditions. The bottom-up approach is used to get the actors' perspective on matters that normally are not studied with this perspective, such as policy instruments, as well as factors that affect other, or all, parts of the value chain from supply to use of biogas in transport, from actors that only represent one part of the chain. It is a region with a large share of the vehicle gas market – 25 % during 2016 – and is thus important for Sweden's vehicle gas development in itself (Statistics Sweden, 2017). In addition, several characteristics of Stockholm County are typical for biogas development in Sweden: the patterns of biogas production and consumption and the type of actors on both the supply and the demand side are very similar to other parts of Sweden. Thus, several results from this case study are relevant for other urban areas in Sweden as well similar regions in other countries where biogas is used in transport. However, contrary to regions in southwestern Sweden, the region lacks access to a natural gas pipeline, and the conditions for vehicle gas distribution thus differ. Thus, results related to the distribution side may be unique for the Stockholm case, yet still of importance for Sweden due to Stockholm's relatively large share of the Swedish biogas market. For a comparison about the development of biogas in different regions of Sweden, see e.g. Larsson and Grönkvist (2013).

The selection of interviewees included both present and potential actors, e.g. large-scale sewage treatment plants with existing production as well as a paper mill that has evaluated but not yet implemented biogas production. Our analysis build on the multilevel perspective (MLP) by Geels et al. (2011, 2008, 2004, 2002). This further explained in section 3.4. Briefly, MLP can be used to understand systemic transitions in which a technological system replaces or become an integrated part of an incumbent established system. A central concept is the interactions between the regime, landscape and niche levels. The regime level is where the established systems are found, while the landscape level contain factors such as the international oil price. Technological development and innovation may take place at the niche level. The policy instruments, i.e. the tools of the policy framework, are part of the regime and described in section 3.3 and a further explanation of the MLP as such is found in section 3.4.

The actors have been interviewed regarding

- the role of the organization and the respondent,
- experiences of biogas production, distribution, and/or use,
- how the organization's business model could include biogas production and/or use,
- perception of the conditions for biogas development,

- view on co-operation with other actors along the biogas value chain,
- biogas in relation to natural gas,
- biogas in relation to other alternatives (in the case of interviews with end-users),
- experiences regarding transportation (in the case of interviews with end-users),
- view on policy instruments,
- the predictability of these instruments, and
- and how the policy instruments affect the organization's decision making process.

Examples of interview guidelines for biogas producers, distributors, and end-users are found in Appendix A. These were developed based on our understanding of the actors' position in the biogas value chain, their core activities, and how policy support may incentivize their biogas activities. The guidelines were developed in collaboration by the research team and evolved in an iterative process considering the specific condition of each respondent.

The interviews were semi-structured, i.e. they followed an interview guide but allowed the interviewees to elaborate their answers and to add information. Most interviews were performed face-to-face, but a few interviews were performed via telephone; the majority of the interviews lasted between one and three hours. The length if the interview were affected by the fact that the interviewees were allowed to elaborate on issues that they found relevant to the topic. The interviewees typically requested to see the questions prior to the interview. The interviews were recorded, transcribed or summarized, and sent to the interviewees for approval.

The interview data were analyzed thematically with some departures from the aims. The analytical themes were predefined by the aims and the interview guidelines, but several additional themes that appeared in the interviews also became part of the analysis and helped structuring the presentation of the results and the discussion.

3 BACKGROUND

3.1 VEHICLE GAS IN STOCKHOLM COUNTY

The vehicle gas demand has remained at approximately 400 GWh since 2013 in Stockholm County, as shown in Figure 3 in the introduction (Statistics Sweden, 2017). However, in 2015, the demand decreased to 370 GWh and in 2016 it increased again to approximately 400 GWh (ibid). Figure 4 shows supply, distribution, and use of vehicle gas 2015.

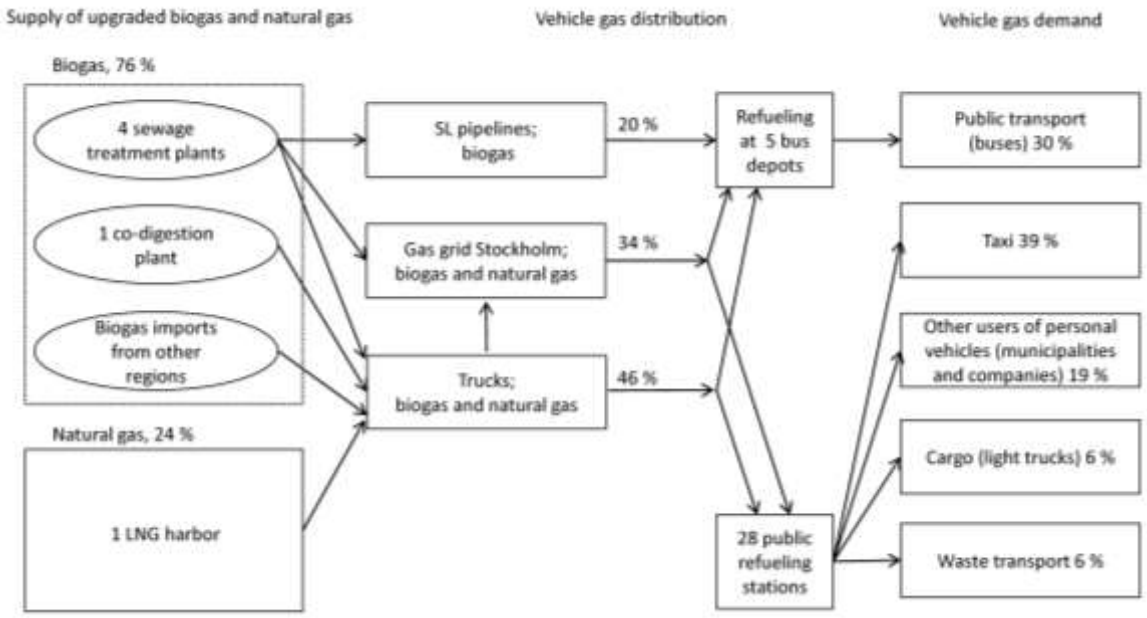

Figure 4: Supply, distribution, and demand of vehicle gas in Stockholm County 2015 (ap. 370 GWh) (Statistics Sweden, 2017).

Biogas is produced and upgraded at four large-scale sewage treatment plants as well as one co-digestion plant, all located in Stockholm County. In addition, biogas may be imported from neighboring regions and natural gas is supplied from the LNG harbor in Nynäshamn. Upgraded biogas is distributed through trucks and grids to refueling stations. There are two vehicle gas grids in the region. The first grid, owned by Stockholm County Council[6] and connecting two sewage treatment plants – Henriksdal and Käppala – with bus depots, supplied 75 GWh upgraded biogas during 2015. The second grid is managed by the company Gas Grid Stockholm[7] that in the same year distributed 125 GWh vehicle gas to public refueling stations as well as bus depots. The vehicle gas in this grid contains a mixture of upgraded biogas and natural gas. LNG is transported with trucks to the gas grid where it is gasified, injected and complements upgraded biogas. The sizes of these distributions grids for vehicle gas are by no means comparable to the natural gas grid that covers the south and west coast areas of Sweden where the delivered amount is approximately two orders of magnitude higher. Trucks also distribute vehicle gas to bus depots and public refueling stations.

[6] Interview with the public transport company SL. See Table 1, actor 12.
[7] Interview with Gas Grid Stockholm. See Table 1, actor 10.

This amount corresponded to 170 GWh or 46 % of the total vehicle gas use in the region in 2015[8]. Vehicle gas is available to end-users at 6 bus depots and 28 public refueling stations.

Buses represent 30 % of the vehicle gas use in the region 2015. Other end-users are taxi (39 %), companies and municipalities using personal vehicles (19 %), cargo companies using light trucks (6 %), and waste transport (6 %)[9]. Privately owned gas vehicles and heavy gas trucks are not common (Forsberg et al., 2012). Vehicle gas is thus established at some niche markets, such as public transport and waste transport, but not as an alternative for private vehicle owners, which is the largest potential market (ibid).

The large share of vehicle gas in taxi services is the result of a regional policy at airports that promotes taxi vehicles that run on renewable transport fuels over conventional fuel vehicles[10]. Thus, this pattern may not be representative for biogas development in Sweden. In addition, the vehicle gas distribution infrastructure in Stockholm County differs from that in the rest of Sweden, as described above and in the introduction. However, several characteristics found in Stockholm County are typical for biogas development in Sweden and the type of actors on both the supply and demand sides are representative for other parts of Sweden. Thus, the results from this case study have relevance for Sweden's national biogas development.

3.2 THE INTERVIEWED ACTORS

The interviewed actors represented the whole biogas value chain from biogas production, upgrading, and distribution to end-use in transport. The actors' position in the biogas value chain is illustrated in Figure 5 and Table 1 contains a brief description of each actor. Most of these actors have a quite specific role in the biogas value chain. However, municipalities are active in several parts of this value chain: waste management, biogas production, and vehicle gas use. Another example of an actor active in the entire value chain is the energy utility company E.ON that participates in biogas production, distribution and sales to end-users in transport.

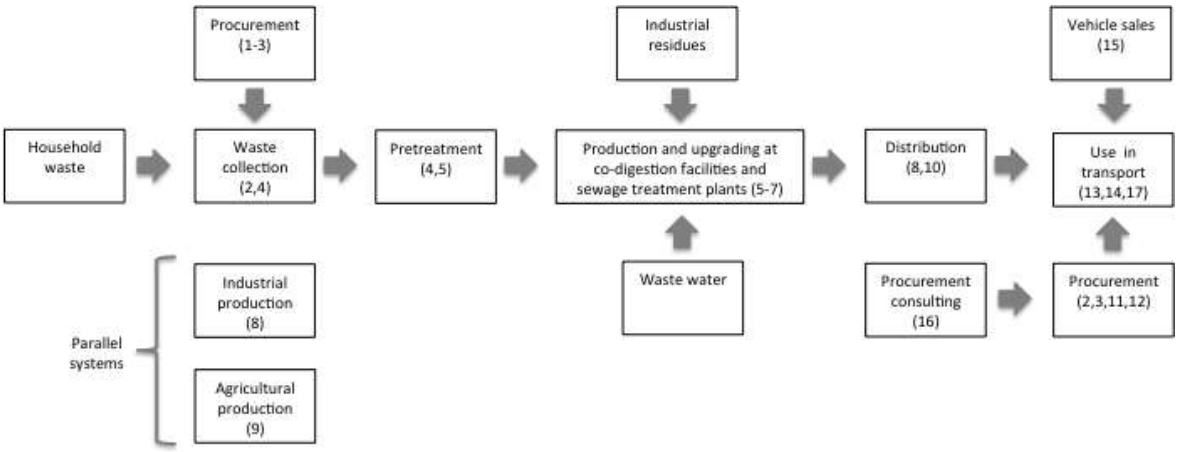

Figure 5: The interviewed actors' position in the value chain.

[8] Source: (Statistics Sweden, 2017) and interviews with SL and Gas Grid Stockholm. See Table 1, actor 10 and 12.

[9] Sources: (Forsberg et al., 2012; Myhr and Svahn, 2016) and interview with SL. See Table 1, actor 12.

[10] See section 4.2.4 for a detailed explanation of the policy at the airport.

Table 1: Description of the interviewed actors.

	Supply side	
1	Stockholm Water	Municipal company for waste management and water treatment in Stockholm Municipality as well as water treatment in Huddinge Municipality. One interview regarding waste management and procurement in Stockholm Municipality (932 000 inhabitants) and one interview regarding the sewage treatment and biogas production plant in Henriksdal. Respondents: Head of unit, planning and development, waste management; Head of unit water treatment.
2	Huddinge Municipality	Large municipality south of Stockholm Municipality with 107 000 inhabitants, which is partial owner of SRV (4). The municipality promotes the use of public transport, and renewable fuels infrastructure. It also works to make the municipality's own vehicle fleet more sustainable. The interview concerned both waste management and sustainable transport. Respondent: Environmental strategist.
3	Lidingö Municipality	Municipality with 47 000 inhabitants northeast of Stockholm Municipality. Target to be "among the best municipalities in Sweden regarding waste management". Works with voluntary commitments to increase food waste sorting as well as with incentivizing tariffs. One interview regarding waste management and procurement and one interview regarding the municipality's own vehicle fleet. Respondents: Environment and waste developer; Project leader vehicles
4	SRV	Waste management company owned by five municipalities. SRV is partial owner of a pretreatment facility in Sofielund together with SBF (5). The pretreatment facility produces a slurry for biogas production. Two interviews were performed: one regarding waste separation and collection and one regarding SRVs participation in the pretreatment facility. Respondents: Transport manager; Business unit director
5	Scandinavian Biogas Fuels (SBF)	Biogas producer; designing and operating biogas plants. This company operates three plants in Sweden, all within Stockholm County. Two are situated at municipal wastewater treatment plants (Henriksdal, Bromma), mainly producing biogas from sludge. The third (Sofielund) is situated in Huddinge municipality, mainly producing biogas from food waste. There, the pretreatment facility is co-owned with SRV (4). A forth plant is operated in Ulsan, South Korea. Respondent: R&D director.
6	SYVAB	Municipal water treatment company owned by three municipalities and two municipal companies and located in the south of Stockholm County. Receives external organic materials and co-digests this together with sewage sludge. The major part of the produced biogas is upgraded. Gas distribution by external partners. Respondents: CFO; Quality engineer.
7	E.ON	International energy company active in electricity, heat, and gas sectors. Produces, distributes, and sells vehicle gas mainly in urban areas of southern Sweden. Two interviews. Respondents: Project leader biogas; Head of marketing and vehicle gas sales.
8	Forrest industry group	Forest industry group that manufactures paper and wood products, and runs forestry and energy production operations. Interview regarding plans to produce biogas at a paper mill. The interviewee is presented anonymously. Respondent: Project leader new business development.
9	LRF Östergötland	Regional branch of the Federation of Swedish farmers – an agricultural interest organization. Interview regarding possibilities for, and perception about, biogas among Swedish farmers. Respondent: Regional manager.
	Distribution side	
8	E.ON	See above.
10	Gas Grid Stockholm	Regional gas distribution company. Owner of gas grid, responsible for maintenance and short-term balance of two grids (vehicle gas and cooking gas). Respondent: Grid marketing manager.
	Demand side	
11	Clean vehicles in Stockholm	Part of Stockholm municipality's administration, with the task to increase the number of clean vehicles in the city (excluding buses and subway – see SL, 12). This mainly includes vehicles used within the municipal operations, but to some extent incorporates sector organizations, companies, and citizens. This organization also works with improved access to renewable fuels and other issues of relevance. Interview regarding the municipality's own vehicle fleet and its work to promote vehicles that run on alternative fuels. Respondent: Project leader with special expertise regarding heavy-duty vehicles.

2	Huddinge Municipality	See above.
3	Lidingö Municipality	See above.
12	Stockholm Public Transport (SL)	SL is an umbrella term and a brand for public transport in Stockholm County. Stockholm County Council procures transport services from private operators, e.g. Keolis (13), under this brand. Public transport includes both road transport (busses) and rail transport (mainly metro and commuter trains). Respondents: Section manager, sustainable development; Strategist, transport fuels and energy, sustainable development.
13	Keolis	One of Europe's largest public transport companies, active in several Swedish regions with 6 000 employees. Works with busses and rail traffic. Keolis is contracted by SL to operate gas busses, but also busses that run on RME and other renewables. Keolis has received several consecutive contracts from SL (12). Respondent: Business area manager.
14	Taxi Stockholm	Regional association for 900 member companies working with taxi services. In total 1 600 vehicles and 4 500 drivers. 65 % of the fleet is currently gas vehicles. The fleet is renewed with 500 vehicles per year. Respondent: Quality and sustainability controller.
15	Volkswagen Stockholm	Regional vehicle sales organization for Volkswagen. Offers gas vehicles, other biofuel and electric vehicles, as well as conventional fuel vehicles to private customers and companies. Respondent: Fleet sales manager.
16	Ynnor Consult	Consultant for vehicle procurement. Procures 15 000 vehicles per year and provides other services such as ownership cost estimates and design of company policies for procurement. Respondent: President of Ynnor.
17	Widrikssons	Regional haulage contractor company with large gas vehicle fleet. 85 % of the 60 light trucks are driven with biogas and 42 % of the 60 heavy trucks are driven with RME. Invested in a refueling station and gas storage to obtain 100 % biogas as vehicle fuel. Target to be fossil free by 2020. Respondents: Owner, operations manager, and communicator.

3.3 THE POLICY FRAMEWORK FOR RENEWABLE TRANSPORT FUELS IN SWEDEN

The implementation and breakthrough for any renewable transportation fuel in the transport sector is dependent on a supportive, stable and foreseeable policy, due to entry barriers such as the established infrastructure for conventional transportation fuels and the relatively low price for the conventional fossil feedstock. Sweden is no exception in this sense. A policy framework with the potential to positively influence biofuels development rests on two pillars: a political desire to affect change, usually manifested through certain goals or visions, and the tools to achieve this, the latter is generally referred to as policy instruments.

The following subsection presents a number of political goals that affect the production and use of Swedish biofuels at different political levels and a general description of policy instruments that directly affect the development of renewable transportation fuels in Sweden. Special emphasis is directed towards the policy instruments that have been – and are – the most influential for the development of biogas in the transport sector.

3.3.1 Political goals and visions affecting renewable transportation fuels

Political visions and goals relevant to transportation biofuels relevant to this analysis have been formulated at European, national and local levels. Goals set at all these levels have affected possibilities to produce different kinds of renewable transportation fuels, including biogas.

EU goals

Political goals for biofuels at the EU level have foremost been driven by energy security and climate mitigation. Apart from this, the possibilities to develop rural regions have also been part of the motives. Energy security was a key driver in the 1990s – see for instance the Green Paper "Towards a European strategy for the security of energy supply" (European Commission, 2000) – but the focus has steadily shifted towards mitigation of climate change. In March 2007 the so-called EU Energy and climate package was passed in the European Council (European Commission, 2016). The package included the following targets:

- 20 % reduction of greenhouse gases by 2020
- 20 % renewables on average in energy supply by 2020
- 20 % energy efficiency improvement by 2020

The goal for renewable fuels was further detailed in the renewable energy sources directive (RES) that was approved by the European Parliament in 2009 (European Union, 2009). In RES, individual national targets and how these should be calculated were determined, as well as a specific target of 10 % biofuels in land-based transport by 2020. Sweden already surpassed this target in 2011 and the use of renewables in the domestic transport sector amounted to 18.7 % in 2014 (Swedish Energy Agency, 2016a). The figure is calculated in accordance with the directive where biofuels from wastes or residues, such as biogas and parts of the HVOs[11], are double counted. See Chapter 1 for the shares of biodiesel[12] and biogas expressed in energy terms. Previous to this, there were other specific targets for biofuels in transport specified in the EU biofuels directive from 2003 (The European Parliament and the Council, 2003a). The targets were set to 2 % biofuels in transport for all member states in 2005 and 5.75 % in 2010. Only Germany and Sweden managed to reach the target for 2005 (European Commission, 2007); the target for 2010 was replaced by the 2020 RES target before its evaluation.

Swedish national goals

Apart from the EU goals that may be general or country specific for the member states (MS), the countries may have more ambitious national goals. In 2008, the Swedish Government presented the ambition that the vehicle fleet should be independent of fossil fuels by 2030 and this was also passed in the parliament (Government of Sweden, 2009a). The ambition may be seen a step towards the general climate-related vision to have no net GHG emissions from Sweden by 2050 (ibid). A more precise meaning of 'a vehicle fleet independent of fossil fuels' was subsequently outlined in a government inquiry as: i) a vehicle fleet that technically can function without fossil energy carriers and ii) fossil-free energy carriers should be available in sufficient quantities (Government of Sweden, 2013a). Although still vague, the current share of renewable energy carriers in the Swedish transport sector indicate that we are far from the presented ambition.

In March 2017, the Swedish Government has proposed a climate policy framework containing a climate act, new climate goals, and a climate policy council in a government bill (Government of Sweden, 2017a). The bill that is expected to pass in the parliament in June 2017 is based on a proposal from a Cross-Party Committee on Environmental Objectives (In Swedish: Miljömåls-

[11] Hydrotreated vegetable oils – a type of biodiesel that may be produced from tall oil.
[12] Biodiesel refers to either hydrotreated vegetable oils (HVO) or fatty acid methyl esters (FAME).

beredningen), in which seven of eight political parties in the parliament participated. The climate goals state that there should be zero net GHG emissions from Sweden by 2045 and there are sub-targets for 2030 and 2040: the emissions from the transport sector should be reduced by 70 % in 2030 compared to 2010 and the ambition of a vehicle fleet independent of fossil fuels in 2030 is maintained. It also recognizes the importance of biofuels and states that these will be necessary to achieve the targets in the transport sector, since a large part of the current vehicle fleet will still be in use by 2030.

Local and regional goals

Political goals and ambitions about the renewable transportation fuels have also been expressed at local and regional levels. In Sweden, this may be particularly significant, since a large share of the fiscal resources are handled at the municipal and county levels. These goals and ambitions are commonly more precise and stringent than the corresponding at the national and EU levels that are mandatory to meet.

One example is the goals set by the Stockholm County Council that the region's public transport should be fueled by 90 % renewables by 2020 and that it should be free of fossil fuels by 2030 (Stockholm County Council, 2012, 2010). Public transport includes transports on rail, roads and water in the county. The public transport in the county seem to be on the right track to accomplish this, since the share of renewables in public transport reached 87 % in 2016 (Stockholm County Council, 2017). Rail traffic are run on electricity that is considered to be produced from renewable sources and in January 2017 the bus fleet also became fossil free; among the remaining challenges to become completely fossil free are the ferry traffic (ibid.).

3.3.2 Policy instruments for biofuels

For renewable transportation fuels, the initial production costs have been too high in comparison to conventional fossil fuels and a spontaneous development of the industry would thus not have occurred without public support, i.e. policy instruments. See e.g. Ulmanen (2013) for an analysis of the development of biofuels in Sweden and the Netherlands. However, the intended outcomes of policy instruments that affect energy carriers – including established energy carriers – have been different at different times and regions. Taxes have been applied to energy carriers for long times, but the intentions have shifted from being purely or predominantly fiscal, towards the achievement of other social or environmental goals such as 'reduced energy dependence' or 'abatement of greenhouse gas emissions'. Other (positive) external effects that may be provided by policy instruments directed at energy carriers can include the development of domestic industries, stimulation of rural economies or development, and poverty alleviation. An overview of arguments that have been used for the promotion of biofuels in countries such as Brazil, Germany and USA is found in Grönkvist et al. (2013).

Biofuel support has commonly taken the form of subsidies (also related subsidies, such as tax alleviations) or mandatory targets. Subsidies, in contrast to taxes, are typically costly for the state and if markets grow significantly it may be perceived as a significant burden to state finances (Peck and McCormick, 2008; Schoepe, 2006). As a consequence, there has been a general shift from subsidies towards quota obligations or volume targets as biofuels have become more established in several countries (Grönkvist et al., 2013). There are several ways by which policy instruments may be categorized, one being the nature of the policy instrument itself as delineated by contents in the

categories: administrative, financial, support to research, development and demonstration (RD&D), and information. This categorization is used by e.g. the Swedish Energy Agency (2008). Vedung (2009) is also using a similar classification: regulatory, economic, and informative instruments. The policy instruments may then be described as stick, carrot, and preaching and the support to RD&D from the classification used by the Swedish Energy Agency may then covered by the last two. Administrative instruments, also called command and control mechanisms include direct steering effect via legislation. For the transport sector, this might take the form of emission limits or demands on energy efficiency for vehicles, mandatory quotas and blending standards for fuels, and demands on distribution infrastructure, or combinations of these. In contrast, financial policy instruments rely on mechanisms such as taxes, tax alleviation or exemptions, investment support, operational support, tradable environmental certificates, loan guarantees, and public procurement. For renewable transportation fuels, support to research demonstration and development may be provided to any link in the chain from feedstock to the operation of full-scale conversion plants and to universities, research institutes, as well as to fully commercial actors. Informative policy instruments intend to convince actors to take certain actions through information campaigns, counseling, education, and lobbying. Informative instruments imply that actions are voluntary and are thus different from economic and administrative instruments, but they may also be presented in combination with e.g. a financial instrument, e.g. a tax incentive may be referred to as an environmental tax.

Another classification of policy instruments is as general or specific. General policy instruments are for example energy and CO_2 taxes for transportation fuels. Specific policy instruments may be directed at a specific fuel and/or towards a specific link in a supply and demand chain. Examples of specific instruments include investment support to production plants and premiums or tax exemptions for environmental cars.

A third way to classify policy instruments is through direct or indirect market interventions, see e.g. Peck et al. (2016). Indirect market interventions can be achieved via mechanisms such as laws and regulation, taxes, subsidies, while direct interventions may be when a public authority aids the creation of a market – for instance as a buyer and seller of fuels or through public procurement. Examples of direct market interventions that affect biogas are municipal wastewater treatment plants and public transport companies that sell and buy upgraded biogas.

EU policy instruments

The European Union commonly poses its visions and targets in forms that the member states should meet by choosing their own preferred policy instruments relatively freely. When specific targets are expressed in a directive such as Renewable Energy Sources Directive (RES), the directive is intended to constitute a (binding) push for the implementation of national policy instruments. It thus will have a strong indirect effect on the development of renewable transportation fuels, both generally and specifically. The RES has also explicitly been promoting transportation biofuels from feedstock such as waste and residues. The original text (European Union, 2009) for this was rather unspecific:

"… the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels."

A more precise list of eligible feedstock was subsequently presented in a directive that also contained stricter regulations for the sustainability criteria of the biofuels that are to be double counted for the RES targets (European Union, 2015). Since the most common feedstock for biogas, and to some extent also for HVO, are different kinds of wastes and residues, the double counting has meant a lot for Sweden's ability to fulfill and surpass the RES targets.

There are also examples of EU legislation that have a direct impact on renewable transportation fuels and, in some cases, negatively. The energy tax directive 2003/96/EC (The European Parliament and the Council, 2003b) specify minimum levels of taxes on energy products including transportation fuels. The directive does not distinguish between fossil and renewable fuels and the tax rate is expressed per volume in the case of liquid fuels. Thus, a renewable liquid fuel with lower energy content, such as ethanol, is taxed at a higher rate per energy unit compared to gasoline. It is not hard to see that this taxation level in the absence of another support system would eliminate ethanol from the market. However, in article 16.1, the directive left a gap open for a reduced tax exemption or a reduced rate of tax for biofuels, and Sweden has had exemptions for biofuels since the introduction of renewable transportation fuels in the 1990s (National revision in Sweden [Riksrevisionen], 2011). In order to maintain a favorable situation for biofuels in its domestic market, Sweden has thus sent in applications for the exemptions of taxes a number of times and these have also been approved – albeit, only for limited time periods. In essence, this has resulted in a situation where certainty for investment in the sector has been limited to around three years in the country. The last exemption for Swedish biofuels was approved in mid-December 2015, only days before the previous approvals for exemptions of taxes would no longer be valid (1 January 2016). The present approval for tax exemptions for liquid biofuels was granted for three years (European Commission, 2015a) – that is until 31 December 2018, and for biogas for five years (European Commission, 2015b). One of the requirements in order to prolong the tax exemptions was that Sweden would continue the measures to secure that overcompensation of the biofuels do not occur. Overcompensation is when the support is judged to be greater than the extra costs for the production of biofuels and thereby is considered to distort EU market conditions.

The so called fuel quality directive, 98/70/EC (The European Parliament and the Council, 1998), with its amendments in directive 2009/30/EC (The European Parliament and the Council, 2009) regulates the permitted volume shares of blend-in from a technical perspective. These limits thus have led to restrictions on the possibilities to use low-blend biofuels to reach the RES target for the land-based transportation sector.

The importance of enabling infrastructure is also recognized in EU. The alternative fuel infrastructure directive (European Parliament and the Council, 2014) specifies a required renewable fuels distribution infrastructure and refueling/recharging points for each member state to fulfill by 2025. These are to support the development of a core corridor called TEN-T. The energy carriers for which the distributions infrastructure is specified are compressed natural gas (CNG) for road transport, liquefied natural gas (LNG) for road and maritime transport, and electricity. Hydrogen is also mentioned but no specific demands or targets are set for this energy carrier. The TEN-T corridor in Sweden only covers some main roads on the west coast and up to Stockholm and Örebro and this corridor is already covered with the required refueling stations every 150 km (Lönnqvist et al., 2017). The required distance between filling stations for LNG is 400 km and this means that this demand is also met or essentially met today (Energigas Sverige, 2014).

Swedish policy instruments

The policy instruments used in Sweden have included several cross-sectorial policy instruments, of which the tax exemptions have been the foundation. These are intended to contribute to similar marginal effects to all actors in a field. Three taxes in Sweden are directly put on transportation fuels: energy tax, carbon dioxide tax, and value added tax (VAT). The two first of these have been reduced or exempted for ethanol since the beginning of the 1990s when ethanol was the only bio-fuel used at any significant extent in the Swedish transportation sector. Ethanol was exempted from the carbon dioxide tax at the introduction of the tax in 1991 – the first carbon dioxide tax in the world – and was also exempted from the energy tax in 1992 (National revision in Sweden [Riks-revisionen], 2011). Even if there was an introduction of biofuels in Sweden in the 1990s, the total use amounted to 0.3 % of the energy use in the transport sector in 2000, indicating that the real growth took place after the turn of the century (ibid). As of April 2017, the energy and CO_2 taxes applied on transportations fuels in Sweden are listed in Table 2. The table illustrates the degrees of tax reductions and exemption for different fuels. All biofuels are exempted from CO_2 tax, while the reduction of the energy tax varies. The tax exemption is also the reason why upgraded biogas has been relatively competitive as a transport fuel but not competitive for industrial use, since the use of natural gas already has been exempted from most of the taxes if used in industrial production[13].

Table 2: Energy and CO_2 taxes on transport fuels in Sweden by April 2017 (Swedish Gasolineeum & Biofuels Institute, 2017; Swedish Tax Agency, 2017). The table does not include the VAT applied on all fuels. For all biofuels, the exemption from energy tax is for the share with biomass origin.

Fuel	Energy tax		CO_2 tax		Total	
	SEK/ liter SEK/ Nm³	SEK/ kWh	SEK/ liter SEK/Nm³	SEK/ kg CO_2	SEK/liter SEK/ Nm³	SEK/ kWh
Gasoline*	3.88	0.43	2.62	1.11	6.50	0.71
Diesel*	2.49	0.25	3.24	1.27	5.73	0.58
Natural gas	0	0	2.42	1.19	2.42	0.22
Biogas	0	0	0	0	0	0
Ethanol (E5)	0.47	0.08	0	0	0.47	0.08
Ethanol (E85)	0.31	0.05	0	0	0.31	0.05
Ethanol (ED95)	0	0	0	0	0	0
FAME **	1.59	0.17	0	0	1.59	0.17
FAME ***	0.92	0.10	0	0	0.92	0.10
HVO ****	0	0	0	0	0	0

* MK1, ** Low blend, *** Pure or high blend, **** All blends

As noted under EU policy instruments above, tax exemptions for biofuels are not in accordance with the general tax regulations in the EU. Overcompensation, i.e. that the tax exemption would cover more than the extra costs for the production and distribution of biofuels, is considered illegal state aid in the European Union. Tax reductions or exemptions may only be granted by member states if biofuels are more expensive to produce than their fossil equivalents. Biogas in transport is exempted from energy tax. This is because its production cost is twice the market price of natural gas (Swedish Energy Agency, 2015a). The tax exemption thus does not imply any overcompensa-

[13] This situation is changing since the exemptions from CO_2 tax for fossil fuels in industrial use have been more limited year by year.

tion. Nevertheless, this exemption has been granted for one year at a time until 2015. The latest tax exemption is valid for a longer period: January 1st 2016 – December 31st 2020, but the approval for this was granted only weeks before the previous approval would expire. This has not sent signals of stability to industrial actors.

For several other biofuels than biogas, the reduction of the energy tax has not been fixed. All reductions or exemptions must be reviewed at least once per year (European Commission, 2014a) and in Sweden this review is performed by the Swedish Energy Agency. The review for 2014 found that E5, E85 as well as low blend-in and pure FAME had been overcompensated. As a consequence, the energy tax reduction was decreased in 2015 (Ministry of Finance, 2015; SEA, 2015; Swedish Tax Agency, 2016). However, the next comparison resulted in an increase of the tax reduction in 2016 (Swedish Tax Agency, 2017). In a case when overcompensation has occurred, the fuel suppliers have to refund the estimated overcompensation and thereby carry the financial risk for this.

Apart from the direct financial comparison that is carried out afterwards, the fuel supplier is required to have a sustainability certification that assures that the EU sustainability criteria are met (EU 2009) to obtain a tax reduction or exemption. Since January 1st 2016, a production plant decision[14] is also required if energy crops have been used (European Commission, 2014b; Swedish Energy Agency, 2015c). To get a production plant decision, the enterprise that is to be granted a tax exception needs to have a control system that ensures that the biofuel is not food-based, or – if food-based – have been produced in a plant that were in operation before December 31st 2013 but is not fully depreciated (Swedish Energy Agency, 2015d).

In 2012, the Swedish government proposed a change of the Swedish support system towards quota obligations for biofuels. This became the law (2013:984) regarding quota obligations for biofuels (Government of Sweden, 2013b). The purpose was to gain control over the share of biofuels in Sweden while avoiding some of the energy tax losses for low blend biofuels induced by the current tax exemptions. The exemptions for the carbon dioxide tax were still kept for low blend biofuels while all the tax reductions and exemptions for the high blend and pure biofuels remained, thereby keeping this support intact. The quota obligations were thus limited to the low blend biofuels.

However, the Swedish Government had to abolish the law before it entered into force, since the European Commission did not provide the necessary approval. The European Commission judged that the combination of carbon dioxide tax exemptions and the quota obligations for low blend biofuels would constitute illegal state aid (Government of Sweden, 2014). The European Commission initiated an investigation, which could have taken up 18 months. Thus, the Swedish Government took the decision not to wait for the result of the investigation and decided to withdraw the law. The government's intention was to create stability; the consequences of a negative response from the commission would have impacted the fuel providers who then would have had to retroactively pay compensation for the state aid (ibid).

Since the failure with the Swedish quota obligation system, work has been ongoing to come up with a new instrument. A reduction obligation quota system[15] that is expected to enter into force

[14] In Swedish: anläggningsbesked.
[15] In Swedish: reduktionsplikt

July 1st 2018 was proposed March 17th 2017 (Government of Sweden, 2017b). According to the memorandum, this instrument is not a form of state aid and thus it does not need an approval from the EU Commission (ibid). The memorandum recognizes that the stability of support for transport biofuels has been low and is aiming for increased stability with this new instrument. The system would mandate liquid transport fuel distributors to blend in biofuels in accordance with estimated GHG reductions that would increase gradually over time. For gasoline, these are set to 2.6 % by 2018 and 4.2 % by 2020. An indicated GHG emissions reduction, considering both fuels, is set to 40 % by 2030. Since no volume shares are given, the instrument would promote biofuels with low estimated GHG emissions, e.g. produced from forest biomass or from wastes and residues. The system would keep the pure or high blend biofuels outside the reduction obligations by providing full tax exemptions instead of the current reductions for all including E85 and FAME (ibid.). Gasoline and diesel fuels that are included in the system would be charged with a CO_2 tax that takes the share of biofuel into account. However, the reduction is for all the fuels supplied in Sweden and the instrument would thus permit trade between distributors; a distributor with an emissions reduction surplus can trade with one with a deficit.

In summary, for the general tax-related policy instruments that are used to promote renewable transportation fuels in Sweden: the requirement that national and EU legislation must be compatible and that national legislation may have to be approved by the EU Commission have posed a constraint on the possibilities for Sweden to promote renewable transport fuels in the pursuit to phase out fossil fuels in the transportation sector. Nevertheless, the Swedish Government seems to have found a way around this problem with the suggested reductions obligation quota system.

Contrary to the general tax reductions and exemptions, there have been several investment support schemes that specifically have provided financial resources to biofuel production plants, but also to distribution and use of renewable transportation fuels during the last decades. Examples are the climate investment program (klimatinvesteringsprogram) KLIMP (Swedish Environmental Protection Agency, 2013) and its predecessor, the local investment program (lokala investeringsprogram) LIP (Swedish Environmental Protection Agency, 2008). An on-going investment support scheme is the KLOKT support, Climate step – local climate investments (Klimatklivet – lokala klimatinvesteringar) (Swedish Environmental Protection Agency, 2016). This support is to be provided to local investments that bring about climate benefits and several biogas production units have received financial support.

A controversial policy instrument that has been directed at the distribution of renewable transportation fuels is the so-called “pump law” from 2005 (Swedish Code of Statutes, 2016). This law stated that all tank stations should provide at least one type of renewable transportation fuel, but tank stations with an annual supply below 1 500 m^3 gasoline and diesel were exempted. The main reason this law has been controversial is that it is an obvious example of when the Swedish Government in its strive to be neutral in the choice of technology, is just the opposite of that. The investment costs for an ethanol pump were so much lower than the investment costs for e.g. a vehicle gas supply pump and the result was that almost all stations invested in ethanol pumps (Parliament of Sweden, 2009). The government responded to this development in 2007 by providing investment support to all renewable transport fuels infrastructure except ethanol (Government of Sweden, 2013a). In turn, this resulted in investments in 57 new stations for vehicle gas between 2007 and 2010 and by the end of 2012 there were 1 832 ethanol pumps and 135 vehicle gas pumps in Sweden (Parliament of Sweden, 2009).

Several policy instruments that affect the demand side for biofuels have also been launched – not only on the national level but also on a regional or local level. Different premiums and vehicle tax exemptions have been given for environmental cars [Swedish: miljöbilar] since 2007 (Lönnqvist et al., 2017, 2016). From April 2007 until June 2009 a premium of SEK 10 000 was granted when a so-called 'environmental car' was purchased, this was followed by a five-year vehicle tax exemption for environmental cars introduced in 2010. The definition from 2007 was based on CO_2 emissions per km for vehicles running on fossil fuels. For vehicles running on renewables the definition was instead based on fuel consumption. However, negatively for biofuels, a definition for a so-called 'super environmental car' together with a significantly higher premium for the cars that qualified took effect in 2012. This definition was based on maximum tailpipe emissions of carbon dioxide that in principle excluded all cars except electric cars, plug-in hybrids, and subsequently fuel cell cars. The grant for super environmental premium cars still exists, but is now split in two categories: electric and fuel cell vehicles in one category and plug-in hybrids in another (Swedish code of Statues, 2011). The definition for an environmental car has also changed and in 2013, the definition was changed so that higher tail-pipe emissions were allowed for heavier cars. The permitted tail-pipe emission level also became higher for ethanol and gas vehicles.

Environmental cars have also been subject to reduced fringe benefit taxes that have benefitted employees that use cars owned by a corporate body, which includes both public services and private companies (Larsson et al., 2016). Reduced fringe benefits taxes have been used for cars with renewable fuels since before the real increase for renewable transportation fuels started after the turn of the century, and the instrument has, in combination with other supports for environmental cars, been important for the growth in the number of environmental cars including biogas cars (ibid.). The fringe benefit tax has been reduced to a level where the environmental car is financially favorable, or at least equally expensive, in comparison to conventional cars. For biogas cars, the significance of the reduced fringe benefit tax is indicated through the relatively large share of biogas cars that are owned by corporate bodies, 53 % by the end of 2016[16]. Nevertheless, as for the biofuel tax reductions and exemptions and the premiums for environmental cars, the reduced fringe benefit taxes have not been a predictable support. Decisions about a continued reduction have typically been made for two years at a time, which has limited the positive outcomes of this policy instrument on the share of environmental cars[17]. Much emphasis was also put on the design of reduced fringe benefit taxes in the government inquiry regarding a vehicle fleet independent of fossil fuels from 2013, (Government of Sweden, 2013a).

Closely related to the premiums and tax exemptions provided for environmental and super environmental cars is a policy instrument called bonus-malus. The name bonus-malus comes from the Latin words for good and bad and as the name indicates, the bonus-malus instrument would promote less environmentally harmful cars on the expense of more environmentally harmful cars. The instrument was first presented in the government inquiry regarding a vehicle fleet independent of fossil fuels (Government of Sweden, 2013a). After that, two versions of the instrument have been proposed by the Swedish Government in 2016 and 2017 (Government of Sweden, 2017c, 2016).

[16] Personal contact with Anette Myhr at Trafikanalys 2017-05-31.

[17] Ronny Svensson, CEO, Ynnor AB, personal contact, 2017-05-30. Svensson is also a respondent described in Table 1. However, this personal contact was made after the interview.

The first proposal was presented April 29th 2016 and would have affected vehicles sold from January 1st 2018 onwards. This instrument would incentivize the purchase of certain vehicles through a premium, and disincentivizes the purchase of other vehicles through a vehicle tax. It would have affected personal cars, light buses (up to 3.5 tons), and light trucks (up to 3.5 tons), but not heavy vehicles. A premium would have been provided to vehicles with low or no tail-pipe emissions and the premium would have been differentiated for vehicles with no emissions, vehicles emitting less than 35 g CO_2/km, and vehicles that emit less than 50 g CO_2/km. Nevertheless, the vehicle tax would have been proportional to the estimated CO_2 emissions above a certain limit and thus higher for the fossil fuels compared to the corresponding biofuel.

This bonus-malus instrument was expected to increase the number of electric vehicles and decrease the number of vehicles that run on fossil fuels. The sales of hybrid vehicles and vehicles that run on biofuels were not expected to be heavily affected by the instrument. The emission levels to obtain the premium were set so low that biofuel vehicles would not have qualified, but, as pointed out above, the vehicle tax would have differentiated between vehicles that run on biofuels and fossil fuels, providing a stronger disincentive for the latter. However, the fact that biofuels were on the malus side would have sent confusing signals to the market. The instrument was expected to be self-financed during the first four years. The system was intended to complement existing general instruments and was seen as an extension of two existing specific instruments: the super-environmental car premium and the vehicle tax.

The Swedish Government did consider criticism from various interest organizations and government agencies directed towards the first suggestion and presented a second and modified proposal of a bonus-malus instrument in March 24th 2017 (Government of Sweden, 2017c). The revised proposal is intended to take effect in July 1st 2018. It will provide a premium (bonus) between SEK 45 000 and SEK 7 500 to vehicles with calculated emissions between 0 and 60 gram of CO_2 per km and gas vehicles would receive a premium of SEK 7 500. This premium is also suggested to be paid six months after the purchase of the vehicle, in order to avoid exports of subsidized vehicles. Moreover, the second proposed bonus-malus system will increase the vehicle tax during the first three years (malus) for gasoline and diesel vehicles: SEK 77 annually per gram of calculated CO_2 emissions per kilometer above 95 grams and SEK 100 above 140 grams CO_2 emissions per kilometer. After three years, the vehicle tax will be lower: SEK 22 annually per gram of calculated CO_2 emissions per kilometer above 95 grams. Gas and ethanol vehicles will not be charged with an increased vehicle tax, but tail pipe emissions are still weighted in accordance with the current vehicle taxation (SEK 11 annually per gram of calculated CO_2 emissions per kilometer above 95 grams as of April 29th 2017). Gas vehicles will thus not be placed on the malus side and will receive a bonus, although limited.

Public procurement has also been used as a policy instrument to promote the sales of environmental cars both nationally and locally. In two governmental propositions from 2009 (Government of Sweden, 2009b, 2009c), emphasis was put on public procurement as one of the policy instruments that could be used to reach climate-related goals. In addition to this, a decree that stated that the Swedish Government and its public authorities as a general rule only should purchase and/or lease environmental cars was decided about the same year (Government of Sweden, 2009d). This demand often applies for service providers to these authorities as well (Hansson and Grahn, 2013). In addition, authorities at local and regional (county) level have also used public procurement as an instrument for their climate-related ambitions. There are also examples of policy instruments that

have been used locally that have had a significant impact on the development for renewable transportation fuels, for instance through exemptions from congestion charges and parking fees for environmental cars (Government of Sweden, 2015, 2013a). In Stockholm, an exception from the congestion charge for certain environmental cars was applied between 2006 and 2009, or until 2012 for environmental cars registered before January 1st 2009. In an analysis of the effects of the congestion tax between 2005 and 2008, it was concluded that the exemption from congestion taxes was the most important policy instrument for the increase of environmental cars in Stockholm during the period (Stockholm Municipality, 2009). However, the main purpose of the congestion charge is to limit traffic congestion and to obtain fiscal resources. For this reason, the exemption was removed when the number of environmental cars increased, and there are similar reasons behind the withdrawal of exemptions from parking fees in many municipalities.

For biogas in transport specifically, there are several examples of policy goals and instruments that have promoted the development indirectly. Waste management policies can facilitate biogas production through e.g. regulations on waste sorting. The national environmental goals set the ambition that 50 % of the food waste should be sorted out and treated biologically by 2018 and that the major part of this, 40 % of the total amount, should be treated so that energy and nutrients are recovered (Swedish Environmental protection Agency, 2017). In practical terms, this means that the major part of the collected food waste should be treated through anaerobic digestion and only a small part may be treated through composting. Other influential policy instruments include the ban on landfilling of organic materials from 2002 as well as the tax on deposition of all materials in landfills from 2000 (Guziana et al., 2011). The intention with these polices is to increase recycling so that all waste fractions are taken care of as far as possible and that only waste that cannot be dealt with in other ways is deposited at landfills (ibid). The indirect effect has been the promotion of biogas production.

3.4 THE MULTILEVEL PERSPECTIVE

This work uses a theoretical framework by Geels et al. (2011, 2008, 2004, 2002) to understand the biogas development. Biogas development can be understood as a systemic transition according to this theoretical framework. The use of the term *systemic transition* instead of the term *technological transition* that is commonly used by Geels et al. (ibid) emphasizes that the transition involves more than a technology, i.e. a socio-technical system. Socio-technical system studies emphasize the relationship between society and technology and thus apply a wider perspective than a pure technological understanding of a system such as biogas (Olsson, 2015).

The framework by Geels et al. (ibid) contains two central triad concepts of which the first is system-actor-institution. In this work, the socio-technical system is understood as fuel production, distribution, and use in the transport sector. Actors in a system may be fuel producers, distributors, and end-users. Institutions[18] and rules regulate the system and may promote a transition to renewable transport fuels. The second triad concept in this framework is the multilevel perspective (MLP). A new socio-technical system may come about through a systemic transition (Geels and Schot, 2007). According to MLP, a systemic transition involves interaction between the landscape, regime, and niche levels. The landscape level entails macro-economic and macro-political factors,

[18] Formal government institutions.

such as energy prices. Changes at this level typically happen over decades. However, the oil price drop in 2014 is an example of a more rapid change of the landscape conditions. The established systems for fuel production, distribution, and use in the transport sector are located at the regime level. The regime level also contains governmental institutions and regulations, as well as actors and infrastructure. The niche level represents protected markets, universities, and other environments where technology may develop. The Swedish Government has supported renewable energy technologies such as biogas from anaerobic digestion at this level during a long period.

The socio-technical regime may change through interaction between these levels, pressure from the landscape (top-down) and/or technologies emerging from the niche (bottom-up). If the conditions at all levels are beneficial for a transition, there is a window of opportunity.

A transition may follow different transition patterns, depending on the interaction between the three levels (Geels and Schot, 2007). If the landscape conditions favor a systemic transition and a technology has developed at the niche level, this technology may substitute an existing system. If, however a technology develops at the niche level but the landscape level conditions are not favorable, a transition may instead come about as a stepwise reconfiguration. A stepwise reconfiguration is normally motivated by performance improvement and as a solution to local problems, e.g. waste management. A stepwise reconfiguration does not substitute the incumbent system immediately, but innovations are instead adopted as add-ons or as component replacements (Berkers and Geels, 2011). The sociotechnical system at the regime level is reconfigured slowly through new combinations of new and old components.

MLP may be used to understand a transition by analyzing the conditions at landscape, regime, and niche level as well as the interaction among these. This analysis may assist in understanding the transition pattern that is more likely to occur and the barriers that a transition may encounter. An understanding of transition pattern and barriers may provide input for an analysis of policy support directed at a transition to renewable transport fuels.

The framework of Large Technical System (LTS) by Hughes (1983) is also used in this work. The vehicle gas system can be described as a young and developing (LTS) with system fronts, such as, biogas supply, natural gas supply, vehicle gas demand, distribution infrastructure, actor networks, and policy frameworks; these fronts may develop at different pace (Hughes, 1983; Olsson, 2015). Some fronts may lag behind, while others may develop more quickly and become forerunners. Which system front that is lagging behind may change over time.

4 INTERVIEW RESULTS

4.1 SUPPLY SIDE

The interviewees on the supply and distribution sides discussed several opportunities for biogas development. These opportunities were primarily related to increased biogas production, improved digestate management, improved profitability, expanded vehicle gas infrastructure, as well as risk reductions. The stagnating vehicle gas demand was identified as a major bottleneck for grasping these opportunities. The interviewees also emphasized the importance of policy instruments for biogas development.

4.1.1 Possibilities to increase biogas production

The use of different feedstocks in biogas production could increase both in Stockholm County and in Sweden (Lönnqvist et al., 2015a, 2013). These feedstocks include food waste, sewage sludge, industrial residues, agricultural residues, and energy crops. In principle, there is room to use more of each feedstock category, except sewage sludge. To a large extent the potential from this feedstock is already being utilized in Stockholm County (Lönnqvist et al., 2015a). However, the interviews revealed possibilities to increase biogas production at existing sewage treatment facilities, both through increased yields and through co-digestion with other feedstocks. One of the interviewed companies is investigating possibilities to increase biogas yield through extended retention time (SYVAB). The company estimates that the production could increase about 10 % based on the same amount of substrate as today. Another interviewed sewage treatment company states that it can receive more external organic materials as feedstock and thus increase biogas production in the present plant (Stockholm Municipality, the facility Henriksdal).

The interviewees also discussed how more food waste could be made available for biogas generation. The main obstacle is related to food waste sorting by households, restaurants and other generators. The interviewed municipalities apply different strategies to achieve increased food waste sorting: differentiated waste collection fees providing incentives for the households to sort; voluntary commitments to waste sorting, which according to the interviewee give a high substrate quality; as well as public outreach and dialogue with large waste generators such as restaurants. One of the interviewees, Stockholm Municipality, has employed extra staff for this task, and aims at achieving a food waste sorting of 50 % by 2018 and 70 % by 2020. The municipality plans to use all the sorted and collected food waste in biogas production and thus aims at a more ambitious target than what is set by the national environmental goals (Swedish Environmental protection Agency, 2017).

The possibilities to make use of other resource categories – industrial residues, agricultural residues, and ley crops cultivated on fallow land – were also discussed with the interviewees, who were pessimistic about the possibilities to make use of the potential related to agriculture. The agricultural interest organization LRF does not recommend its members to invest in biogas production because of low profitability in farm-based plants. In addition, the interviews revealed that more large-scale producers do not consider energy crops as an option because of increased bureaucratic demands related to the sustainability certifications that are necessary to obtain the tax exemption, as mentioned in section 3.3.2.

4.1.2 Possibilities to improve digestate management

The interviewees[19] consider digestate handling a barrier rather than an opportunity. According to them, it is costly and the benefits of nutrients recycling that it brings are not sufficiently reflected in policy support. The interviewees discussed possibilities to improve digestate management. This includes dry digestion technologies that reduce the digestate volume since the water content is lower; reduction of the water content after wet digestion to facilitate logistics; and sludge quality certification systems that can facilitate the process of finding an output of the digestate. In addition, LRF mentioned that ecological farming might increase the demand for biofertilizer and thereby make biogas production more profitable.

Several interviewees (not only on the supply side) stated that the societal benefits related to different uses of the digestate, such as biofertilizer, are not reflected in policy support.

4.1.3 Possibilities to improve profitability in biogas production

The profitability in biogas production can improve, not only through an increased gas price, but also through gate fees and commercialization of the digestate. Gate fees may be collected for certain feedstocks such as slaughterhouse residues, while other feedstocks may imply a cost.

4.1.4 Possibilities to expand vehicle gas infrastructure

One of the interviewed distribution companies (Gas Grid Stockholm) and one of the biogas producers (SBF) have discussed a pipeline between a plant and the existing local grid, but the gas volumes are currently too small to make it profitable. Increased vehicle gas demand could enable an expansion of the vehicle gas infrastructure. These results reflect the conditions for vehicle gas distribution in Stockholm County and not for distribution in e.g. south and southwestern Sweden where a natural gas grid exists.

4.1.5 Possibilities to reduce risks through agreements

Risks in biogas production may be reduced through short and long-term contracts. For example, Stockholm Water had agreements with SL and other customers that allowed the company to invest in an upgrading facility in 2000. Another sewage treatment company (SYVAB) expressed that it manages risk by limiting its participation in the value chain to biogas production. Instead, it has agreements with private companies for upgrading and distribution.

4.1.6 Possibilities to improve cooperation and integration along the value chain

The producer E.ON is cooperating with the waste management company Ragnsells to build a new plant that would combine material recycling, biogas production, as well as heat and power generation. Stockholm Water buys heat from an external actor and the biogas that otherwise would be used to generate process heat is thus upgraded and sold as a transport fuel instead.

Stockholm Municipality is active in several steps of the biogas value chain and intends to increase cooperation between its different biogas-related activities. The municipality has placed waste col-

[19] Refering to the four biogas producers mentioned in Table 1.

lection and biogas production in the same unit, Stockholm Water. Municipal actors are active on both the supply and demand side – as procurers of waste management, owners of biogas production plants at sewage treatment facilities, and as end-user of vehicle gas in their own vehicle fleets. In addition, the County Council is an end-user of vehicle gas through the public transport bus fleet. There should thus be opportunities to increase cooperation between municipal and county level actors along the biogas value chain to promote production and use in transport.

4.1.7 Stagnated vehicle gas demand

The vehicle gas demand in Stockholm County has remained fairly constant at approximately 400 GWh_{pa} between 2013 and 2016, except for 2015 when the use decreased to 370 GWh (Statistics Sweden, 2017). This is illustrated in Figure 3. The stagnation in Stockholm County reflects the national development, illustrated in Figure 2. Thus this barrier is relevant both at the regional and national level. Basically, all interviewees perceive this stagnation as a major barrier to biogas development and suggested that the demand should be stimulated through policy. The interviewees suggested that an increased use of biogas could come from both existing and new user segments, the latter exemplified by privately owned cars and trucks (e.g. E.ON and Gas Grid Stockholm). The company E.ON, which is active on both the supply and demand sides, has opened five new refueling stations in Stockholm County. This is part of the company's strategy to stimulate the demand side in order permit a new production facility in the region.

4.1.8 Influence of policy instruments

The interviewees on the supply and distribution sides agreed that policy instruments are very influential for biogas development. However, most of the interviewees – with the exception of the waste management actors – perceive that the predictability of Swedish policy instruments is very low. Although the interviewees are active on the supply and distribution sides, they specifically mentioned policy instruments directed at the demand side when discussing the low predictability: the late approval of the tax exemption, the changed definitions of environmental cars, the late approval of reduced fringe benefit for environmental cars, and the uncertainty of how the new bonus-malus system will treat gas vehicles.

The tax exemption is perceived as essential for the profitability. Its late approval in December 2015 – only two weeks before expiration – has strongly contributed to the perception of a low predictability of Swedish policy instruments. One of the interviewed companies (SYVAB) expressed that it considered shifting from upgrading of biogas for use in transport to electricity generation with raw biogas because of these uncertainties.

The concept of environmental cars was criticized for having changed, for including vehicles that run on fossil fuels, and for not considering the multiple benefits of biogas since it focuses on tailpipe emissions. Several of the interviewees (e.g. Gas Grid Stockholm) suggested an environmental truck definition and premium, similar to the support given to environmental cars.

The proposed bonus-malus instrument was also criticized. The criticism did not concern the mechanism itself, which provides incentives (bonus) to low-emissions cars and disincentives (malus) to high-emissions cars, but the focus on tailpipe emission and the fact that gas vehicles are placed on the malus side, which would send the wrong signals to the market.

A low second-hand value of gas vehicles was also mentioned as a barrier and it was suggested that policy instrument could address this barrier by providing incentives to gas vehicles for a longer period of time (e.g. E.ON).

SBF states that there is a risk in relying on public support when making an investment. Most producers prefer an investment support to a production support, since the first is provided at some time in the beginning of the operations, and will generally not change during the lifetime of the plant. Investment programs such as Klimp and Klimatklivet are mentioned as influential for investment decisions.

In contrast, the waste management actors perceive that the policy instruments that affect them – mainly the national environmental goal concerning food waste sorting – are predictable. These national environmental goals are important for the municipal waste management actors. Huddinge Municipality expressed that "*the environmental goals are the base for our internal goals*". This policy target is thus an exception from the general perception that the predictability of Swedish policy instruments that affect biogas development is insufficient.

Several interviewees (e.g. Gas Grid Stockholm) pointed out that the multiple benefits of biogas and its role in the circular economy must be communicated better and that they should be reflected in policy support. Multiple benefits may refer to e.g. nutrient circulation through the use of the digestate as a biofertilizer and to biogas as a solution to handle waste. Interviewees (e.g. Stockholm Municipality) mentioned the use of biogas in waste collection vehicles as an illustrative way to communicate how biogas provides multiple benefits – it is both a transport fuel and a waste solution. Other examples of multiple benefits are: reduced GHG emissions from transport, reduced emissions of particles, reduced emissions of GHG from manure, reduced leakage of nitrogen from agriculture, increased recycling of nutrients to agriculture, and reduced used of chemical fertilizers (Energigas Sverige, 2015).

The low predictability is a result of the quickly changing policy framework. The changing policy framework does not provide a long enough planning horizon for biogas investments, since the conditions may change during the lifetime of an investment.

The interview results suggest that important actors are waiting for policy instruments to be clearer and more stable before taking investment decisions. One interviewee (E.ON) described the current state of biogas development as "hibernation". Another interviewee, an international biogas company (SBF), stated that there are no investment plans for Sweden, but that there are investment plans for Norway. Some interviewees were even more skeptical towards biogas development and expressed a fear that it will decline and follow the ethanol trend[20].

4.2 DEMAND SIDE

To a large extent, the respondents on the distribution and demand side provided a similar picture as those on the supply side. There appears to be a consensus regarding many central issues influencing the development for biogas solutions. On the demand side, several respondents compared different transport solutions, and argued for or against certain alternatives. Their answers revealed that there

[20] The use of ethanol had a peak in 2008 and it has been decreasing after that, see Figure 1.

are great challenges in comparing different types of transport solutions, regarding e.g. their environmental performance. The interviews further showed that policy issues are viewed as very central and influential, and many respondents declared that policy instruments strongly influence the development regarding biofuels including biogas.

4.2.1 The role of the public sector

The public organizations: the county represented by SL (Stockholm Public Transport) and the three municipalities (Stockholm, Huddinge and Lidingö) have several important roles influencing the development of the transport systems. They all mentioned political objectives, ranging from the national to the local level, as influential for this development. Further, public procurements seem to be key processes that significantly affect how transport services are constructed.

SL has a very central role within the whole county regarding public bus transports. In public procurements renewable solutions are required for the 2 200 buses. The operators can choose what type of renewable technology they prefer. However, a specific amount is dedicated to biogas as SL has the strategy to procure an amount of biogas that matches the biogas production of two relatively large municipal wastewater treatment plants in the county, called Henriksdal and Käppala. This ensures the demand for the biogas produced within the public sector, which is used to fuel about 330 buses (corresponding to 15 %) that are operated by the transport service providers that SL contracts. The annual volume of biogas has grown from about 11.1 to 12.8 MN m^3 from year 2014 to 2015, and is expected to reach 15 MN m^3 in 2017 (corresponding to circa 150 GWh). Long-term contracts (8+2+2 years) facilitate for the bus operators, as 12 years almost match the depreciation time for buses. SL and the operator Keolis have long term experience regarding different transport solutions, involving fossil fuels, bio-ethanol, biogas, and biodiesel.

The municipalities use different types of vehicles, mostly cars but also light trucks. Stockholm municipality is a much larger organization (Table 1) and has many more vehicles than the other municipalities. This organization has to deal with the traffic situation and emissions in the capital's most central areas with relatively intensive traffic. Stockholm municipality has reached far in replacing fossil fuels vehicles with other alternatives. Its internal organization Clean Vehicles in Stockholm, has long-term experience regarding these issues and has actively contributed to the changed vehicle fleet. This organization was a pioneer regarding procurement of 'environmental cars' in the beginning of the 21st century, then focusing on ethanol. This development has been ongoing since then – the respondent stated that almost 100 % of the vehicles fulfill the national 'environmental car' requirements, referring to requirements due from the year 2013 and onwards, deciding if a vehicle is exempted from tax. The fuel type and the vehicle weight in relation to its CO_2-emissions[21] decide if a certain vehicle is an 'environmental car 'or not. This means that heavier vehicles can have higher emissions while still being approved. Even if almost 100 % are 'environmental cars', a smaller share of about 70 % of the fuel is renewable, because some of the vehicles used by Stockholm Municipality are efficient diesel vehicles and gasoline is used in dual fuel cars. Huddinge and Lidingö municipalities have not come as far, even though they have policies and recommendations for vehicles, the share of 'environmental cars' is lower. Huddinge reported a 42 % share of 'environmental cars', but the employees commonly refuel the dual-fuel vehicles with

[21] Tail pipe, not well-to-wheel.

gasoline, resulting in a 20 % share of renewable fuels in total. However, during the last few years, Huddinge has intensified the work regarding transports with the ambition to increase the share of 'environmental cars' further and to expand the use of renewable fuels. Lidingö stated that the share of 'environmental cars' was 58 %, but despite a higher share than Huddinge, Lidingö seemed less ambitious, with a focus on the cheapest way to reach internal objectives regarding vehicles, not any further. About 45 % of the cars were gasoline-electric hybrid cars. In total, less than 1 % of the fuels used were renewable – this very small share was ethanol used in two cars. Lidingö is also smaller than the other municipalities, making it more feasible for employees to use public transports or bicycles for their trips, and short transportation distances means relatively low fuel costs for the municipality.

All respondents from municipalities indicated that the functions the vehicles are supposed to provide influence the choices. Electric vehicles were viewed as an option for shorter distances, biogas or ethanol driven vehicles for longer distances. But the interviewed environmental officers stressed that they only provide recommendations and the actual decisions are taken by the different units of the municipalities. All found it hard to steer their own organization and were considering how they can influence in the most effective way. The respondent from Clean Vehicles in Stockholm stated that the recommendations were commonly followed, but that some managers can have very strong opinions, for example selecting diesel vehicles instead of the recommended renewable alternatives. Huddinge uses very few biogas-fueled vehicles and the respondent stated that they are to be replaced by other types. This development was seen as undesirable, because hir found biogas a favorable option that should be supported, partially because the municipality has made investments in biogas pretreatment facilities and other types of infrastructure for biogas. Huddinge municipality has for example contributed to the establishment of refueling stations for biogas together with seven other municipalities in the southern parts of the county. The other municipalities are Botkyrka, Nykvarn, Nynäshamn, Haninge, Salem, Södertälje and Tyresö[22]. The mentioned reasons for choosing other alternatives than biogas included internal skepticism and fear of accidents, which the respondent viewed as consequences of a low level of knowledge. In Lidingö there is no biogas refueling station, which was stated as the reason why the municipality has no biogas vehicles. The respondent did not think that the municipality should engage in this matter.

All the interviewed municipalities use electric vehicles, and such vehicles were described as favorable or interesting by the interviewees. Stockholm appeared to focus a lot on electric vehicles and Clean Vehicles in Stockholm expressed that they view electric cars as the best option, at least within the central parts of the city. This organization was involved in projects to test electric vehicles, for example the use of electric heavy trucks during night hours when such transports are prohibited to avoid noise[23].

All three municipalities have activities directed towards the citizens, to influence their choices of transport solutions, but the respondents view it as more challenging to influence the citizens than the municipal organizations.

[22] Commonly referered to as "*Södertörnssamarbetet*" in Swedish.
[23] For more information (in Swedish): http://www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Trafikkontoret/Leveranstrafik/Off-Peak-/

4.2.2 Infrastructure and technology

Town gas has a long history in Stockholm, where a gas grid was established in the late 19th century. The gas was from the beginning produced from pyrolysis of coal, which later was changed to steam reforming of naphtha. Currently, natural gas combined with biogas makes up the town gas that is used by households, restaurants and local enterprises. The town gas grid covers the central and some other parts of Stockholm city, but this area only makes up a small part of the county. The later developed a grid for vehicle gas is more relevant for the transport sector. This grid has been expanded in a step-wise manner and includes pipes, depots and some refueling stations. It is owned and operated by Gas Grid Stockholm. This company distributed 200 GWh of gas 2015, including both the town gas and vehicle gas. Of this amount 125 GWh was distributed as vehicle gas to public refueling stations and refueling stations dedicated to busses in public transport, corresponding to about 34 % of the vehicle gas use in the region ("Leveranser av fordonsgas," 2017). The vehicle gas distribution in Stockholm County is further described in section 3.1. Since the region lacks access to the natural gas grid in south and southwestern Sweden, the conditions for distribution are quite different between these regions.

According to several of the respondents, limited access to vehicle gas was initially an essential problem in the Stockholm region, with too few refueling stations and occasionally shortage of gas at the existing ones. Widriksson Haulage invested in a refueling station and equipment for mobile storage, due to the mentioned problems. The respondent from Lidingö municipality stated that the long history with limited access to refueling stations and insecure supply has led to a bad reputation for biogas as a vehicle fuel and still hinders biogas expansion. However, some interviewees stated that the access now is sufficient in several parts of the county, even if there still are some areas with very limited access to refueling stations. Clean Vehicles in Stockholm is actively working with the further development of the grid including refueling stations, so is E.ON, Gas Grid Stockholm and others. Volkswagen and Ynnor, with experiences from many parts of the country, emphasized infrastructural aspects as one of the main obstacles for the development of biogas in transport and pointed out the very limited access to vehicle gas in the northern half of Sweden as a factor that makes it difficult to use biogas vehicles there. For example, this was stated to influence companies that wanted uniform deals for all their units in the country, meaning that biogas is sometimes not chosen because it cannot be supplied all over Sweden.

The respondents were asked if and how the natural gas content of the vehicle gas affects them and other actors of relevance. A majority described natural gas as an important enabler and backup solution that for example have been used to supply gas when there have been disturbances at some production plants. However, it was stressed that the share of biogas should be kept high. Several respondents mentioned that most users or potential customers have a low level of knowledge and therefore do not really know the difference between biogas and natural gas. On the contrary, some of the interviewees found the 'natural gas issue' to be central, and for example stated that:

- The higher share of biogas the better environmental performance, which improves the environmental declarations,
- They only wanted to use 100% biogas,
- Natural gas soils the reputation of biogas.

Several of the respondents mentioned that a challenge for biogas driven vehicles has been their efficiency, but they were convinced that this is improving and referred to new types of engines with an efficiency similar to diesel engines. Almost all respondents commented on issues related to vehicles, ranging from very general comments to very specific issues. For example:

- E.ON and Taxi Stockholm expressed a need for a wider variety of biogas driven vehicles, to better fulfill the customer needs and expectations. Taxi Stockholm was worried about the opposite development, with fewer models and a lower number of vehicles to choose from. A specific concern seems to be a potential lack of relatively large cars, appreciated by taxi drivers and their customers, and seen as suitable company cars preferred by managers.

- Widriksson Haulage has made a significant transformation during ten years; from 100% diesel to a significant share of renewable fuels (biogas + RME). In addition, they have implemented other improvements such as environmentally friendly containers and studless tires. Their trucks driven on biogas have a bit shorter service intervals, which is a disadvantage.

- Keolis described the current technology development as rapid, even very rapid for electric vehicles. In relation to this, it was emphasized that large and long-term contracts (via public procurements) are essential, so that they can continue to play a role in technology development (e.g. of gas-fueled vehicles), striving towards improved efficiency in cooperation with suppliers.

- Ynnor described plug-in hybrids as an interesting future alternative, but stated that it can be a gas-electric combo, referring to models developed by Saab several years earlier.

- Taxi Stockholm stated that customers probably will expand their focus, also to include NO_x and particles. After they have compared different car manufacturers and models that use the same type of fuel, they claimed that the performance varies significantly regarding NO_x and particles.

Keolis are operating buses from several different manufacturers that run on different types of fuels, which is challenging. This company has a long-term experience and during the years has changed its operations to become more efficient. One example is the choice to only have vehicles from one supplier and one type of fuel at each depot. This change made it possible to better adapt the technology at the depots and facilitated regarding competence.

When asked about the future development and role of biogas, several of the large actors (E.ON, Keolis, Clean Vehicles in Stockholm) expressed that electric solutions would be favorable in the city center, but that biogas would be a complement in the surrounding areas and urban fringe; for long-distance buses, heavy duty vehicles, and working machines. The respondent from Clean Vehicles in Stockholm stressed that transports of low value goods (gravel, stone, soil, waste, etc.) is an area where gas driven trucks can be a favorable option. Biodiesel (FAME) was also mentioned as a good choice for longer distances; HVO[24] was mentioned by several as a fuel with good performance, but limited amounts of the used raw materials (slaughterhouse waste) was stated as an

[24] Hydrotreated Vegetable Oils (or Hydrogenated Vegetable Oils)

essential barrier for expansion. To shift towards liquid biogas (LBG) was mentioned by several as a strategic way forward. Clean Vehicles in Stockholm found several advantages with LBG, and suggested investments in production and transportation of LBG, and to equip refueling stations with possibilities to provide biogas in both liquid and gas form.

4.2.3 Knowledge, information and behavior

The actors that sell vehicle gas, cars or taxi services described a situation with a low level of knowledge concerning biogas among the customers. The different customer groups lacked knowledge about the possibilities to use biogas and about essential differences between different types of technologies and fuels according to these interviewed actors. The municipalities observed similar challenges regarding the units ordering and using vehicles in their organizations, and in addition, skepticism and – in accordance to the interviewees – an unfounded fear of accidents. This was also the case for electric cars, but some had experienced a more positive attitude towards these vehicles. Clean Vehicles in Stockholm stated that old habits influence the behavior (for example the use of gasoline in dual-fuel vehicles), as some of their employees are used to refuel at a specific station and use a certain fuel. Ynnor claimed that it was common to choose dual fuel vehicles to get the subsidies, but then to mainly use gasoline.

According to an absolute majority of the interviewees, the national 'environmental car' requirements greatly influence the choice of vehicles when a 'green alternative' is preferred. This standard is currently based on vehicle weight and tailpipe CO_2 emissions, implying that a heavier vehicle is allowed to emit more. The answers indicate that it may be common that the user/owner know very little about the 'environmental car' requirements and that some, for example, believe that a relatively large diesel vehicle is a good environmental choice. In general, in the process to decide on transport solutions by companies and units within public organizations, there seem to be a very limited focus on the broad range of positive synergy effects that can be linked to biogas solutions (cf. Hagman and Eklund, 2016; Fiksen et al., 2016). This was acknowledged by several actors, who recognized a need to communicate more about biogas solutions and thereby increase the level of knowledge and as a result also the demand for these solutions.

4.2.4 Market conditions and economic viability

The biogas sector has expanded in Sweden and within Stockholm County for many years, where actors such as E.ON have played a significant role. The respondent from E.ON described a long period of growth, but where the limited demand has forced the company to focus on building the market stepwise in Sweden: first to market and sell biogas and via contracts create a basis; then supply gas bought locally or to secure a non-local supply and establish fueling stations; and finally, if possible, establish its own production and expand the supply. However, the relatively steady development towards reasonable profit, was now stated to have shifted to 'abeyance' – a more passive mode while studying the market development, including future policy. Volkswagen also reported a slowdown regarding the sales of biogas vehicles, and they pointed out that the development resembles what happened with bioethanol some years ago. This company has conducted a customer survey involving the 500 largest customers in Stockholm, Gothenburg and Malmö[25]. Its

[25] The three cities in Sweden with the largest number of citizens.

customers clearly regard environmental performance as important, but find economic issues most important. In line with these findings, the interviews clearly revealed that economic considerations play a major role on the choice of vehicles, especially when biogas vehicles (and other renewable options with similar characteristics) are compared with vehicles fueled by fossil fuels. The lower second-hand value of gas vehicles was often emphasized as an important factor influencing what types of vehicles companies choose to lease or what types a consultancy firm such as Ynnor recommends. Volkswagen also pointed out that the great customer interest in diesel influences the market in terms of what models the company develops, markets and demonstrates. The answers regarding economics were focused on vehicle costs, indicating that these kind considerations often do not take image/branding effects into account. Widriksson Haulage is thus an exception. This company has been striving to create an environmental profile that contributes to improved profit, and views the extra costs related to the investment in renewable technology as marketing costs.

However, the trend with increased use of electric cars contradicts the conclusion that economic considerations are decisive, as many of the organizations prioritize electric vehicles although they are aware that they can be significantly more expensive. None of the respondents brought up the second-hand value of the electric vehicles, but one acknowledged that there are many uncertainties regarding the life cycle costs of electric vehicles, for example, costs for disassembly and battery handling – concluding that it might be an expensive option. However, one of the municipality representatives stated that electric vehicles were good from an economic perspective, because they could charge them without any extra costs, as the costs for electricity were included in the rents of the buildings where the cars were charged. However, these buildings were owned by a municipally owned real-estate company, i.e. another part of the 'same' organization.

Taxi Stockholm uses about 1 600 vehicles of which almost 70 % are gas vehicles. However, the share of gas cars has recently decreased, while the share of diesel cars has increased. As taxis are replaced every third year, a transformation of the fleet may be rapid. This taxi organization has many very small member companies that when deciding about vehicle investments are making choices to get favorable owner conditions, which are related to the extent customer requirements and needs are fulfilled. Examples of customer requirements that have been and are very essential for the development are:

- Taxi Stockholm, referring to a Swedavia's[26] system/requirements regarding taxi transports from airports, but also requirements from other clients.
- Widriksson Haulage has gone through a major transformation towards renewable solutions, mainly due to requirements from a very large customer. This company has chosen 100 %

[26] Swedavia is a state owned company that owns, operates and develops Sweden's national basic infrastructure of airports, including Arlanda and Bromma airports in Stockholm County. At Arlanda airport Swedavia only allows taxis fulfilling the national 'environmental car' requirements to pick up customers. However, all taxi vehicles may leave customers at the airport. Further, the time of queuing is shortened for vehicles with low CO_2-emissions, which has been an important driver to choose biogas within the taxi sector. Thus, the system also favors electric cars over bio-fueled cars. Emissions from biofuels, however, is adjusted with a factor, thus favoring biofuel vehicles over fossil-fueled vehicles. Moreover, the system takes into account if a vehicle is using high blend-in biofuels. Vehicles must be preregistered and have a transponder when entering the airport. The system has existed since 2005 and uses the definition of environmental cars from 2013 to decide which vehicles qualify.

biogas supplied from Scandinavian Biogas (its Södertörn plant), due to requirements regarding traceability to source.

- Ynnor stated that biogas is recommended to, or prioritized by, some customers, e.g. suppliers of services to municipalities or county councils with environmental requirements, or those that have a connection to the production of biogas (e.g. feedstock supplier).
- Volkswagen reported that biogas is seen as a favorable option by customers that are really eco-aware with an expressed and strict environmental or corporate social responsibilities profile. A majority of these organizations are found within the public sector.

Taxi Stockholm stated that the dynamic situation, with for example unstable policies, makes it difficult to choose between different options. In addition, they would prefer a more stable gas price, not linked to fossil fuels. Currently, the biogas distributors adjust the price of biogas in relation to the price of petroleum, to make customers regard biogas as a competitive option. The respondent from Clean Vehicles in Stockholm expressed that this is a big mistake for the biogas business as these adjustments cause losses in a sector with no or small margins. Instead, the interviewee argued for a development towards a market with more stable prices, where the prices are sufficiently high for the biogas producers. Many of the current owners of gas-fueled cars are satisfied with their choice and with the right communication about the positive environmental effects of their choice, it may be that a higher relative price versus gasoline is accepted if the price for petroleum plunges. Both the producers and the consumers will be happy if the opposite happens and the price for petroleum surges. The interviewee continued by acknowledging that the relative price for the fuel is important for private car owners, but that more and more people are making a decision based on the environmental performance. Several of the respondents stressed that it is very problematic that gasoline and diesel fueled vehicles are chosen to such a large extent, and sometimes even are considered as 'environmental cars' in accordance with the national regulations. E.ON emphasized that fossil fuels do not have to pay for all their costs, while biogas is not fully rewarded for the values created by biogas solutions. Lidingö municipality was considering some kind of internal bonus-malus system, where those buying cars with worse environmental performance would have to support those investing in cars with better performance.

4.2.5 Policy instruments

All respondents found policy to be very influential regarding transport solutions and choices of vehicles/fuels, not least regarding biogas. Especially actors representing the county or municipalities, together with Keolis hired by public organizations, stated that the national ambitions and environmental objectives (e.g. regarding climate change) have a significant impact on its organization regarding transportation. Several described the national long-term ambitions as clear since many years, e.g. to phase out fossil fuels, but indicated that there is a lack of a national strategy for how to get there within the set timeframes (i.e. 2030 or 2050). Some rules for public procurement were perceived to limit the possibilities to provide long-term conditions or require vehicles/fuels that were regarded as the best from an environmental perspective. Huddinge stated that more effective policy instruments to support biogas solutions on the national level are needed and this was supported by comments from several others (e.g. E.ON & Taxi Stockholm). Clean Vehicles in Stockholm mentioned the possibility to use local regulations to transform the transport systems.

An absolute majority of the involved actors described the biofuel policy landscape as very dynamic and uncertain, which they perceived as problematic. For example, the respondents mentioned new and significantly amended regulations within Sweden and the EU that make it difficult to know what vehicles and fuels to choose, as that the conditions can change a lot during their life time. Tax exemptions were perceived as essential from an economic standpoint, but also mentioned as an example of short planning horizons. Several respondents mentioned that late in 2015, it was still not clear if the tax exemptions were going to remain in 2016. The economic policy instruments, such as investment support, tax exemptions, and exemptions from congestion and parking fees, influence the economy for many actors on the supply[27], distribution and demand side in several ways. Policy changes can relatively rapidly influence the demand. SL exemplified this by referring to the reduced use of RME/FAME as a response to increased taxation (in 2015). Clean Vehicles in Stockholm stated that the decision in 2015 to grant tax exemptions for biogas from 2016 to 2020 was important as it for example influenced the rapid introduction of new gas trucks.

The series of interviews manifested that the national 'environmental car' requirements play a major role regarding choices of vehicles, for example by being commonly referred to in public procurements of vehicles and transport services. The municipalities of Stockholm and Malmö have established a web page[28] that can be used to find vehicles fulfilling these requirements – a page that is frequently used according to Clean Vehicles in Stockholm. The respondents saw essential drawbacks related to the 'environmental car' definition, exemplified by statements indicating that:

- It incorporates a very limited environmental scope, focusing on tailpipe CO_2 emissions. Several of the environmental advantages with biogas solutions are not well assessed by such a definition. It was mentioned that biogas solutions contribute to decreased NO_x and noise levels, as well as nutrient recycling (circular economy).
- In practice, these regulations have led to a large share of diesel vehicles, i.e. not towards a fossil free transport sector.
- We are facing serious environmental challenges and our future development depends a lot on policy instruments, so the requirements should be tougher.
- The definition has been frequently changed, thereby undermining investments with a long-term perspective.

Clean Vehicles in Stockholm pointed out that they have considered the possibilities to introduce an environmental car definition that covers additional environmental impact categories and also mentioned ongoing work in cooperation with the Swedish Transport Association on a definition for trucks. Such a definition was also requested by a few other respondents.

All of the actors were asked about future policy instruments, regarding both what they expected or believed and what they preferred. Looking ahead, several of the respondents were critical to the suggested new bonus-malus[29] system. They did not criticize the basic concept, which simply is that high polluting alternatives to some extent are to fund transport solutions with a superior environmental performance, but argued that biogas vehicles/solutions should be supported, i.e. not be seen

[27] See Section 4.1 and Lönnqvist et al. 2017.
[28] www.miljofordon.se
[29] See section 3.3.2.

as neutral or malus as some preliminary suggestions have indicated[30]. Some comments were more general, arguing for a strong support of all renewable alternatives. One of the interviewees said that we still could have used ethanol on a large scale in Sweden, but we do not due to a too limited support on the national level. Several of the actors mentioned a risk of a similar development for biogas.

Volkswagen and Ynnor pointed out that the policy focus is on new vehicles (e.g. investment support, or reduced taxes for a few years), and thought it should also include the second-hand market. Otherwise, a significant focus is on short periods, for example a leasing period of three years for new cars. Longer time perspectives would give stronger incentives and a faster transition towards renewable alternatives, making environmental cars more attractive on the second-hand market. Both these actors emphasized the importance of understanding how customers/users make their choices, where some types of support might be good for the employee using a vehicle (e.g. providing reduced value of fringe benefits), while others are more relevant for the employer/owner. These respondents also emphasized the importance of designing policy instruments that address the relatively low second-hand value of the gas vehicles in comparison with the diesel vehicles they compete with. The respondent from Volkswagen suggested a combination involving investment leverages and operation-aids, while Ynnor stated that road taxes adapted to the total amount of emissions would increase the incentives to use biogas vehicles, thereby improving their second-hand value. Regarding future development of renewable fuels, several respondents mentioned EU-regulations as problematic, especially the indirect land use change (iLUC) regulations. These were viewed as unmotivated and significantly hindering for parts of the Swedish biofuel development. Arguments concerned that Sweden has a lot of fallow agricultural land and that this land could be used for energy crop cultivation, which would be more efficient from an economic and environmental perspective.

[30] According to a memorandum from the Swedish Government, the bonus-malus proposal has been modified after the interviews were conducted. In March 2017, it was suggested that biogas vehicles get a premium (i.e. are seen as bonus), but a significantly smaller premium than electric vehicles (Government offices of Sweden, 2017). This is further described in section 3.3.

5 DISCUSSION AND CONCLUSION

Biogas solutions have an essential role in the Stockholm region, mainly regarding public bus transports and taxi services. They are part of the Large Technical Systems (LTS) that provide transport services of different kinds. The vehicle gas system is relatively young and the respondents described long-term development towards improved services and efficiency, and ongoing advances in several areas. Most of the results from these interviews also reflect the national conditions for biogas development, although regional differences exist, especially regarding gas distribution.

From a feedstock potential standpoint, the amount of biogas could increase significantly within the region (Lönnqvist et al., 2015b; 2017), and this potential may be needed to reach the national objectives of a fossil-fuel independent vehicle fleet in 2030 and CO2-emission neutrality for Sweden in 2050. However, some of the expansion and development for biogas seems to have slowed down. The last years' uncertainties about policy and the future demand for biogas seem to be important reasons – results in line with those presented by Fenton and Kanda (2016), studying Basel, Switzerland, and Odense, Denmark. They also found institutional challenges that act as a barrier for biofuel/biogas development. Our case study in Stockholm County indicates that some influential actors are awaiting the coming 'rules of the game' and signals from central customers, before deciding about future steps. The system fronts have developed at different pace. Currently the demand side is lagging, but a few years back (around 2010 and 2011) there was a lack of sufficient and stable supply in this region (Lönnqvist et al., 2013; Statistics Sweden, 2017). The stagnating vehicle gas demand is viewed as the major bottleneck for biogas development. This perception is shared by actors on the supply, distribution, and demand side. An increased demand would allow for expanded biogas production, based on waste, residues or other types of feedstock, and further development of the gas distribution infrastructure. Waste sorting has been increasing as a result of government policies, such as the national environmental goals regarding food waste sorting and the ban on landfilling organic materials. This has made more feedstock available for biogas production. Existing large-scale sewage treatment facilities in Stockholm County could increase the biogas production, via increased production efficiency and use of additional types of feedstock. Actors in the region have investigated possibilities to expand the vehicle gas distribution infrastructure with new pipelines, but presently find the volumes insufficient to obtain profitability.

This study, in line with several other findings (Ammenberg et al., 2017; Ersson et al., 2015; Martin, 2015), found it challenging for biogas producers to establish a profitable digestate handling, i.e. to produce and distribute biofertilizers with reasonable economic outcome. The digestate handling is commonly seen as a barrier rather than an opportunity. The societal benefits that digestate can bring, e.g. nutrients recycling and contribution to the circular economy, are thus not properly translated into economic incentives for the biogas producer.

Public organizations are central actors in the development of biogas and other renewables within the transport sector (Fallde and Eklund, 2014; Fenton and Kanda, 2016). Via public procurements, SL has phased out fossil fuels successively from the public transports, in parallel ensuring a demand for the biogas produced at municipal wastewater treatment plants in the Stockholm region. This approach means that several regional and municipal interests are handled simultaneously using a collaborative approach, in contrast to cases where each unit handles its own matters in isolation (de Paiva Duarte, 2015; cf. Senge et al., 2005). By linking socio-technical systems the focus is broader than optimizing transport services and reducing the use of fossil fuels: it also involves effi-

cient water and waste management, and nutrient recycling in the biogas case – it is about systems integration to come further (Vernay et al., 2013). Regarding cars, another public organization was mentioned as very influential – Swedavia – that operates the two larger airports in the region. The requirements and queuing systems for taxis at these airports promote taxis that run on biofuels, and have thus strongly contributed to a shift towards taxis driven on renewable fuels and especially so for biogas-fueled taxis. The three municipalities provided a mixed picture. Stockholm has come very far regarding the share of 'environmental cars', and its organization Clean Vehicles in Stockholm seems to be very engaged and competent. Huddinge and Lidingö clearly work with these issues but with lower ambition levels (Lidingö appears to have lower ambitions than Huddinge). In Sweden, public organizations can be expected to be forerunners and to work extensively with renewable solutions. However, the involved municipal environmental strategic organizations stated that they recommend vehicles, but do not have the mandate to decide.

This study shows a large and widespread interest in electric vehicles – the number of buses and cars fueled by electricity is likely to increase, which is in line with scenarios in the public inquiry about a fossil-free vehicle fleet (Government of Sweden, 2013a). High energy efficiency, low levels of noise and reduced exhaust emissions, were arguments that were put forward as why electric buses are favorable in inner city centres. This may be rational if the buses have been found to cause the problems that should be addressed in these areas. However, a positive effect is less certain regarding the national targets to phase out fossil fuels, as the future role of biogas will be affected by how an expansion of electric solutions come about. Electric vehicles are often perceived as a competitor to gas vehicles, rather than a complement. We want to underline that biogas is not only a renewable transport fuel, but also a waste management solution and a way to provide biofertilizers to agriculture, thus providing other societal benefits that cannot be attributed to electric vehicles or to other transport biofuels. Several respondents saw a risk that electricity will replace biogas as decision-makers often tend to favor one particular alternative. This would not be in line with scenarios in the public inquiry about a fossil-free vehicle fleet, which indicates a need for the biogas sector to expand further, in parallel with the expansion of renewable electricity and other renewable alternatives. The large and more experienced organizations (such as SL, Keolis, E.ON, and Clean Vehicles in Stockholm) in the region argued for a mix of renewable alternatives, where biogas could be used for public transports in the outer city and urban fringe, long-distance buses, heavy duty vehicles and working machines. However, how to open up for new user groups for biogas is an essential challenge to solve. It can be wise to look at this before a large scale implementation of electric alternatives, otherwise there may be a risk of a transition where electric buses and cars replace biogas solutions, instead of complementing them (Fenton and Kanda, 2016). Such developments could hinder the biogas sector from further expansion and thus put the investments in this socio-technical system at stake, possibly preventing the development from a niche to an established regime (Fallde and Eklund, 2014; Geels, 2011). Stockholm County is large enough for several different types of solutions, and the public organization SL manages a large amount of bus transports of different character. But for smaller regions and cities in Sweden and other countries, it may be even more important to consider if and how existing biogas systems shall be complemented, to expand the total share of renewable solutions and not mainly shift to new solutions within the same share.

Several respondents compared different transport solutions, and argued for or against certain alternatives. Economic aspects are influential and were mentioned by many. For example, the lower second-hand value of gas vehicles was mentioned in comparison to diesel cars, as an explanation to

the relatively low share of gas driven vehicles. However, it cannot be taken for granted that the second-hand value of diesel cars will remain high (for example noticing plans to ban diesel cars in several large international cities). The logic seems to be different regarding electric vehicles, as they are commonly relatively expensive to buy and the second-hand value and other costs (for battery handling and other issues) must be characterized as very uncertain, but still this study showed a great interest in electric alternatives. These results are in line with findings from the Netherlands (Bakker et al., 2014), investigating stakeholders views on electric vehicles.

The answers showed that there are essential challenges in comparing different types of transport solutions efficiency and environmental performance. The scope can be very different, ranging from energy for propelling a certain type vehicle to much broader considerations including the whole transport system from a life-cycle perspective and a broad range of factors/impacts. In addition, the comparisons appear to be based on different types of values: old values, existing or expected future values, where the transport sector seems to use many test values with significantly underestimated impacts (Fontaras et al., 2017; Kadijk et al., 2015). Therefore, it can be urgent for decision-makers (and others) to thoroughly check what type of data that has been used for this type of comparisons. Finally, there appears to be many uncertainties involved, not least regarding the costs for the potential new electric solutions. For informed decision-making, it is essential to handle these uncertainties in a strategic way (Feiz, 2016). Regarding efficiency, it should be noticed that the studied systems are large socio-technical systems, meaning that they are relatively slow developing (Geels and Schot, 2010).The biogas solutions have become more efficient, but if such systems are frequently replaced by other types of systems, they will not reach more mature/efficient levels (Fallde and Eklund, 2014).

Policy issues are viewed as very central and influential by the actors – many respondents stated policy instruments to strongly influence the development of biofuels including biogas. It was commonly suggested that policy instruments should stimulate the demand side. The interviewees suggested that policy instruments should be directed at both existing and new user segments, e.g. privately owned vehicles and trucks. Technology pathways compete both for end-users and for the attention of the policy makers.

The ‘environmental car’ definition and the financial support that it will bring about has been a powerful instrument, but the definition has shifted and at times it has even encompassed cars driven on fossil fuels. The focus on tailpipe CO_2 emissions in the definition means that the scope is very limited and does not cover what should be included in a broad environmental systems analysis of transport solutions. As biogas solutions may involve several different types of positive synergy effects (Ammenberg and Feiz, 2017; Hagman and Eklund, 2016), such regulations can be seen as most unjust for them, assuming that the purpose is to promote transport solutions with a good overall environmental performance (or societal resource efficiency), when a life-cycle perspective is applied. Several respondents expressed a need to increase the level of knowledge about biogas solutions, to get an improved understanding among decision-makers and customers regarding the broad positive socio-economic effects, and to be able to make better comparisons with other alternatives. It was specifically suggested that the societal benefit that biogas production provides through biofertilizers should be better reflected in policy instruments.

The very dynamic policy landscape with great uncertainties about decision-makers’ view on biogas, seems to be one important reason behind the decreased pace of development. The low predictability is partially due to that the Swedish government must consider compatibility with the EU

framework. Swedish policy instruments, such as the tax exemption, may even be subject to approval from the EU Commission. The Swedish government is thus not free to design policy instruments. The different proposals regarding a bonus-malus instrument have increased the uncertainty in the sector. The first proposal would give incentives to electric vehicles and disincentives to biogas and other transport biofuels. Although the instrument would differentiate biofuels and fossil fuels it may send confusing signals to the market by giving biofuels a disincentive. The second proposal of this instrument is more positive for biogas development, although the incentives for gas vehicles are quite small.

There seems to be a need of a clear national long-term strategy showing how the far-reaching national objectives about reduced dependence on fossil fuels and climate change mitigation should be realized. Such a strategy should include well designed policy instruments to support such a transformation, from a strategic to operational levels (cf. Upham et al., 2016). Olsson et al. (2015), studying Stockholm's road transport system combining policy analysis and back-casting, describe it as crucial to rapidly change the policy with the purpose to strengthen the development of renewable alternatives. In addition to programs to mitigate negative environmental impact, both the European Union and Sweden have high ambitions and visions regarding bio-based and circular economy (European Commission, 2012; FORMAS, 2012; cf. de Besi and McCormick, 2015), which should favor biogas solutions as they commonly to a large extent are both bio-based and circular by, for example, transforming waste flows into fuels and contribute to nutrient recycling. But, a large share of the actors within the biogas sector in Stockholm County appears to be very frustrated, as the fossil-based alternatives still commonly are chosen in the society, although being heavily polluting, not bio-based and not part of a circular economy.

5.1 FUTURE RESEARCH

Biogas is a local solution that addresses global problems such as climate change. The conditions for biogas solutions will, to a certain extent, depend on the specific region and its conditions, as shown in this case study of Stockholm County. Case studies in other regions that reveal the specific needs of the regions as well as the general trends that may be valid for the whole of Sweden may complement this report. A general theme in this report has been the low confidence in Swedish policy instruments and future policy and actor-oriented research may build on this and suggest more concrete ways to create trust in Swedish policy instruments as well as suggestions regarding what the biogas actors themselves could do to address the barriers of biogas development, such as a stagnated demand side and low profitability.

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APPENDIX A

A.1 EXAMPLE OF INTERVIEW GUIDELINE WITH A BIOGAS PRODUCER (IN SWEDISH)

Intervjufrågor tillförselsidan: Stockholm Vatten, Henriksdal och Bromma

Organisationens strategiska beslut

- Hur ser ni på er verksamhet och hur har den förändrats över tid?
- Hur har biogas och uppgraderad biogas vuxit fram?
- Vem tog initiativ till anläggningen? (uppgraderingsanläggningen samt utbyggnad)
- Vem tog beslut om anläggningen? (uppgraderingsanläggning samt utbyggnad)
- Hur ser ni på risk och hur har det påverkat investeringsbeslutet?
- Hur hanterar ni rötrester från biogasproduktion?
- I vilken mån är rötresterna ett hinder och vilken mån är det en affärsmöjlighet?
- Om hinder: Hur kan hanteringen förenklas och göras billigare?
- Var anläggningen tänkt för uppgradering från början?
- Upplever ni att det finns konkurrens om substrat som matavfall? I.s.f. från vem och för vad?

Inverkan av styrmedel i beslutet att genomföra investering

Intervjuaren dokumenterar svaren och tolkar dem också på nedan skala. Respondenten får en chans att godkänna detta då transkriptionen skickas ut.

5 Mycket starkt; 4 Starkt; 3 Neutral/i viss mån; 2 Svagt; 1 Mycket litet eller inget; Vet ej

- Har ev. drifts-, investerings-, eller FoU-stöd påverkat ert investeringsbeslut?
- Har offentlig upphandling och/eller långsiktiga avtal påverkat ert investeringsbeslut (t.ex. att länstrafiken köper drivmedel)? (*Obs: kan också gälla långsiktigt avtal med privat aktör*)
- Har information från Energimyndigheten eller annan offentlig organisation haft betydelse för investeringsbeslutet? På vilket sätt?
- Har erfarenheter från andra drivmedelsanläggningar varit behjälplig haft betydelse för investeringsbeslutet? På vilket sätt?
- Har samarbete eller informationsutbyte med forsknings-, utvecklings- och demonstrationsprojekt på företag och högskola påverkat investeringsbeslutet?
- Har lagar och regleringar påverkat investeringsbeslutet (t.ex. förbud mot deponi av organiskt material)?
- Det finns flera typer av stöd för slutanvändaren av er produkt. Exempel på detta är t.ex. skattereduktion för biogasbilar och undantag från energi- och koldioxidskatt. Har denna typ av stöd påverkat ert investeringsbeslut? Ange vilket och hur.

- Hur värderar ni ett driftsstöd gentemot ett investeringsstöd i beslutsprocessen att genomföra en investering?

  Intervjuaren dokumenterar svaret och betygsätter de bägge alternativen.

  5 Mycket starkt; 4 Starkt; 3 Neutral/i viss mån; 2 Svagt; 1 Mycket litet eller inget; Vet ej

- Hur tror ni att nya och förändrade styrmedel kommer påverka *de generella* förutsättningarna för biogasproduktion och –uppgradering inom de närmsta fem åren?

Intervjuaren dokumenterar svaret och betygsätter på nedan skala. Vi kan också följa upp med om respondenten har räknat in någon framtida förändring eller är säker på att ett visst styrmedel ska bestå.

5 Gynnsamma förändringar i stor utsträckning; 4 Gynnsamma förändringar i mindre utsträckning; 3 Oförändrat; 2 Ogynnsamma förändringar i mindre utsträckning; 1 Ogynnsamma förändringar i stor utsträckning; Har ingen uppfattning

- Hur uppfattar ni förutsägbarheten för styrmedel som, direkt eller indirekt, påverkar biogasproduktion?
- Hur har förutsägbarheten för styrmedel, eller avsaknad av detta, påverkat er beslutsprocess, under de senaste fem åren?

Intervjuaren dokumenterar svaret och betygsätter på nedan skala. Om det behövs kan vi förslå nedan alternativ.

5 Mycket starkt; 4 Starkt; 3 Neutral/i viss mån; 2 Svagt; 1 Mycket litet eller inget; Vet ej

- Att genomföra investeringen i anläggningen
- Att utöka kapaciteten
- Investering i infrastruktur för t.ex. råvarutillförsel, uppgradering, gasdistribution eller hantering av rötrest
- Att ingå långsiktiga avtal
- Annat beslut (ange)

- Vilka styrmedel bedömer ni vara de viktigaste för att öka produktionen av uppgraderad biogas? Beskriv hur ett sådant skulle kunna vara utformat.

  Vi har flaggat för denna fråga i bakgrundsenkäten.

- Kommer ni att ha kapacitet för att röta extra organisk material efter utbyggnad?
- Vilka hinder finns för att utnyttja ev. överkapacitet?
- Har ni/ert partnerföretag kapacitet att uppgradera mer biogas?
- Ni uppgraderar idag nästan all producerad biogas och täcker de interna energibehoven med andra energikällor. Vilka har utmaningarna varit för att uppnå detta?

Energigrödor kan samrötas i er anläggning för att utnyttja överkapaciteten och öka produktionen. Dessutom skulle närliggande odlingar av energigrödor kunna ta emot rötresten och ev. minska kostnaden för dess hantering.

- Har detta diskuterats i organisationen?
- Ser ni några möjliga samarbetspartners för detta?
- Ser ni detta som en möjlighet?

Vad ser ni för hinder för detta?

A.2 EXAMPLE OF INTERVIEW GUIDELINE WITH A BIOGAS DISTRIBUTOR (IN SWEDISH)

Intervjufrågor distributionssidan: E.ON

E.ON:s fordonsgasförsäljning

- När började ni sälja fordonsgas?
- Varför har ni valt att satsa på fordonsgas (specifik tankställen i Stockholms län)?
- Vad kom ”först” i era planer, biogas eller naturgas?
- Är fordonsgas en bra affär för er?
- Vilka är möjligheterna med biogas?
- Finns det några svårigheter med biogas?
- Hur har försäljningen sett ut över tid? Ökar eller minskar efterfrågan?
- Hur upplever du överenskommelsen om minst 50% biogas i fordonsgasen?
- Hur ser ni till att det är 50% biogas i ”biogas 50”? Kan det överstiga 50% biogas? Gäller 50% alla tankställen eller är det ett medelvärde (för hela E.ON Gas)? Vem kontrollerar?
- Hur hanterar ni produkten ”biogas 100” – var finns den biogas som kunderna betalar för?
- Ser du naturgasen som en möjlighet eller ett hinder för biogas? Varför?
- Hur tror du att förhållandet mellan naturgas och biogas kommer att vara på 10 års sikt?
- Tror du att ni kommer att kunna expandera er fordonsgasförsäljning i Stockholms län?
- Varför/varför inte, och hur?

Styrmedel

- Har pumplagen och stödet för att tillhandahålla biogas påverkat era beslut? I så fall, hur?
- Har andra styrmedel påverkat era beslut? I så fall, hur?
- Hur anser du att förutsägbarheten i styrmedel, eller avsaknaden av den, påverkar era beslut?

Kunder

- Varför tror du att era kunder väljer fordonsgas? (miljö, ekonomi, tjänstebil…)
- Tror du att de bryr sig om hur mycket naturgas det är i fordonsgasen?
- Vilken typ av kunder väljer ”biogas 100”?
- Tror du att ”biogas 100” är något som kommer att växa?
- Vad tror du skulle få fler bilägare att satsa på fordonsgas respektive biogas?

Avslutande

- Vilket slags styrmedel tror du är viktigast för att öka efterfrågan på och distribution av biogas som drivmedel?

A.3 Example of interview guideline with a biogas end-user (in Swedish)

Intervjufrågor användarsidan: widrikssons

Generellt/inledande

- Hållbarhet verkar vara något som är viktigt för er. Hur blev det så? Vem är det som initierade ert hållbarhetsarbete?
- Vilka drivmedel använder ni i er verksamhet?
- Hur har ni valt fordon och drivmedel?

Biogas

- Hur kommer det sig att ni satsat så mycket på biogas?
- När bestämde ni er för att bygga ett eget tankställe?
- Hur gick processen med att uppföra ett tankställe till?
- Var det en stor investering? Fick ni något ekonomiskt stöd för investeringen i tankstället?
- Vi har förstått att Scandinavian Biogas Fuels levererar biogas till er. Har ni ett långsiktigt avtal med dem?
- Hur stor roll spelar det för er hur mycket biogas respektive naturgas det är i fordonsgasen?
- Finns det några svårigheter/nackdelar med att använda biogas i er verksamhet?
- Ser ni några konkurrensfördelar eller liknande, med att använda biogas?

Styrmedel

- Vad påverkar era framtida val av fordon och drivmedel (t ex tillgång, kostnad, teknik, aktörer, opinion)?
- Hur påverkas ert val av fordon av regleringar och hållbarhetsmål?
- Hur påverkas ert val av fordon av ekonomiska styrmedel?
- Ser ni några trender i era val av fordon och drivmedel?
- Kan dessa trender kopplas till styrmedel?
- Hur anser ni att förutsägbarheten i styrmedel, eller avsaknaden av den, påverkar era val av fordon och drivmedel?

Avslutande

- Vad tror ni är det bästa sättet att öka användningen av biogas som drivmedel hos åkerier?
- Kan styrmedel åstadkomma detta eller är det andra åtgärder som måste till?

LINKÖPINGS UNIVERSITET

STOCKHOLM GAS

THE SWEDISH KNOWLEDGE CENTRE FOR RENEWABLE TRANSPORTATION FUELS

www.f3centre.se

Swedish Energy Agency

www.energimyndigheten.se