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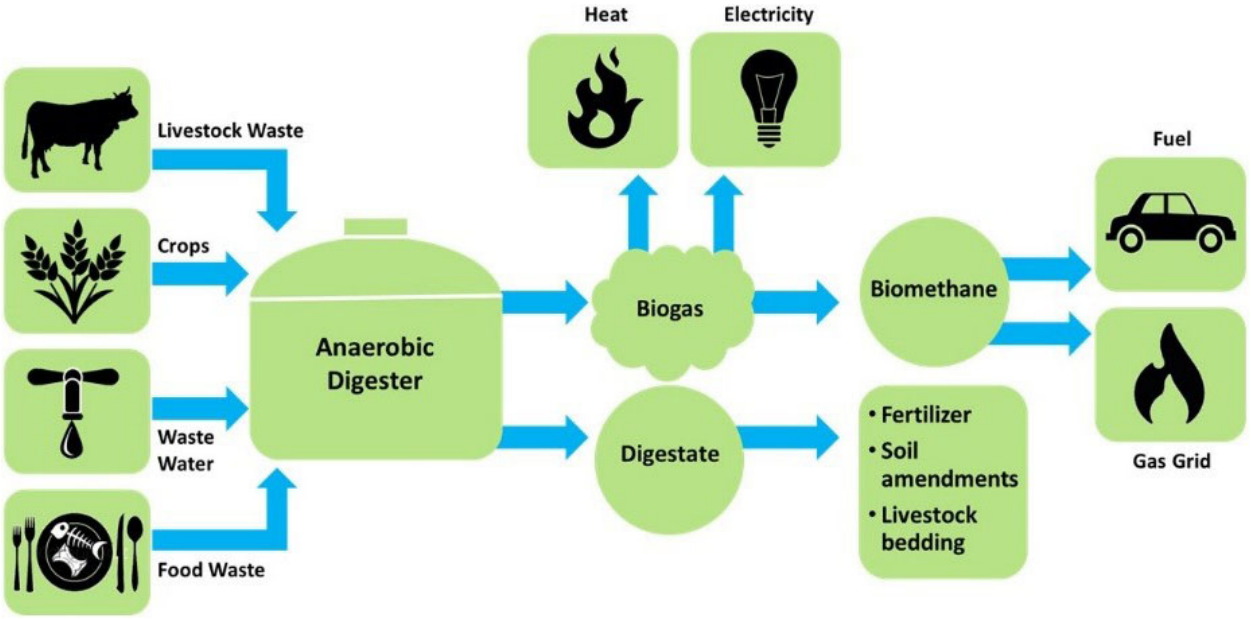

Identifying barriers and enablers of the biogas value chain

Supporting biogas development to fulfill potential in Västra Götaland

SEEX30

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Gothenburg, Sweden 2018

Master's thesis 2018

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Abstract

Due to ambitious targets for a fossil-free Västra Götaland by 2030, development of local production facilities for renewable alternatives is urgently needed. Despite a push on biogas production by the Swedish government in 2015, that same year only 14% of the national biogas capacity was being exploited. Västra Götaland has a target of 2.4 TWh annual biogas production by 2020, which presents a significant challenge considering that the 2015 national output was only 1.4 TWh. This study explores the research question: *What barriers are hindering biogas from being used to its full potential in Västra Götaland, and what enablers could help to reach this potential?*. The aim is to identify how the forecast potential for biogas in Västra Götaland can be fulfilled. The study assessed the current situation by conducting a case study on the existing biogas value chain in Västra Götaland. Consequently, relevant stakeholders from the value chain were identified and semi-structured interviews were held to gain perspectives on the current biogas market state, perceived barriers and potential enablers. Grounded theory was applied to statements gathered during interviews to enable a SWOT analysis and thematic categorisation process to be carried out, with priority given the statements that had been mentioned by the most stakeholders. From this analysis, it was identified that inconsistency in supply and demand, lack of long-term planning and agreements at a national level, and competition with imports of cheaper biogas from Denmark were the main barriers to development in Västra Götaland. A key enabler was that circularity aspects of the value chain made biogas a regional political focus. Policy change was considered as an appropriate measure to address the identified barriers. Detailed investigations were undertaken into the biogas policies in place in Sweden and Denmark, with comparisons also drawn between policies in 13 other EU countries. This revealed that Sweden was one of only three countries investigated that did not offer any form of feed-in tariff for direct injections of biogas to the natural gas grid. Follow-up discussions with stakeholders identified that this may be due to potential controversy resulting from the lack of a universal Swedish gas grid. This excludes producers who are not in geographical proximity to the grid and therefore cannot benefit from it. Furthermore, a private monopoly on grid ownership means that the cost of grid connection and transmission has increased rapidly in recent years. It was agreed that greater transparency was needed between actors within the value chain, particularly with regard to grid connection options. It was also concluded that clearer information on the economic support available would encourage development of new biogas production facilities, and that financial support should be provided on a basis of potential GHG emission reduction. It was acknowledged that these issues would need to be addressed at a national rather than regional level, but discussions with stakeholders implied that the environmental benefits associated with biogas would be a strong driver for government change.

Keywords: *biogas, sustainability, fossil-free, SWOT analysis, grounded theory, policy*

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Sara Vagiström and Alice Whetstone
Gothenburg, May 2018

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1
Introduction

This study investigates the biogas value chain in Västra Götaland and what can be done to increase regional production and consumption of biogas and related products. It also covers the backcasting methodology for sustainable development, which was the approach taken to identify the research topic for this project. Biogas production and use can help to create circularity in society; nutrient-rich organic waste is treated in a way that reduces the climate impacts of that waste, and in the process creates both renewable fuels and high quality organic fertiliser. The fertiliser can be returned to land, preserving the minerals from the original organic matter and enabling these minerals to be cycled back into arable crop production, thereby closing the loop to create circularity in the socio-technical regime. However, the value chain of actors involved in biogas production and consumption is complex, demanding good collaboration between different parties in order to sustain itself.

1.1 How to Read this Report

This report was written following a study conducted as part of a Challenge Lab project, where a diverse range of students are given the opportunity to, in a neutral arena, take a backcasting approach to sustainability transitions while interacting with stakeholders in the region. Although this report is to a large extent reflective of the title outlined on the cover page, the approaches outlined in some sections deviate somewhat from more traditional master's thesis project work. As such, it is also natural that the report is rather atypical in comparison to a traditional master's thesis report.

Chapter 2 offers an insight into the journey taken in order to identify a suitable topic of research for a master's thesis project; other sections of the report are directly related to the specific research project on biogas. If the reader is primarily interested in learning more about *Identifying barriers and enablers of the biogas value chain*, it is possible to omit Chapter 2 and instead simply focus on the of the project that relate solely to biogas. For readers looking for a more holistic view on this project, Chapter 2 offers an outline of the process through which this research topic (deemed relevant to the sustainability challenges for the Western Region of Sweden) was identified. Readers with a specific interest in recommendations for biogas policy implementation based on the findings of this study can go directly to Section 6.5.2.

It should be noted that the phrase to “Västra Götaland” refers to the county of Västra Götaland which comprises a geographical region in western Sweden; “Västra Götalands Region” is an organisation governed by the state which provides public services within the region of Västra Götaland.

1.2 Background on Biogas

Biogas is a methane (CH_4)-rich biofuel formed through the anaerobic digestion of organic materials. These are typically either energy crops (grown with the intent purpose of use as a feedstock for biogas production) or organic waste, such as agricultural residues, manure and household food waste (Wilkie, 2018). When organic matter is digested in an anaerobic environment, the volume of the matter decreases and a methane-rich gaseous mixture, plus a nutrient-rich solid digestate, are produced (Lantz et al., 2007). The solid digestate can be used as a high quality organic fertiliser which can improve both yields and protein-content of crops, whilst simultaneously reducing Green House Gas (GHG) emissions associated with organic waste storage (assuming waste materials have been used a the feedstock for the process) (Börjesson and Berglund, 2007; Santosa et al., 2018). Using the digestate as fertiliser also reduces agricultural eutrophication and demineralisation through more effective nutrient cycling. The gaseous mixture, referred to as biogas, can be used as a renewable alternative to fossil fuels for both transportation and energy, resulting in reduced GHG emissions in these sectors as a result of the carbon offset from growing crops and/or prevention of methane emissions through better management of organic waste. Furthermore, if organic waste is used as the feedstock for biogas production, this enables circularity through both improved cycling of minerals and by seeing the materials as resources rather than waste (Lantz et al., 2007).

Considering the credentials of biogas production outlined above, the authors argue that biogas has the potential to be used for both sustainable production of renewable fuels and improved waste management, resulting in reduced GHG emissions and improved use of resources. This could help achieve the targets outlined in the ambitious 2015 Swedish governmental policy, focused on energy, climate and the environment, which aims to see Sweden "become one of the world's first fossil-free welfare countries" (Government Offices of Sweden, 2015; Government Offices of Sweden, 2017). At a more localised level, biogas has been cited by Västra Götalands Region as a way to productively utilise food waste as part of their "climate-smart and healthy food" focus in their Climate 2030 strategy (Klimat 2030 - Västra Götaland ställer om Strategiska vägval). Furthermore, increasing demands for organic food from both the public and private sectors in the region will result in greater need for organic fertilisers, which could in part be fulfilled through the fertilisers produced alongside biogas (Västra Götalands Regionen, 2018b).

In spite of the identified benefits of biogas, it was estimated that in 2007, only 10% of biogas potential in Sweden was being utilised (Lantz et al., 2007). By 2015, the total biogas production had increased only slightly to just under 14% of forecast potential (Statens Energimyndighet and Energigas Sverige, 2016; Fagerström, 2013). This is a slow rate of growth considering claims that the demand for biogas as a fuel has grown by 30-40 % each year during the two decades in which the Swedish biogas sector has been developing (Fagerström, 2013). Västra Götaland has been identified

as one of the regions in Sweden with the most potential for biogas production, but at present this potential is far from fulfilled (Västra Götalandsregionen and Länsstyrelsen, 2016) This limited growth despite considerable potential could be explained by the poor current market conditions; at present, it is often not profitable to produce biogas in Sweden at present. This lack of economic feasibility is typically most acute for small scale producers in rural areas who lack convenient access to supporting infrastructure and may not have the time or the expertise to take on additional work. Additional barriers lie within unfavourable policies in terms of taxation on biogas production and poor public perception (Lantz et al., 2007). As such, although there is potential for biogas to play a key role in meeting both regional and national environmental targets, investigation needs to be carried out into what changes need to occur in order for these opportunities to be grasped.

1.3 Aim

The aim of this project is to identify how the forecast potential for biogas in Västra Götaland can be fulfilled. By looking into the barriers and enablers for the regional biogas value chain, a focus that could further support the development of an existing sector will be highlighted. This focus will be selected based on the perspectives of relevant stakeholders within the value chain. Considering this focus and drawing inspiration from biogas successes elsewhere in the EU, proposals will be presented that address the key barriers to development of biogas in Västra Götaland, and enablers that could further support development will be outlined.

1.4 Scope

The study will address the biogas value chain in Västra Götaland, with some reference to biogas in Sweden as a whole, for aspects where centralised decision-making means that it is not possible to look solely at Västra Götaland. It will also consider the import-export market for biogas, which has a direct impact on the biogas value chain in Västra Götaland due to a direct natural gas pipeline connecting the region to other European countries (this is not the case for most of the regions in Sweden) (ENTSOG, 2018). The forecast potential for biogas production in Västra Götaland was based on the availability of organic waste and agricultural residues in the region (Västra Götalandsregionen and Länsstyrelsen, 2016). Consequently, this study will only consider the production of biogas from waste materials, as opposed to energy crops.

To align with the ethos of Challenge Lab, it is key that when considering the potential for biogas production in Västra Götaland, there should be reflection on whether the suggested approach to increasing development can be considered sustainable. Sustainability will be considered in three dimensions. Environmental sustainability will be assessed, but the economic sustainability will be the most critical aspect at this stage, since industries implementing biogas technologies must

be able to sustain themselves financially. Social sustainability is another important factor, as trust, transparency and openness are needed between different actors involved in the biogas value chain (Holmberg and Robèrt, 2000).

1.5 Research Questions

During the early stages of research, it was identified that although there are enablers which could increase the expansion of regional biogas production and use, there are also barriers that must first be overcome in order for these enablers to become effective. In order to investigate these barriers and enablers, the following principle research question is proposed:

"What barriers are hindering biogas from being used to its full potential within the current socio-technical regime in Västra Götaland, and what enablers could help to reach this potential?"

The purpose of this research question is to provide information on why there has been limited development of what has been identified as a very promising renewable technology with significant potential capacity in Västra Götaland. In this study, the definition of biogas potential encompasses both potential for biogas production and potential for use of biogas. It is intended that through understanding the barriers which are currently preventing biogas from becoming a mainstream technology, it will be possible to identify changes which could be made in order to facilitate more widespread production and use.

To fully address the principal research question, the following supplementary research questions will be addressed:

1. *"What is the current situation for biogas in Västra Götaland, and what is the potential for further development?"*
2. *"What are the main barriers which must be overcome to enable development of the biogas value chain in Västra Götaland?"*
3. *"What changes are needed to support the development of biogas in the region?"*

The purpose of the supplementary questions is to support data gathering which will provide a suitable understanding of the current regional situation for biogas. Based on this, suggestions for changes can be made.

2

Process for Formulating Research Question

2.1 Introduction to Challenge Lab Process

Inspired by the proposed actions to mitigate against the great global challenges posed in Section 1.1, Challenge Lab was established in 2014 by John Holmberg (then Vice President of Chalmers University of Technology, Gothenburg), with the purpose of creating an arena where students from different disciplines can work together towards tackling major sustainability issues. The idea behind the Challenge Lab is to enable a catalyst within the "triple helix... [of] academia, business and society" (Holmberg, 2014) (see Figure 2.1), with students operating as agents of change. As the Lab is based at Johanneberg Science Park, adjacent to Chalmers, a boundary has been set so that the issues to be investigated should lie within the geographic area of Västra Götaland.

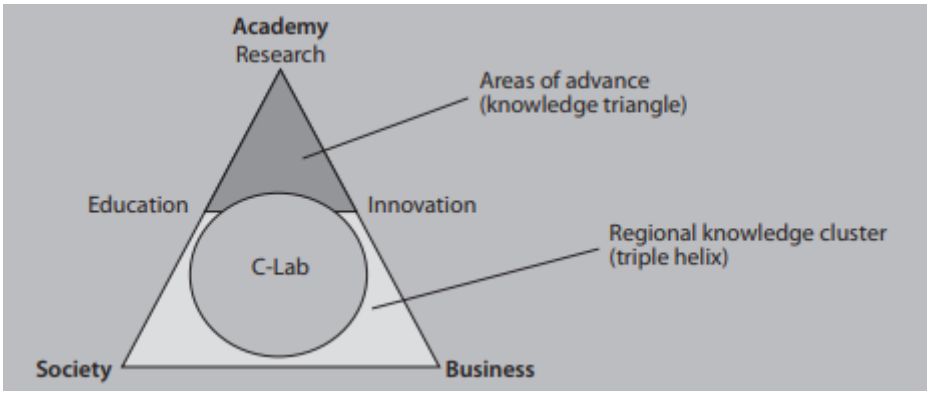

Figure 2.1: The triple helix of academia, business and society, united by Challenge Lab, taken from Holmberg (2014)

Aside from student participation via Challenge Lab, within the triple helix, collaboration is also enhanced by forging links between different actors in "the three corners of the *knowledge triangle*: education, research and innovation" (Holmberg, 2014) through the formation of "Areas of Advance" at Chalmers. These Areas of Advance were designed to create synergy between academic departments and external organisations, with a specific vision to encourage activities and research into sustainable futures (Holmberg, 2014). This has been

further enhanced through the establishment of "knowledge clusters" in West Sweden, which bring together both academic institutes and regional bodies by means of:

- "Trust-based values
- Low barriers to promote inclusion and active, sustained participation
- Good co-operation between different actors
- Openness to external factors"

(Holmberg, 2014)

Participation in Challenge Lab allows students to engage with stakeholders within these Areas of Advance and knowledge clusters, broadening student perspectives and providing fresh insights into the most complex problems in the region. As "An understanding of complex systems and inter- and transdisciplinary approaches is critical in this process" (Holmberg and J. Larsson, 2018), the structures created by Challenge Lab, the Areas of Advance and the knowledge clusters enable students to learn in an open environment with diverse external influences. But it is not only the students who benefit from this open and engaging approach. Through Challenge Lab, the "core values of scepticism, curiosity and freedom of speech" (Holmberg, 2014) that are central to the university setting are extended to include all parties in the triple helix; by allowing students to invite external stakeholders into dialogues, everybody involved becomes empowered to speak out and challenge norms. Isaacs (1999) describes dialogues as "an inquiry that surfaces ideas, perceptions, and understanding that people do not already have.". As such, dialogues create a unique forum in which collaborative thinking can take place, liberating participants from the agendas of the organisations that they represent. This is fundamental to the philosophy used in Challenge Lab.

The rationale behind Challenge Lab is that it offers benefits from the following aspects:

- *interdisciplinary* - students come from a range of educational backgrounds, which means that they bring a broad spectrum of perspectives to the Lab. Similarly, the co-location of different organisations within Johanneberg Science results in more varied inputs from stakeholders; science parks can be viewed as centres for collaboration and shared development. The involvement of academic stakeholders and supervisors from different department also offers the benefit of a wider overview of current practices within different academic fields. By creating safe spaces for dialogue, the Challenge Lab setting allows for flows of information and ideas between disciplines and organisations, potentially inspiring new ways of thinking and working for students and stakeholders alike.
- *sustainability* - the learning processes in Challenge Lab allow students both to be curious and to challenge norms. By exploring socio-technical systems in different ways to traditional engineering approaches, students are able to

define their own criteria for sustainability.
- *neutrality* - students are independent and as such can enable more openness in forums. Their neutrality renders them unthreatening, which enables external stakeholders to be bolder in their answers to challenging questions that the students pose.
- *transitions* - the tools used in the Lab enables students to develop new ways of thinking and approaching tasks. Combined with forward-thinking and innovative insights from stakeholders, this can help students to identify opportunities for transitions from the current regime to more sustainable scenarios.

These aspects are relevant to the approach taken to both formulation of challenges to be considered and proposal of potential solutions. The early involvement of stakeholders allows ideas to spread further through society, or be implemented more quickly, as dialogues may encourage stakeholders to challenge the way they think or operate.

For the Challenge Lab in 2018, Urban Futures, Mobility and Circular Product & Services were set as thematic areas in which the students could choose work. These were selected to align with the four thematic areas highlighted within the Klimat 2030 vision for the Västra Götalands region (the fourth area being Climate-smart and Healthy Food) (Lunder and Roupe, n.d.).

2.2 Backcasting Theory

This section outlines the theories which inspired the process by which a basis for the thesis project was formulated.

2.2.1 Introduction to Backcasting

According to the World Wildlife Foundation "Current approaches to tackling global challenges are failing" (Crompton, 2010). Backcasting is a methodology which takes a somewhat different stance on problem solving compared to conventional approaches. Vergragt and Quist (2011) describe backcasting as "generating a desirable future and then looking backwards from that future to the present in order to strategise and plan how it could be achieved." Holmberg and Robèrt (2000) suggest that backcasting can be seen as "a planning methodology that is particularly helpful when problems at hand are complex and when present trends are part of the problems." They also highlight that "society often deals with one problem at a time in a fragmented fashion. The result is often confusion and sub-optimized measures that are not integrated in a large enough system perspective." (Holmberg and Robèrt, 2000). Dreborg (1996) specifies that situations where backcasting is the most suitable way to approach "a major societal problem" can generally be characterised by fulfilment of the following criteria:

- "when the problem to be studied is *complex...*
- when there is a need for *major change...*
- when *dominant trends are part of the problem...*
- when the problem to a great extent is a matter of *externalities...*
- when the time horizon is long enough to allow considerable scope *for deliberate choice*"

A primary benefit of using backcasting methodology when approaching a problem is that it is centred around an idealised vision of sustainability. In the description of sustainability given by Holmberg (2015), in addition to the economic, social and environmental dimensions of sustainability described by the UN (United Nations General Assembly, 2015), well-being is proposed as a fourth dimension that should be included in sustainability criteria. These dimensions were described by Holmberg (2015) as pillars of sustainability, as shown in Figure 2.2. This diagram shows the interdependence of all dimensions of sustainability, with ecological conditions forming a foundation upon which human activities can be built.

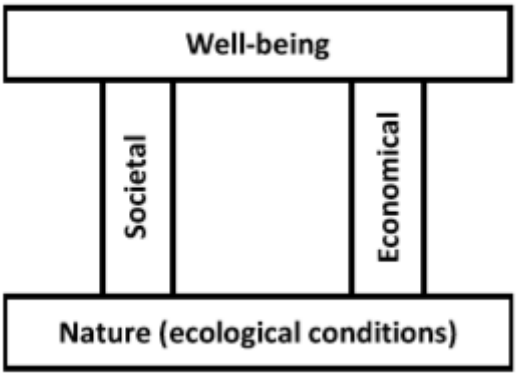

Figure 2.2: The four pillars of sustainability (Holmberg, 2015)

When faced with complex, uncertain circumstances, planners could apply backcasting methodology to "start planning from a description of the requirements that have to be met when society has successfully become sustainable" (Holmberg and Robèrt, 2000). By then working from the current situation to the desirable future, it becomes possible to create more innovative solutions which are not bound by existing lock ins (Geels, 2005). There are 4 steps to consider in backcasting, which are as follows:

1. "Define a framework for sustainability
2. Describe the current situation in relation to the framework
3. Envisage a future situation
4. Find strategies for sustainability"

(Holmberg and J. Larsson, 2018)

In terms of the objectives of Challenge Lab, it is clear that a backcasting approach is favourable. The ambition is to take on major sustainability challenges, and the arena in which this should be done is relatively open to change and alternative ways of thinking.

In order to develop a proposed topic for this thesis project, it was necessary to first envision what a desirable future might look like, and then to assess the current situation. As such, the theory section of this report will focus primarily on Steps 1 and 2 of the backcasting methodology. This is because the remainder of this part of the thesis process works with the tools included within the first two steps of the backcasting methodology; the methods used and results attained will be outlined in the remainder of this report. According to this methodology, in order to approach a challenge, it is first necessary to "Define a framework for sustainability" (Holmberg, 1998). This can be achieved by taking an inside-out approach by reflecting on personal values from which to set principles for sustainability, as described in Section 3.1 on the method used in this process.

2.2.2 Backcasting - Step 1

The first step in backcasting involves envisioning a future which is sustainable and establishing what conditions enable such a future to be defined as sustainable (Holmberg, 1998). This can be achieved by creating principles which must be fulfilled in order for a situation to be described as sustainable. There are two aspects involved in the identification of guiding principles. By taking an outside-in perspective, it becomes possible to consider the issue at hand from a very high level. Conversely, the inside-out perspective gives a highly personal insight into both the topic under consideration and the definition of sustainability. Both perspectives are outlined below.

2.2.2.1 Backcasting - Step 1: An Outside-In Approach

In formulating principles for visualising a sustainable future, the outside-in approach can be used to guide thinking to become holistic in terms of both ecological and humanitarian factors. It is therefore necessary to consider a number of perspectives so that more of the essential elements of a sustainable future can be captured within the guiding principles. These concepts have been explored in a number of ways in literature.

Holmberg (1998) states that:

"In order for a society to be sustainable, nature's functions and diversity must not be systematically:

1. Subject to increasing concentrations of substances extracted from the earth's crust
2. Subject to increasing concentrations of substances produced by society
3. Impoverished by over-harvesting or other forms of ecosystem manipulation

And

4. Resources must be used fairly and efficiently in order to meet basic human needs worldwide."

Rockström et al. (2009) extend this further, by introducing the idea of nine different "planetary boundaries" which "define the safe operating space for humanity with respect to the planet's bio-physical subsystems or processes.". In addition to proposing categories for these boundaries, Rockström et al. (2009) also quantifies the acceptable limits for the different factors, and assesses the current situation with respect to these. Rockström et al. (2009) forecast that exceeding these limits could have significant negative consequences which would impact humanity. Most notably, it was found "that three of the Earth-system processes - climate change, rate of biodiversity loss and interference with the nitrogen cycle - have already transgressed their boundaries." Transgressing these boundaries may cause a butterfly effect, leading other earth systems to reach their "tipping point" (Rockström et al., 2009). In terms of setting guiding principles as part of the first step in backcasting, it seems imperative to use these planetary boundaries as a core (Raworth, 2017).

Cruz, Stahel, and Max-Neef (2009) take a slightly different stance on this issue, by focusing around human needs and the value and quality of life. They discuss Human-Scale Development, which involves "organic articulations of people with nature and technology, of global processes with local activity, of the personal with the social, of planning with autonomy, and of civil society with the state." and where development centres around people rather than material goods or other gains (Cruz, Stahel, and Max-Neef, 2009). This could be considered somewhat at odds with conventional approaches to development and policy making, but would be beneficial for inclusion in guiding principles in order to achieve inherent fairness for people across society and globally.

2.2.2.2 Backcasting - Step 1: An Inside-Out Approach

To compliment the outside-in approach to formulating guiding principles for a sustainable future, it is also important to consider an inside-out perspective. The benefit of doing this is that it gives a better understanding of the personal motives and needs of individuals. It is essential to consider this facet as well as the over-arching holistic aspects because this can help ensure that the guiding principles are relatable at a human level.

Ryan and Deci (2000) empirically identified that in order for people to be self-motivated and able to express their own personality, three innate psychological needs must be fulfilled. These are competence, autonomy and relatedness, described as seeming to be "essential for facilitating optimal functioning of the natural propensities for growth and integration, as well as for constructive social development and personal well-being" (Ryan and Deci, 2000). Competence refers to when an individual perceives that they are able to complete an action to such

an extent that they become intrinsically motivated (that is, they attain an inherent satisfaction from simply completing the task.) Autonomy is linked to competence as it implies that the behaviour of an individual does not dependent on a tangible reward as a direct consequence. As such, autonomy is not the same as individualism or independence. Relatedness is when an individual experiences interest from others.

Intrinsic motivation is beneficial as it enables people to act without the need for external drivers. A need for extrinsic motivation implies a level of reluctance from the individual carrying out an action, whilst a motivation will inevitably result in nothing being achieved. In terms of sustainability transitions, it could be seen as important to nurture the qualities of competence, autonomy and relatedness in order to make individuals intrinsically motivated towards making a positive change. This is because it removes the constant need for external stimuli (such as rewards and punishments) to direct and control behaviours. If individuals feel intrinsically motivated to carry out an action, they are probably much more likely to be persistent and satisfied than if somebody else is dictating how they should behave. To link with the outside-in aspects, the concept of relatedness could help foster a sense of community within an individual, which could make them more inclined to want to contribute to developing a sustainable future for society as a whole.

2.2.3 Backcasting - Step 2

The second step of backcasting involves establishing an understanding of the current system which can then be compared to the envisaged sustainable future. By completing such an analysis, it becomes possible to identify which need to be addressed or the challenges which must be overcome in order to reach a sustainable future state.

2.2.3.1 Backcasting - Step 2: An Outside-In Approach

Much like in Step 1, the outside-in approach to Step 2 provides an overall view of the system as it is at the moment. Geels (2005) describes taking a multi-level perspective (see Figure 2.3), where the relationship between society and technology is presented on three different levels. The landscape represents the existing material infrastructure; “landscapes are beyond the direct influence of actors and cannot be changed at will.” Geels (2005). The socio-technical regime represents integration and establishment of technologies into mainstream society; to some extent, this offers an opportunity to challenge the existing regime as at this level, there is an emerging market for a certain technology, allowing users to become more familiar with the technology and begin to influence its functionality (Geels, 2005). Finally, the technological niches at the bottom level of Figure 2.3 show novel technologies which are competing to become part of the established socio-technical system (Geels, 2005).

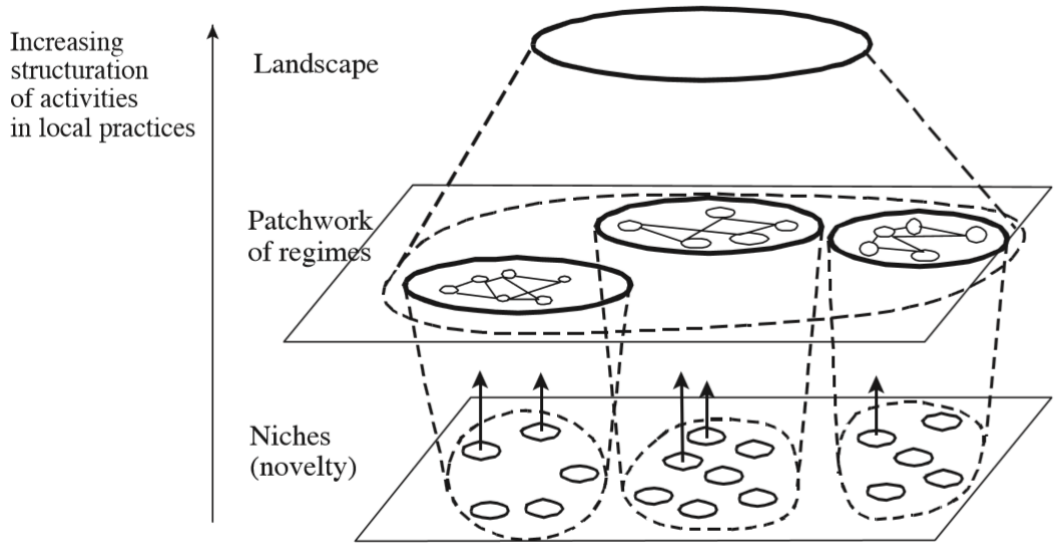

Figure 2.3: Multi-level perspective, taken from Geels, 2005

In order for a novel or niche technology to become more widespread, it is important to understand where the current regime can be challenge and is likely to accept new ideas. Meadows (1997) describes "leverage points" as "places within a complex system... where a small shift in one thing can produce big changes in everything.". Meadows (1997) argues that it is vital to assess which aspect of an existing system to select as a leverage point, in order to maximise the impact of an effort, and most importantly to not be constrained by existing paradigms. An example of a leverage point could be finding a powerful actor who is prepared to make a sustainable change in way that may inspire others to take similar actions, thereby ultimately shifting the socio-technical regime.

2.2.3.2 Backcasting - Step 2: An Inside-Out Approach

To take an inside-out approach to assessing the current situation, it is necessary to understand how individuals within wider society function and interact. Sandow and Allen (2005) emphasise the importance of trust in social collaborations to enable innovative development. Figure 2.4 shows how positive interactions can become consolidated into a cycle where trust is continuously built, enhancing collaborations. Conversely, Figure 2.5 shows how negative behaviours can degrade the quality of interactions.

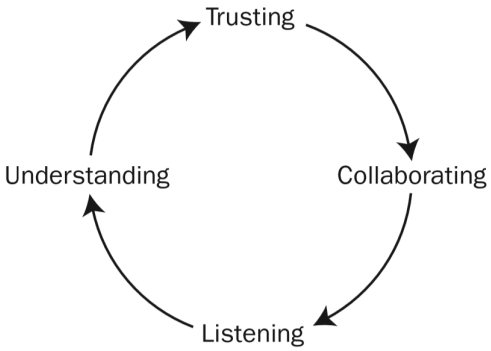

Figure 2.4: Cycle reinforcing trust, taken from Sandow and Allen, 2005

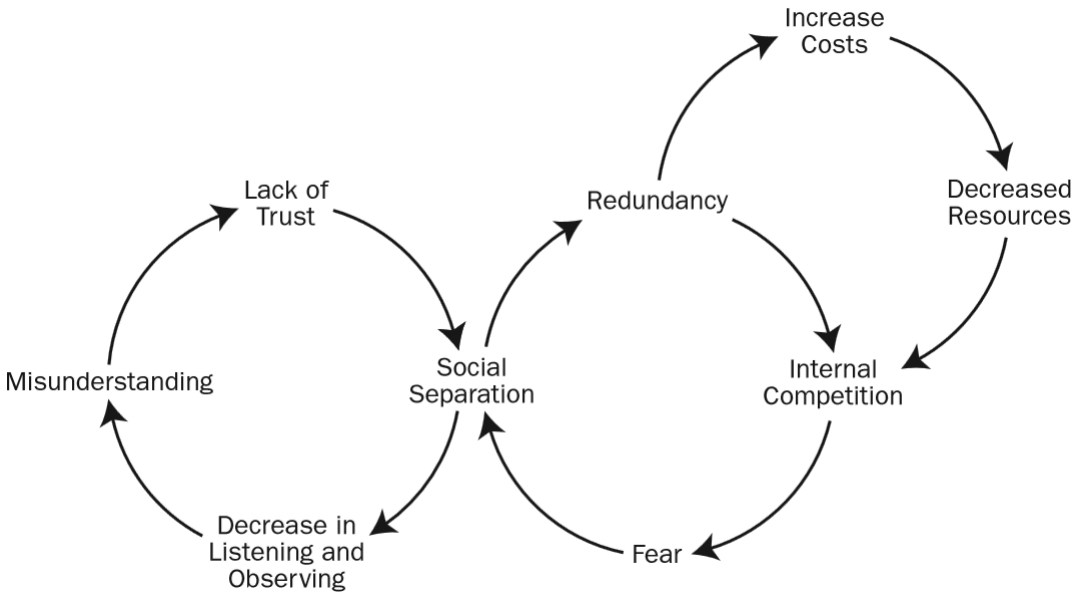

Figure 2.5: Cycle depleting resources, taken from Sandow and Allen, 2005

In order to foster positive reinforcement cycles such as the one shown in Figure 2.4, (Isaacs, 1999) describes a dialogic approach to leadership, through which it becomes possible for leaders:

1. "to evoke people's genuine voices
2. to listen deeply
3. to hold space for and respect as legitimate other people's views, and
4. to broaden awareness and perspective."

(Isaacs, 1999)

By engaging with people through dialogue, it becomes possible to encourage much greater trust (and thereby collaboration), as participants become more open to new ideas. Consequently, dialogues can be a powerful tool in sustainability transitions as they can be used to help people with differing views and priorities come to a mutual understanding. In addition to dialogue, learning is another powerful tool which can

be useful in sustainability transitions. Human nature means that in general, there is resistance to change, resulting in individuals avoiding confrontation of norms as there is reluctance to declare identified errors or flaws within existing systems (Aygyris, 1977). Aygyris (1977) suggests that double loop learning can be used to tackle major challenges; double loop learning usually occurs at times of unrest, such as external crises, revolution of some kind (internal or external) or radical changes made by management within the organisation. The idea behind double loop learning is to take away inhibitions which prevent organisational self-awareness, and also persuade people to be open to change (Aygyris, 1977). Making sustainable changes should be possible within an organisation which encourages double loop learning, as people at all levels are empowered to be more curious, state their own values or views and confront what they see as wrong (Aygyris, 1977). However, it is difficult to create environments where people are comfortable with doing so. The processes used within Challenge Lab are designed to enable a more open approach. The following section will describe the methods used in the Lab.

2.3 Method for Identifying Research Question

The following sections will describe the approach to formulating research questions for masters theses in the Challenge Lab. The scope for such questions should ensure that the research projects are relevant to sustainable development in the Västra Götaland Region. The method follows the first two steps in the backcasting methodology (as described in the previous section), and was carried out by 15 students in Challenge Lab. The aim was to execute the first two steps of the backcasting methodology in order to derive a suitable research question from an identified leverage point. As described earlier, these steps (along with the relevant tools used to achieve the objectives of each step) are as follows:

Step 1: Envisioning the future
- Self-leadership
- Sustainability principles for creation of a common framework

Step 2: Current situation
- Stakeholder dialogues
- Challenges, leverage points and research question

This section will provide an overview of the method applied, including sub-sections describing how the specific tools were used for each step.

2.3.1 Self-leadership

Inside-out

Creation of a common framework for sustainable development towards a desirable future formed the basis of thesis project formulation in Challenge Lab. As the students had defined the criteria for sustainability collaboratively, this fostered

engagement and motivation. In order to ensure that individuals within the group were able to fully relate to the proposed criteria, exercises in self-leadership were undertaken to ensure that participants were able to identify and express their own values which would contribute to the overall framework formed by the group.

The introduction to the Challenge Lab began with clarification of what values are, where they come from and why they are important. This was to ensure mutual understanding prior to a student workshop on values and principles. The workshop started by splitting out into groups of three in order to give each individual the opportunity to present their own core values through a process called story-telling. The main aim of the story-telling exercise was to enable each group member to clarify their own values for themself, but it also served a secondary purpose of creating an atmosphere of openness and trust between the students, which would be beneficial for the rest of the thesis process.

There were three roles in each story-telling group: a focus person, a listener and an observer. Prior to this exercise, the individuals had selected up to 10 core values from a list of around 500 words which had been provided to all participants. The exercise involved the focus person using concrete examples to explain why each of their core values was important to them. In the meantime, the listener actively listened to their story-telling without responding or interrupting, and the observer watched the process. The roles were rotated round to enable each person to experience all three roles.

To further develop self-leadership abilities, the students also participated in a workshop on mission statements. Howard Behar, the former president of Starbucks, claims that by developing a mission statement, it is possible to improve self-leadership skills, giving a purpose and direction to life which will strengthen resilience in the face of adversity (Creating Space with Wes Knight, 2017). Creating Space with Wes Knight (2017) also emphasises the importance of formulating and writing down the mission statement, so that it can be revisited and reflected on over time in order to train self-leadership.

As part of the mission statement workshop, the students individually created a statement which reflected their own values which had been identified for the story-telling exercise. These were not to be shared with the group, but rather to help each student to better visualise what they wanted to achieve, not only through the thesis process, but also in life. As such, the mission statement workshop was not intended to deliver a finalised mission statement as an output, but rather to inspire a reflective focus which would help each student guide themselves through future challenging situations.

2.3.2 Sustainability Principles for Creation of a Common Framework

Outside-in

Before creating the common framework together, the group was first briefed on the dimensions of sustainability. Holmberg and J. Larsson (2017) provided a new alternative to the pillars of sustainability: "The sustainability lighthouse". This is shown in Figure 2.6.

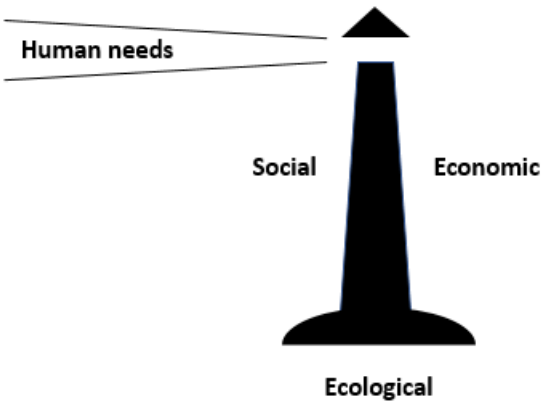

Figure 2.6: The sustainability lighthouse (Holmberg and J. Larsson, 2017)

The lighthouse is built upon the economic, social and ecological dimensions of sustainability, but also shines out the perspective of well-being. This is the foundation for the common framework that was created by the group dividing into smaller group which each considered one dimension of sustainability by linking key-words associated with a desirable future to their respective dimension, and visualising them on whiteboards. In such a diverse group of people, it was important that each individual could contribute with their values and be heard within each dimension. To ensure fair consideration of all perspectives, the four groups rotated between the different dimension boards to offer their thoughts on each dimension of sustainability, based around the key-words formulated in the earlier part of the exercise. Each group had an allocated secretary who also functioned as facilitator and who remained at the same board throughout. The secretary aspect of the role was to brief the arriving groups about previous discussions, and to observe and document alterations to the key-words, both in terms of new additions and re-prioritisations. Finally, the whole group re-banded and the proposed key-words for each dimension were presented, providing opportunity for further discussions and finalisation of the the framework.

2.3.3 Stakeholder Dialogues

Outside-in

As outlined in the theory section, dialogue can be a useful tool for ensuring that all voices within a group are heard. In Challenge Lab, the overall aim of the dialogues was to gain information on the current situation by utilising the knowledge of people in the system, providing an opportunity to inspire research questions which would lead to relevant and useful thesis topics. There were two sets of dialogues held prior to creation of research questions. In order to reflect the different groups that could collaborate towards resolving major challenges (as outlined in the introduction to this report), the stakeholders during these sessions included representatives from:

- Academia
- The city and region of Gothenburg
- Industry

The first set of dialogues took place during Autumn 2017. The purpose of these dialogues was to allow students to gain knowledge of the current situation and sustainability challenges in the region, and additionally to experience working with stakeholders in a dialogue setting. Three dialogues (one for each thematic area) were conducted in collaboration with students from the Chalmers course *Managing Stakeholders for Sustainable Development (ENM130)*, thereby also including students who were not affiliated with the Challenge Lab. Although staff at Challenge Lab had invited stakeholders to the dialogues, it was students from the ENM130 course who planned and executed the sessions, including the dialogue structure, questions which would be posed and the layout of the room. A fishbowl setting was used, with a small inner circle of inward-facing chairs surrounded by a large outer circle of chairs looking to the inner circle. In this setting, the inner circle consisted of stakeholders and student representatives functioning as facilitators. The outer circle was made up of students whose roles were as observers or secretaries. The secretaries were responsible for documenting what was said, as the dialogue was not recorded. A conscious decision to not record was taken as it was felt that use of sound recording equipment may have inhibited the stakeholders from speaking freely. The observers were there not only to gain insights from the dialogue, but also to give a more external view on how the dialogues had been conducted. Those in the outer circle were given opportunities to voice their perspectives at allocated times.

The second set of dialogues was conducted by the Challenge Lab students at the start of their masters thesis process in January 2018. These dialogues aimed to achieve the following:

- Identification of further leverage points targeting challenges identified in the first set of dialogues
- Find valuable contacts in the region, to whom the results of thesis work could be beneficial
- Gain more insight into city level and regional climate strategies and ongoing work for sustainability

Due to the smaller number of participants, it was deemed more appropriate to conduct these dialogues in a single circle of students and stakeholders, with some students acting as facilitators to provide structure and ensure that everyone had equal opportunities to speak. Furthermore, at the start of the thesis process, the Challenge Lab students had selected which thematic area they wanted to work in for the remainder of the thesis. Like the first set of dialogues, each dialogue in the second set focused on one thematic area. It was agreed before the dialogues that the students who had chosen each area would steer their respective dialogue, to ensure that as much information as possible could be gathered on topics of particular

interest.

2.3.4 Challenges, Leverage Points and Research Question

Inside-out
The final steps required before research questions could be formulated involved considering multi-level perspectives and finding leverage points. Information derived from the dialogues was refined as part of an iterative process from which leverage points were identified. Following the dialogues, the personal perspectives of each students (based on both academic backgrounds and general interests) were integrated into the leverage points that ultimately would become potential areas of research for the thesis. The leverage points included relevant key-words which had been identified earlier in the process. Based on the socio-technical regime described by Geels (2005), the different leverage points in each thematic area were categorised into different levels depending on whether they related to external factors (such as legislation), problems with the existing regime or ongoing projects and processes which could challenge the existing regime.

Once the leverage points had been finalised, each student in the group selected and ranked the three leverage points which they felt would be most interesting to base their thesis on. This enabled pairs to be formed and 8 thesis topics to be chosen. Following this, each pair formulated a principal research question derived from their chosen leverage point. During this process, collaborations continued both within the larger group of students and with the Challenge Lab team in order to identify potential connections between the theses and evaluate how to continue utilising the collective knowledge and learning in spite of the different directions of the work.

2.4 Results from Process for Identifying Research Question

The ultimate outcome of the Phase 1 process was a proposed research question. This section will firstly outline relevant results from earlier stages of the process, before finally culminating in the research question. Section 5 offers reflections on the process used to attain these results.

2.4.1 A Common Framework for Sustainability

In order to address the first step in the backcasting process, it was first necessary for the group to create a framework for sustainability. The key-words associated with each pillar of sustainability, as illustrated below in Figure 2.7, were identified by the group during one of the sessions described in the method section.

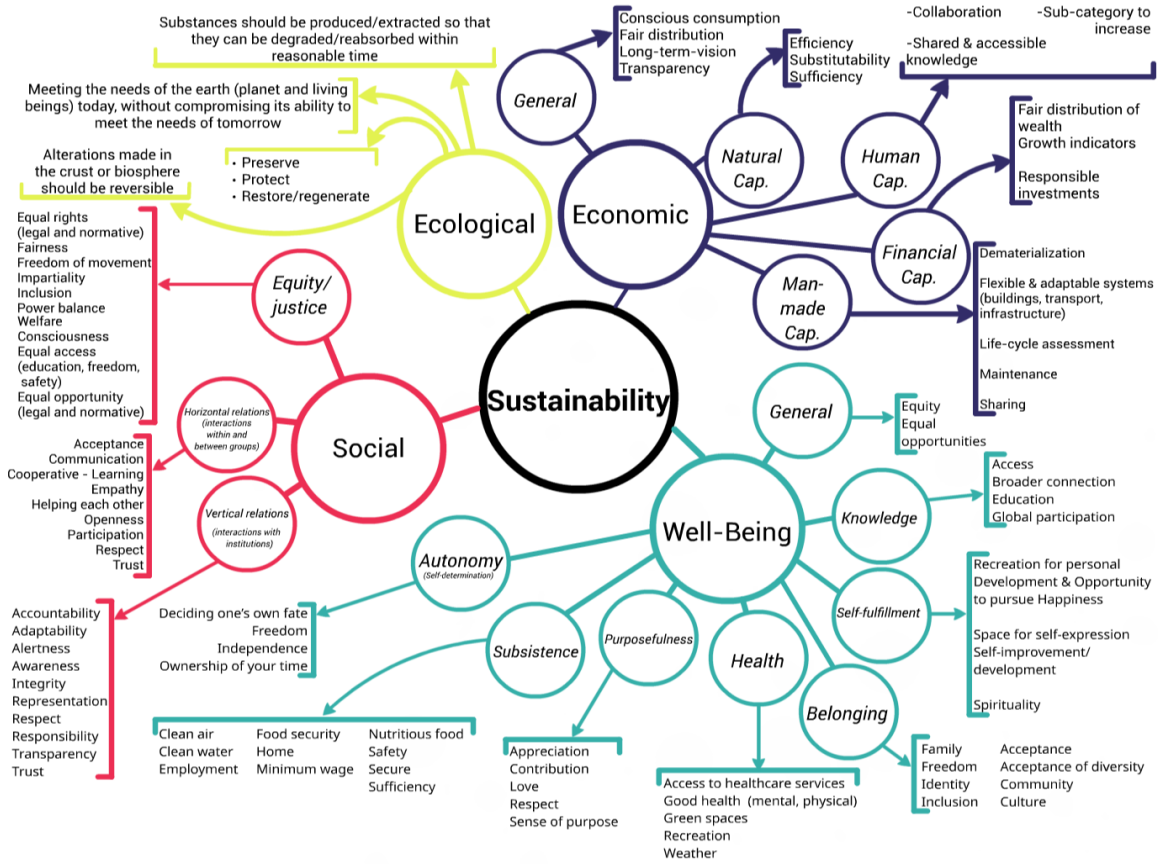

Figure 2.7: Common framework based around key words

2.4.2 Insights from Dialogues

During the dialogues, the authors found that Circular Products and Services was the most interesting thematic area. Therefore when given the opportunity to break out into smaller focus groups, this topic was selected for more in-depth exploration. Exchange of presentations and discussions between the different groups further confirmed that Circular Products and Services was both of most interest and most directly related to future aspirations. The authors also believed that their backgrounds in Industrial Ecology and Chemical Engineering would provide an adequate understanding of issues addressed within Circular Products and Services, and therefore result in a better overall project quality.

There was overlap with other thematic areas, as circularity aspects were mentioned in most of the dialogues. During the dialogue for Circular Products and Services, it was mentioned that there are difficulties in connecting actors who are interested in taking part in a symbiosis. Furthermore, there also seemed to be problems with identifying suitable symbiosis opportunities in terms of linking existing waste streams with potential consumers. An overarching theme that emerged was that there is limited understanding of what industrial symbiosis entails and the benefits it can offer; this can be a significant barrier to developing such collaborations. Sotenäs Symbios Centrum is an inspiring current example of a successful symbiosis

project in Västra Götaland, which was felt to demonstrate an approach that could be emulated elsewhere in the region. In tandem with further research into the work at Sotenäs, a need for organic, nutritious and local soil was highlighted as part of an additional dialogue on urban farming. A clear link between industrial symbiosis and provision of quality soils was identified from the case of Rena Hav at Sotenäs, where co-digestion of waste from fish processing industries was creating both biogas and bio-fertiliser. The idea that combining waste from multiple industries could create products which could be valuable in many different ways enabled the inspiring leverage point *"Providing clear criteria and mapping to enable informed decision-making about effective and sustainable opportunities for symbiotic biogas production in the region"* to be identified. Both authors felt that there was significant personal interest which would create a suitable scope for a thesis project based around this leverage point.

As the project progressed, the focus shifted from industrial symbiosis to the biogas value chain. Although this is not strictly speaking based on the leverage point identified during the Phase 1 process, the authors felt that viewing the overall biogas value chain in Västra Götaland from a circularity perspective enabled the ensuing project to have an inherent element of industrial symbiosis, even though this was not mentioned explicitly during the remainder of the study. Furthermore, changing the focus of the study enabled the results to be potentially useful to a broader range of identified stakeholders.

2.4.3 Formulation of Research Question

Based on the identified leverage point, initial research was undertaken to establish some understanding in order to find an appropriate focus for the research questions. From this, a challenge was identified in a need for increasing the uptake of biogas production opportunities in order to fulfill the forecast potential in the region, whilst also understanding and overcoming the problems occurring in existing regime. One aspect which was considered important was that the research question should lead to findings which would be useful to somebody. The principal and supplementary research questions are outlined in Section 1.5.

By exploring the proposed research questions, it is intended that key aspects which could help further the development of biogas in the region will be identified. At present, it appears that to some extent development is ongoing and there is strong interest from multiple actors, but there still appear to be significant barriers which are preventing the forecast potential of biogas in Västra Götaland from being fulfilled. By investigating different aspects of the biogas value chain and considering the actors involved, it is hoped that light can be shed on the precise nature of these barriers, and that enablers which could promote development can be identified.

2.5 Reflection on Process for Identifying Research Question

The process taken to reach the research question was stimulating and challenging and resulted in high levels of openness and integrity within the group. The iterative process combined with the broad selection of topics explored led to research questions in which researchers felt strongly invested, following development of genuine personal interest.

There were additional advantages of working through this process as part of a diverse group; not only was there opportunity to share technical knowledge between different disciplines, but also experiences from different cultures and parts of the world. This was invaluable in formulating criteria for sustainability, as it enabled much broader perspectives to be taken. It was also a good opportunity for personal development as it allowed exposure to new ideas.

One criticism of the approach taken was that by splitting out into thematic areas early on, silos were created and valuable information may not have been as effectively communicated between the groups. A conflicting issue was that because the time spent working in the smaller groups covered a broad range of topics, issues that people felt very strongly about were treated in the same way topics where nobody had expressed an interest. This meant that time was spent pursuing areas which were not of particular interest, whilst there was not always enough time to nurture genuine curiosity on other subjects.

Better connection between the initial dialogues held as part of the Managing Stakeholders course and the students from the Challenge Lab may have resulted in more efficient formation of leverage points. It would have been good if the Challenge Lab students had had greater influence over the topics discussed during the dialogues, as this could have helped to focus information onto areas of specific interest. It is acknowledged that practical limitations may have prevented this.

3
Method

This chapter will outline the research methods used to derive relevant information for this project. Figure 3.1 gives a visual representation of the

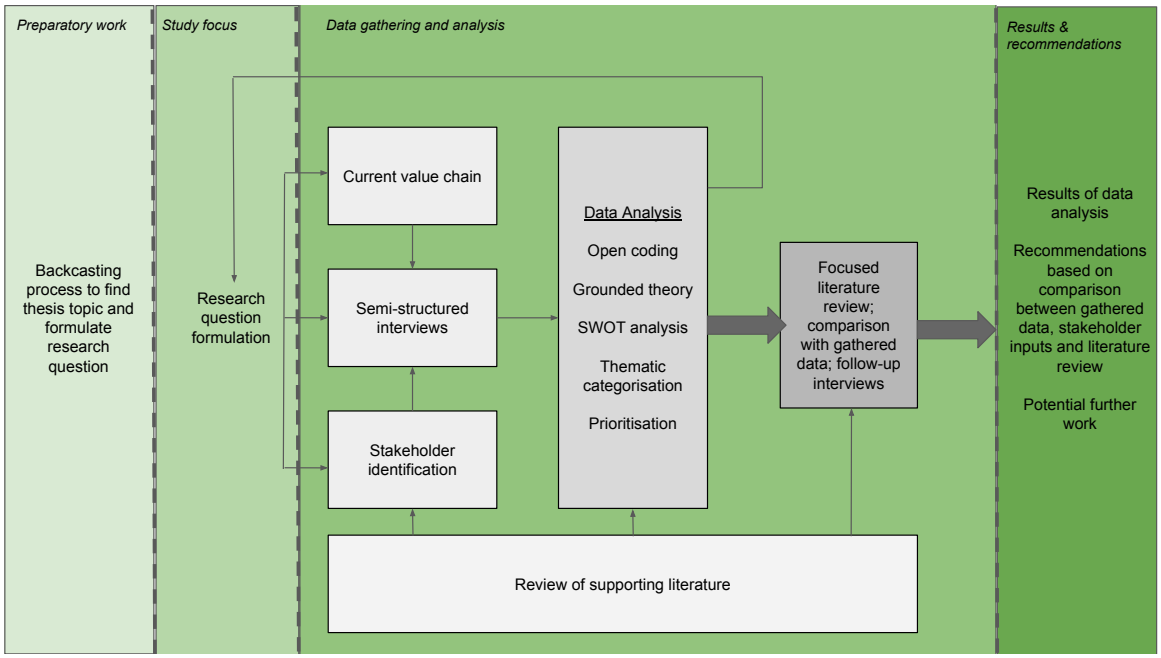

Figure 3.1: Visual representation of sequence for methods used in this study

3.1 Case Study: A Value Chain Overview for Västra Götaland

In order to be able to address the research questions for this project, it is important to first establish a realistic overview of the current situation for biogas production in Västra Götaland, with the aim of gaining knowledge about the current situation. By taking a value chain approach, the focus is on ensuring that consumers perceive value in the product. Within a value chain, consideration is given to the perspectives of both direct stakeholders, who are involved in production or marketing, and indirect stakeholders, who may be potential consumers or those affected by environmental conditions caused by the product or production process. This means that how these stakeholders affect the creation of

product value is included within the appraisal of the situation. The value chain approach allows for life-cycle thinking and gives the opportunity to develop and market products from a sustainable, moral and ethical standpoint rather than focusing heavily on profits (University of Cambridge, 2018; Florida Technical Institute, 2018). Consequently, looking at biogas in Västra Götaland from a value chain perspective is a way to gain a holistic overview which is well-aligned with the sustainability criteria within the scope of this project; taking a value chain perspective enables the inherent benefits of biogas to be brought out, as opposed to just the profit potential.

In this case study, the value chain was considered from a material flow perspective, from raw materials through to finished products. Considering the value chain in this way enabled the manner in which consumers create demand by placing value on products to be highlighted (as the types of final products from the value chain are identified), which in turn would deliver upstream benefits of improved waste management and waste valorisation. The aim of the case study was to provide a foundation of understanding from which suggestions for improvements can be made, based on the current situation and the identified potential found in literature studies.

3.2 Stakeholder Engagement

This section outlines the approach taken to ensure effective data gathering through stakeholder interviews.

3.2.1 Stakeholder Identification

A stakeholder identification process was carried out to establish individuals or organisations whose perspectives could be valuable to the study. The criteria for selection was that the stakeholders should be in some way linked to biogas in the region. Preble (2005) suggests that stakeholders can be divided into three categories, *primary*, *secondary* and *public*, and that each of these groups has intrinsic value. In this case, primary stakeholders were considered to be producers and consumers of biogas and associated raw materials. Secondary stakeholders were those with technical knowledge on biogas production, or who were in some way involved in lobbying or promotion related to biogas. Public stakeholders were involved in regional management or local politics.

Initially, stakeholders were identified from the outputs of the dialogues, as described in Section 2.4.2. Online research was carried out to identify further potential stakeholders. An element of the snowball sampling technique was used, as interviewees were asked if they knew of others who could be of relevance to the study (Law, 2016). Although this method presents a risk of introducing bias through similarity between interview participants (Law, 2016), within the scope of this study, this was not felt to be problematic. This was because one of the purposes of conducting interviews was to establish an overview of the biogas value chain in the region. As such, specific to this case there was some benefit in

speaking to stakeholders who were in some way connected, as this enabled different perspectives on the same issue to be gathered. The stakeholders were kept anonymous, it was felt that this would lead to more openness during interviews.

3.2.2 Interview Process

The aim of the interviews was to gain stakeholder perceptions of biogas development in the region in terms of drivers and enablers. In order to achieve this during relatively short interviews whilst not compromising the way that stakeholders responded, a semi-structured approach to interviews was decided upon. Semi-structured interviews are a research method within social sciences and qualitative research that is open and flexible in order to allow the interviewer to raise new ideas, ask extra or unplanned questions and explore and clarify the interviewee's answers (Elliot et al., 2016). Additionally, during a semi-structured interview, the interviewee has the opportunity to suggest new topics. That said, there is still consistency in the topics discussed during a semi-structured interview due to use of pre-defined questions (even if these are not necessarily brought up in a pre-determined sequence) (Evaluation Toolbox, 2010). The flexibility of semi-structured interviews makes this technique better suited to addressing complex research questions, as it enables the interviewer to steer the discussion in a general direction whilst at the same time empowering the interviewee to reflect upon their own experiences and perspectives (Miles and Gilbert, 2005).

12 semi-structured interviews were conducted, using an interview guide which had been designed with generic questions that could be addressed to all stakeholders (Bryman and Bell, 2003). These questions were not ordered, allowing researchers the flexibility to adapt the interview structure to better reflect the direction of conversation. Yet, consistently asking the same questions to multiple stakeholders gave the opportunity to obtain different perspectives on particular topics. There was slight variation in the wording of the questions, which may have had some effect on the resulting answers. However, this was also necessary in some cases to ensure that the question had been correctly understood.

In addition to the standard set of questions, more specific questions were also targeted at stakeholders, based on their backgrounds in order to maximise the amount of information which could be gathered during each interview. Prior to conducting interviews, comprehensive research was conducted into stakeholders and their organisations, which enabled questions to be better tailored to the individual stakeholders, thereby making the data gathering more efficient for the interviewers. This also made the interviewees feel more comfortable, as the questions they were asked were relevant to their perceived competences.

Most interviews were conducted face-to-face, although telephone interviews were used where this was not possible. During all interviews, the researchers took on consistent roles, with one researcher asking questions and the other taking manual notes. The interviews were not recorded digitally to reduce the pressure on

interviewees by creating a more open and less formal environment; it was hoped that this would also result in interviewees speaking more freely. Therefore, one researcher acted secretary and one facilitated the interview. The researcher presenting the questions used a mirroring technique by presenting a summary of interviewee responses immediately after they had said it to clarify that what they had said had been interpreted correctly (Dreeke and Navarro, 2009). This helped both to guide the interview structure and ensure that the notes taken were reflective of stakeholder opinions.

3.2.3 Interview Analysis

Data handling techniques were employed to facilitate appropriate analysis of the data obtained during the interviews. In this study, this was carried out by firstly using open-coding to identify independent statements from raw interview data, then categorising statements using grounded theory. Corbin and Strauss (2014) claim that whilst carrying out analysis, researchers quickly move between the concrete and the abstract; this creates the challenge of managing data whilst simultaneously identifying patterns. The aim of this is to create a funnel which leads towards a more "concentrated", concrete result. According to Corbin and Strauss (2014), analytic strategies enable the researcher to "think in logical and systematic ways" during this process. These strategies include maintaining flexibility and responsiveness to data and research goal, and also how much time to devote. Corbin and Strauss (2014) describe the benefits of using Strauss' proposed Grounded Theory for qualitative research. They claim that this approach enables flexibility and constant evaluation whilst considering quantitative data, and simultaneously allowing researchers to distance themselves from technical literature and personal experience, thereby creating the possibility for them to arrive at new interpretations which may challenge normalised ways of thinking.

Figure 3.2 provides a visual representation of the methods by which the interview statements were analysed in order to identify a final focal point for the project. These steps are outlined in more detail below.

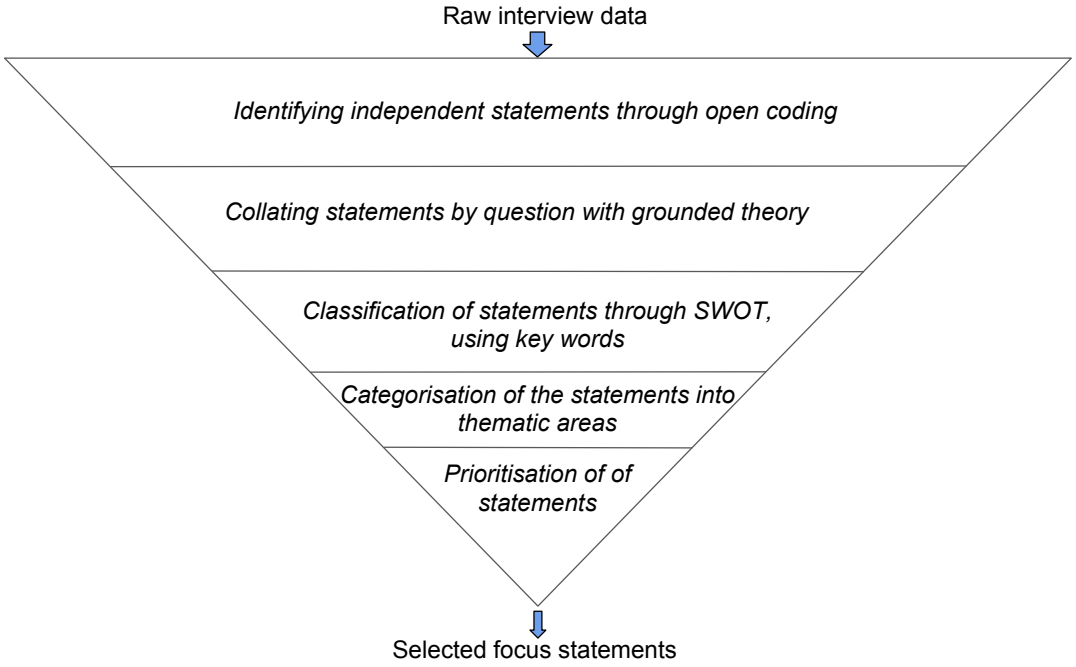

Figure 3.2: Visual representation of interview analysis process

3.2.3.1 Identifying and Collating Statements with Open-Coding and Grounded Theory

An open-coding approach inspired by the techniques and procedures proposed by Corbin and Strauss (2014) was used for analysis of interview outputs in this research project. This was done by analysing the statements given by each stakeholder and breaking them out into stand-alone statements (known as "codes") (Corbin and Strauss, 2014). Because a relatively large volume of information was captured within a relatively short time-frame, coding was not implemented as part of the data gathering process and it was not feasible to analyse data whilst collecting it. This prevented bias from being introduced through analysis during the data collection phase. However, it is acknowledged that some inherent bias may have been introduced by this method of data gathering, as it allows data to be selectively recorded. Consequently, a degree of coding may have been included in the data gathering process as information deemed irrelevant was immediately discarded.

Following the initial coding, Corbin and Strauss (2014) recommend reflecting on the results before starting to analyse or drawing conclusions. The interview results from this study were explored using the open-coding approach which enabled overall themes to be identified. The outputs from the interviews were recorded in a way which meant that it was possible to attribute what had been said to the

stakeholder who had said it. This simplified the comparison between perspectives from different stakeholders. Once the interview information had been broken out into themes by question, and then by stakeholder for the specific questions, the grounded theory process was extended by analysing the text within each theme into stand-alone statements which were distinct from each other. Repetitions were recorded as this enabled the most important points to be emphasised.

After all of the interviews had been completed, grounded theory was applied to the data gathered in order to collate independent statements for further analysis. This was done by separating the statements given for the same questions by different stakeholders. Once this activity had been completed, the researchers grouped very similar statements, replacing them with a single summary statement and noting the number of interviewees who had said something which was reflected by that summary. The main objective of this data handling approach was to create these distinct statements. Furthermore, as the data was refined through the analysis process, it is possible that information may have become slightly distorted. However, it was felt that there would not be significant detrimental impact on the overall results as the researchers had been present in all interviews and therefore had a good impression of what stakeholders had expressed on different topics. Additionally, treatment of qualitative data is inevitably subjective, which influenced the placement of statements into the different categories and themes.

3.2.3.2 Statement Classification

Once the statements had been documented, they were classified by first SWOT analysis and then thematic area. The purpose of this exercise was to highlight themes which were important to stakeholders, on the basis that the issues valued most by stakeholders would be likely address the research questions posed in this study.

SWOT Analysis
SWOT analysis was conducted as a way to further classify the statements in order to make the analysis process easier. In SWOT analysis, identified factors (in this case, the statements generated with grounded theory) are categorised into Strengths, Weaknesses, Opportunities and Threats. Strengths and Opportunities are inherently positive, whilst Weaknesses and Threats are inherently negative. This means that Strengths and Opportunities are helpful to the objective being pursued, whilst Weaknesses and Threats hinder success. In this study, statements were considered on a basis of whether they would help or hinder the development of biogas in Västra Götaland. To determine if something is a Strength or Opportunity (or similarly a Weakness or Threat), the factor is assessed on the basis of whether it can be controlled within the system being considered. If the factors can be controlled by internal actors (for this study, this could be the actors within the value chain), then they can be classified as Strengths or Weaknesses. On the other hand, if external factors (such as government decisions, or environmental conditions) dictate the factor, then it is classified as an Opportunity or Threat (Sarsby, 2016). In order to maintain consistency in the way in which the

statements were classified, criteria were set to guide how the classifications would be made. These were as follows:

Strengths and Weaknesses -

- Defined by inherent properties of a concrete aspect of the value chain (e.g. biogas itself, or existing infrastructure)
- Related to the cultural norms in the geographical region (i.e. perceptions and behaviours of stakeholders and the general public)
- Related to direct impacts on the biogas value chain or direct implications from the biogas value chain on society or the environment

Opportunities and Threats -

- Beyond the control of actors in the value chain (e.g. directed from a political level)
- Related to potential societal changes which have not yet occurred and are not guaranteed (such as increases in demand for a particular service or product)
- Related to behaviours or approaches to working which are not currently the norm

Furthermore, in order to stay true to the sentiments expressed by stakeholders, care was taken to ensure that positive statements given by stakeholders were not rephrased in a negative way, and vice-versa with negative statements. In order to distinguish which category statements should be placed in for data analysis in this study, key words for each category were compiled prior to carrying out the SWOT analysis. The key words were identified by looking for reoccurring words within the list of statements and then attributing these words to specific SWOT categories. The selected key words are summarised below:

For Strengths, the following keywords were identified

- provides/produces/creates enables - concrete things delivered by biogas production/use
- good/high/better - inherent strengths relative to something else
- existing - concrete things which are already in place
- benefits/gains/useful - positive aspects resulting from biogas production/use
- improved/reduced (with respect to environmental aspects) - ways in which biogas production/use leads to realisation of environmental benefits
- encouraged - positive influence on development of current behaviours
- positive adjectives e.g. resilient, responsible, renewable

For Weaknesses, the following keywords were identified:

- need for/lack of - things which are currently missing but also critical to future biogas developments
- unclear - no obvious solution
- risk - potential exposure to harm/loss/danger
- complex/difficult/challenging - not easy to achieve/implement

- negative adjectives e.g. unpopular, unsuccessful, slow

For Opportunities, the following keywords were identified:

- growing/potential/demand/expansion - future needs which could be fulfilled with biogas production/use
- ongoing - processes which are in place and will continue to be in place
- learning/knowledge sharing/education/examples - increasing development by sharing information
- support - things which help with development
- priority/interest/important - perceptions which bring biogas to the forefront
- positive adjectives e.g. alternative, confidence, integrated

For Threats, the following keywords were identified:

- poor - behaviours or perceptions which prevent developments
- difficult - not easy to achieve/implement
- conflict - causing/resulting in disagreement
- need for/lack of - things which are currently missing but also critical to future
- risk - potential exposure to harm/loss/danger
- negative adjectives e.g. inexperience, inefficient, unknown

Categorisation by Thematic Area

The statements within the four SWOT categories were then split out into thematic categories in order to further simplify the data analysis process. The thematic categories were selected in order to group the statements into similar themes, which enabled general trends to be identified more easily. The purpose of creating thematic categories was to reflect the three pillars of sustainability (Social, Environmental and Economic (United Nations Economic and Social Council, 2018)), as well as technical and material aspects of the biogas value chain, which were not felt to be represented under the sustainability categories.

The thematic categorised were identified as:

- Value Chain
- Social
- Environmental
- Economic

Table 3.1 gives an overall summary of all categories and subcategories, with descriptions. These are defined in more detail below. The descriptions presented in Table 3.1 were used as a basis for deciding how to categorise statements as part of the analysis.

Table 3.1: Thematic Categories

Main Category	**Subcategory**	**Description**
Social	Relevant Actors	Aspects relating to non-concrete aspects of the biogas value chain, such as actors or market
Social	Political	Related to policies or governmental issues
Social	Public Sector	Related to impact of politics on everyday life
Social	Society	Wider social aspects that are independent of politics
Value Chain	Feedstocks	Materials which could be digested to produce biogas
Value Chain	Upstream Logistics	Transportation of raw materials from producers to biogas production sites
Value Chain	Biogas Production	Sites where biogas is produced
Value Chain	Transformation	Upgrading of biogas into vehicle fuels or other products
Value Chain	Downstream Logistics	Transportation or distribution of products to users
Value Chain	Products	Products that are ready for use
Environmental	Not Applicable	Aspects relating to the natural environment and ecology
Economic	Not Applicable	Financial aspects

Value Chain
The benefit of selecting Value Chain as a category was that this enabled statements highlighting overarching themes in terms of technical and material aspects of the value chain to be identified. It also helped to reflect the multi-disciplinary nature of the value chain, by showing the different contributing factors for production, upgrading and use of biogas. The statements within the Value Chain category were separated into sub-categories which reflect the different concrete parts of the Value Chain:

- *Feedstocks* - raw materials used for biogas production
- *Upstream Logistics* - transportation of raw materials from their origin to the biogas production facility
- *Biogas Production* - the facility where biogas is produced
- *Transformation* - upgrading of biogas into higher quality biogas, liquid biogas or using in Combined Heat and Power (CHP)
- *Downstream Logistics* - transport of upgraded biogas products to end user
- *Products* - point of application by different users

These sub-categories are also reflective of the stages in the value chain that were identified as part of the case study on biogas in Västra Götaland.
Social
The Social aspects identified were separated out into:

- *Relevant Actors* - Human aspects of the biogas value chain, where Relevant Actors are considered to be those involved directly. An example would be be the trust between different parties in a collaboration.
- *Political* - Aspects (from regional, national or EU level) that affect the market and societal conditions under which biogas operates, such as regulations, laws and targets.
- *Public Sector* - Aspects relating to interactions between the government and society, most often carried out through a public organisation which acts as a medium through which communication between political and societal actors can communicate, such as independent state-funded bodies.
- *Society* - Related to social aspects in a wider sense and independent of both politics and direct involvement the value chain, such as mindset of consumers and other societal trends.

Environmental
Statements categorised as Environmental included aspects of direct environmental and/or climate impact, such as amounts of GHG emissions and resource cycling. However, it was not necessary to break the Environmental statements down into sub-categories, as there were no obvious distinctions between types of statements in these categories, as well as there being far fewer statements to handle.

Economic
As with the Environmental statements, it was not considered necessary to break the Economic statements down into sub-categories due to a lack of clear thematic divisions and a lower total number of statements within the category. Statements in this category were related to monetary aspects in terms of e.g. costs, profitability and taxes.

Statement Priotisation
The data in the SWOT analysis and further thematic categorisation was used to identify a focus for the research. This was established by looking at the number of statements in each category, and also by applying a weighting metric. Equal weighting was given to each statement made by a single stakeholder, so if multiple stakeholders gave a similar statement then that statement was counted for each time it was said. For example, if a statement was only given by one stakeholder it received a weighting of one, whilst if five stakeholders had given a similar statement then it received a weighting of five. Both the weighted and non-weighted categories were included in the analysis, to allow for further comparison.

When considering the thematic categories rather than the SWOT categories, positive and negative statements were combined. This was because the number and weight of statements in a thematic category was considered significant regardless of whether

those statements were positive or negative. As such, categories with more statements and weight were assessed as being more valued by stakeholders, and therefore more important to focus on in further research. Initially, a compilation of all statements given by at least two stakeholders was made. This enabled more popular trends between what stakeholders had said to be outlined. To create a stronger focus for the remainder of the study, these statements were narrowed down further to only include a top three most frequently reported statements (including their placement in the SWOT and thematic categories). Analysis of how these statements were interconnected and what relevance this could have to the research questions was carried out to give more defined direction to the subsequent research work.

4

Case Study: A Biogas Value Chain Overview for Västra Götaland

This chapter presents a case study describing the current situation for the biogas value chain in Västra Götaland, along with the current regional production, use and targets for biogas. A general overview is presented, along with more detailed descriptions of the actors and processes involved in the value chain.

4.1 Current Value Chain in Västra Götaland

Following research into the current biogas value chain in Västra Götaland, Figure 4.1 was created, based on information gained through a review of the sources cited in Sections 4.1.1.1 - 4.1.3.1, which explains the formation of 4.1. The purpose of Figure 4.1 is to outline the stages involved in the biogas value chain, from raw materials through to end users.

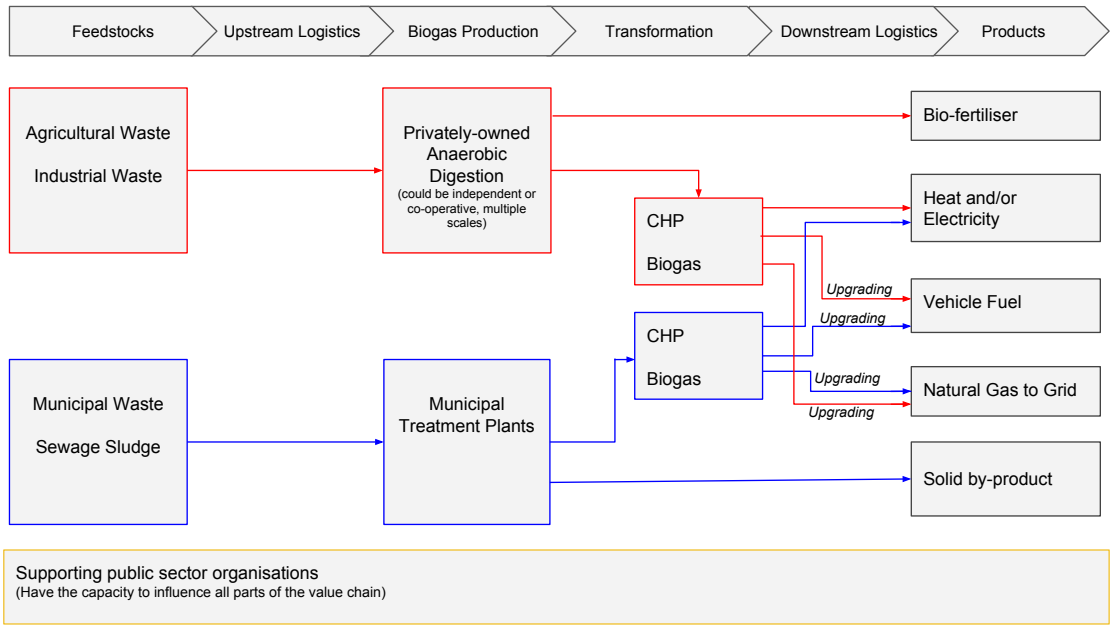

Figure 4.1: Generalisation of the biogas value chain for Västra Götaland

The main stages of the biogas value chain, seen in the arrows across the top of Figure 4.1, are:

- Feedstocks - raw materials used for biogas production
- Upstream Logistics - transportation of raw materials from their origin to the biogas production facility
- Biogas Production - the facility where biogas is produced
- Transformation - upgrading of biogas into higher quality biogas, liquid biogas or using in CHP
- Downstream Logistics - transport of upgraded biogas products to end user
- Products - point of application by different users

Furthermore, the overall value chain is both governed and supported by three public sector organisations. This is represented in 4.1 by the arrow underpinning the whole value chain, evoking a bedrock of stability. These public sector organisations were identified as follows:

- *Västra Götalands Regionen (VGR)* - Politically governed organisation responsible for ensuring provision of medical care, public transport, access to cultural activities/resources and growth and sustainable development in Västra Götaland (Västra Götalands Regionen, 2018a).
- *Länsstyrelsen* - The County Administrative Board representing Västra Götaland, linking people and municipalities with the government and centralised authorities. The head of Länsstyrelsen is responsible for keeping the government up to date on the needs within the county (Länsstyrelsen, Västra Götalands Län, 2018).
- *Hållbar Utveckling Väst (Sustainable Development West)* - The regional energy and sustainability office for Västra Götaland. Runs networks and projects alongside public organisations and businesses, co-ordinating municipal energy and climate advisers to help establish a sustainable development network and support energy efficiency in companies (Hållbar Utveckling Väst, 2016).

As can been seen from these descriptions, the role of Public organisations is important in terms of the type of support they can provide for the development of biogas in Västra Götaland. In terms of the overall value chain, these organisations are able to link private actors with providers of municipal services such as waste management. Furthermore, they have an influential connection with the national government, meaning that they are able to escalate issues that cannot be resolved within the region.

In Figure 4.1, the feedstocks are waste-based, with a distinction between private sector and municipal waste producers. This segregation is representative of the situation in Västra Götaland at present. The boxes outlined in red represent private sector biogas production, based on agricultural or industrial organic waste. The boxes outlined in blue represent biogas production as a part of municipal waste management. Although representation in Figure 4.1 shows the biogas

produced in the private and municipal streams mostly as parallel processes, there are commonalities for the end use after upgrading.

To further simplify the value chain, these stages were grouped into three categories: Production, Distribution and Use. It should be noted that the grouping is reflective of the type of activity conducted in the different parts of the value chain, which is not consistent with the sequence of the different stage. These are outlined in Sections 4.1.1 - 4.1.3. These summaries also provide suggestions of actors who could be involved in the three categories; this will be used later to help identify relevant stakeholders to interview as part of this study.

4.1.1 Production

The Production aspects of the value chain include production of raw materials (*Feedstocks*), production of biogas from those raw materials (*Biogas Production*) and upgrading of biogas into more refined product forms (*Transformation*).

4.1.1.1 Feedstocks

It has been forecast that Västra Götaland has the capacity to fulfill 60% of the forecast demand for 20 TWh biofuels in Sweden by 2030, largely due to the strong agricultural and forestry sectors in the region (Västra Götalandsregionen and Länsstyrelsen, 2016; Eriksson and Harrysson, 2017). Västra Götaland, along with Skåne, has been identified as having the highest regional biogas production potential based on the availability of waste and residues as feedstock (Västra Götalandsregionen and Länsstyrelsen, 2016).

The exact types feedstock used in biogas production in the region was difficult to trace, but it is possible to extrapolate back from the type of facilities used to assume which feedstock was used. Furthermore, it would be possible to verify the feedstocks used through interviews at a later stage, if required. In 2015, the production facilities for biogas were dominated by wastewater treatment works (WWTW) and co-digestion facilities (Energigas Sverige, 2018). As such, the main substrates used in the process would be sewage sludge, combined with either municipal organic waste (in areas such as Borås and Falköping (Energigas Sverige, 2018)) or different agricultural wastes and/or industrial waste from food processing. There is also farm-scale biogas production in Västra Götaland. As there is specific financial support available for farmers who treat manure biologically (Avfall Sverige, 2017b), it is assumed that the feedstocks used in these facilities are manure, possibly blended with other agricultural residues produced on the same farm. These claims can be supported to some extent by the national statistics on feedstocks from 2016, which stated that most of the biogas nationally is produced from waste and residues, with only 2% of the biogas originating from energy crops (Eriksson and Harrysson, 2017). That same year, 34% of the biogas was produced from sewage sludge, 19% from manure and 11% from municipal food waste. The rest of the biogas was produced by either residues from food processing or slaugtherhouses. In the absence of more specific information for Västra

Götaland, it is assumed that the proportions of biogas produced from these sources was similar within the region as it was at a national level.

Actors involved involved in this part of the value chain would primarily be organic waste producers, such as farmers, food processors and municipal waste treatment providers.

4.1.1.2 Biogas Production

In 2016, there were 45 biogas production facilities were located in Västra Götaland, contributing 327 GWh to the total national production of 2 TWh (Energigas Sverige, 2017). This was a decrease of 7% from the previous year. Nonetheless, it remained the second biggest regional producer in Sweden, providing 16% of the biogas produced in the country that year (Eriksson and Harrysson, 2017; Västra Götalandsregionen and Länsstyrelsen, 2016).

It was not possible to collate any more detailed information on biogas production processes in Västra Götaland. However, as in Section 4.1.1.1, it was felt that data for Sweden as a whole could be considered as a reasonable proxy for the region. Nationally, the majority of biogas produced originates from digestion of waste and residues (Eriksson and Harrysson, 2017). It is worth noting that there is also a gasification facility in Västra Götaland that has capacity to produce biogas, but this is primarily a research facility and has not produced biogas at a commercial scale in recent years (Eriksson and Harrysson, 2017; Energigas Sverige, 2017).

The County Administrative Board of Västra Götaland (Länsstyrelsen) has developed a strategic plan called "Kraftsamling Biogas" to help realise the biogas production potential in the region. This will be carried out as a project between 2017-2020 (Västra Götalandsregionen and Länsstyrelsen, 2016). In this plan, the following targets have been set based on calculated potential:

- The production of biogas in VG shall reach 2.4 TWh/year by 2020; 50% through anaerobic digestion and 50% through thermal gasification.
- The use of biogas in VG shall reach 2.4 TWh/year by 2020, with vehicle fuel as the predominant application.

(Västra Götalandsregionen and Länsstyrelsen, 2016)

In 2015, 2 TWh of biogas was produced nationally; in Västra Götaland, just 0.35 TWh biogas was produced and 0.25 TWh vehicle gas (composed of 79% biogas) was sold, indicating that drastic changes are needed if the ambitious targets set out in Kraftsamling Biogas 2017-2020 are to be reached (Västra Götalandsregionen and Länsstyrelsen, 2016). It has been recognised by Biogas Väst that these targets are unreasonably high and more or less unachievable by 2020. However, it has also been agreed that the targets should be kept as a way of demonstrating the long-term potential, ambition and vision in the region (Västra Götalandsregionen and Biogas Väst, 2018; Västra Götalandsregionen and Länsstyrelsen, 2016).

Typical actors in this part of the value chain could include large-scale biogas production, such as energy and waste treatment companies (who could include anaerobic digestion as part of their treatment processes), or farmers, for small-scale production.

4.1.1.3 Transformation

For farm-scale anaerobic digestion, CHP production may be more economically viable within the existing regime, providing there is demand for the digestate (fertiliser), access to cheap substrate and adequate equipment in place (JTI - Institutet for jordbruks- och miljöteknik, 2010). It it also desirable in this case that the farmer can use the electricity in onsite activities. However, these conditions frequently vary significantly enough to affect the profitability of such ventures for farmers (Sundberg, Svensson, and Johansson, 2011). Operating larger-scale plants tends to result in positive effects (Lantz, 2010), and it has been observed that there are opportunities to increase the profitability of biogas production when several farms collaborate to co-digest their waste. In Västra Götaland, there are several examples of such collaborations that have been successful, including Brålanda and Vårgårda-Herrljunga (Götalandsregionen, 2018)

Västra Götaland hosts the most biogas upgrading facilities in Sweden, with 12 different plants undertaking upgrading activities (Eriksson and Harrysson, 2017). Although it is difficult to source information about the processes used by upgrading companies, it was learned through stakeholder interviews that the at least some of the upgrading facilities in Västra Götaland use spoiled grain as a feedstock. These upgrading facilities liquify the biogas (to LBG; Liquid Biogas) for use as a vehicle fuel (Stakeholder interview, n.d.), but the upgrading can also refer to increasing the proportion of CH_4 so that the biogas reaches the quality required to be used as vehicle fuel and/or as a replacement for natural gas (Lantz, 2013).

Actors in this part of the value chain are likely to carry out biogas upgrading at a large scale.

4.1.2 Distribution

The distribution aspects of the value chain relate to how materials are transported between the different stages; *Upstream Logistics* for the transport of raw materials and *Downstream Logistics* for product distribution.

4.1.2.1 Upstream Logistics

Upstream logistics (transport of feedstocks from waste producer to biogas producer) were not researched in detail, as this was not felt beneficial for a case study that did not focus on specific sites. However, it should be noted that distances between producers, processors and consumers should be considered carefully in order to ensure that the environmental sustainability of the process is

maximised. This is because additional transport requirements would lessen the GHG emission reduction of effects from production process, when considering the overall value chain (Lantz, 2010).
Actors who could be involved may be municipal waste collectors, specialised freight companies or even the waste producers themselves for small-scale production.

4.1.2.2 Downstream Logistics

In spite of Västra Götaland having the highest number of upgrading facilities, the county experienced a 13% decrease in the amount of biogas injected to the grid between 2015 and 2016, only injecting 89 GWh out of the 327 GWh produced. This contrasts the trend elsewhere in Sweden, where there were increases in the quantities of upgraded biogas injected to grid within the same period (Eriksson and Harrysson, 2017). Moreover, Västra Götaland is not connected to the same gas grid as the regions where direct injection is prevalent. The Swedish grids have about 13 injection-stations for biogas in total (Energigas Sverige, 2017), of which only two are situated in Västra Götaland (Eriksson and Harrysson, 2017).

Another aspect of Downstream Logistics for the biogas value chain in Västra Götaland that is not shown in Figure 4.1 is the import of biogas from Denmark (Energigas Sverige, 2017). This is possible due to direct connection via a gas main pipeline (ENTSOG, 2018). This aspect of Downstream Logistics conflicts with the ambition to produce and use biogas locally and sustainably, as this results in a need for longer distance transportation between producers and consumers, increasing energy demands and reducing overall efficiency.

LBG is likely to be transported by truck, whilst upgraded gas could theoretically be injected directly into the natural gas grid. Fuel stations and other infrastructure required to distribute biogas (liquid or gaseous) as a vehicle fuel have been included as part of Downstream Logistics in this study. Consequently, actors responsible for constructing, operating and maintaining this type of infrastructure are also relevant to this part of the value chain.

4.1.3 Use

The Use aspect of the value chain relates to the applications of the final product outputs (*Products*).

4.1.3.1 Products

Due to a lack of specific data for Västra Götaland, information about products is for Sweden at a national level. However, this is felt to be a reasonable proxy for Västra Götaland. 64% of the total biogas produced in Sweden in 2016 was upgraded and used as vehicle fuel. Considering the end use from different types of facilities, 88% and 62% of the biogas produced at co-digesters and WWTWs respectively was upgraded, while only 25% of the farm-based biogas was used for this purpose (Energigas Sverige, 2017).

The digestate has potential for demand (and revenue) as it can be used as a fertiliser, high in nutrients. The total national production of biogas via anaerobic digestion of all types of organic waste in 2016 resulted in 4 million tonnes of digestate, of which half was used as fertiliser. However, biogas producers operating at farm-scale or through co-digestors used 100% and 96% of their digestate as fertilizer respectively. The digestate that was not used as a fertiliser can be attributed to that produced at WWTWs. The reason that this digestate was not used as a fertiliser was probably related to low social acceptance of the use of sewage sludge on agricultural land among farmers and consumers, in spite of the digestate from this source being certification for use as a fertiliser (Energigas Sverige, 2017).

Actors using biogas-related products could range from individuals who own biogas-fuelled cars right the way up to industrial-scale manufacturers who produce biogas-fuelled vehicles. They could also include arable farmers who need organic fertilisers and may want to use the solid digestate for this purpose.

4.2 Discussion on Case Study for Biogas Value Chain for Västra Götaland

The case study presented in this part of the project outlined the current biogas value chain in Västra Götaland, broadly considering biogas feedstocks, production, transformation, consumption and logistics in the region. The most striking discovery about the current situation is that the target for production in Västra Götaland by 2020 is greater than the total production in Sweden was in 2016; 2.4 TWh versus 2.0 TWh (Västra Götalandsregionen and Länsstyrelsen, 2016; Energigas Sverige, 2017). However, in 2015 the total production in Västra Götaland was only 0.35 TWh, decreasing to 0.33 TWh in 2016 (Västra Götalandsregionen and Länsstyrelsen, 2016; Energigas Sverige, 2017). This indicates not only that it is highly unlikely that the 2020 target will be met, but also that the regional production is getting further away from rather than closer to that target. Furthermore, at present there are no plans for expansion of regional biogas production capacity, despite targets being based on calculated potential production levels (Avfall Sverige, 2017b; Västra Götalandsregionen and Länsstyrelsen, 2016). However, the ambitious target remains in place, showing that there is a will to develop the biogas industry in Västra Götaland. Considering the fall in production in recent years, it is clear that this study into barriers and enablers could be beneficial to help identify factors which may bring about positive change.

5
Results & Discussion

Stakeholder engagement was a key way in which data was obtained during this study. Using stakeholder engagement enabled perspectives to be obtained that would not otherwise be available through literature-based research methods. This section outlines aspects of the project related to stakeholder engagement.

5.1 Stakeholder Identification

The process of identifying stakeholders relevant to biogas in Västra Götaland revealed a complex and heavily interrelated network called Biogas Väst (VGR, 2018). This was beneficial as it meant that the researchers were able to efficiently identify a large number of stakeholders involved in the biogas value chain through their involvement in the network. It was also found that there had been a major conference on biogas in the region in October 2017 (Biogas Väst, 2017). Identifying the network and conference rendered the original approach to the study obsolete, as it transpired that biogas was more developed in the region than had been anticipated. This meant that whilst the aim of the study consistently centred around barriers which prevent the widespread application of biogas in the region, the focus of the study shifted from being technical to more socio-technical in order to maximise potential benefits to the stakeholders. This enabled the aim of the study to be better tailored to addressing the real barriers affecting the development of biogas in the region, rather than areas that the researchers found immediately interesting. In this sense, bias from the personal interests of the researchers was reduced in order to create better conditions for addressing the core of the problem from the perspective of the stakeholders affected.

As described in Section 3.2.1, according to Preble (2005), stakeholders can be categorised as Primary, Secondary or Public. Table 5.1 below presents the stakeholders identified for this study, where Primary stakeholders are producers or consumers of biogas, Secondary stakeholders are involved with biogas lobbying and Public stakeholders were involved in biogas through regional management or local politics. In this study, stakeholders were selected to represent actors from different parts of the value chain. A total of 12 stakeholders were interviewed, 5 Primary (3 producers and 2 consumers), 1 Secondary and 6 Public.

Table 5.1: Identified Stakeholders

Stakeholder	**Category**	**Relevance to Study**
Operations manager at Trollhättan Energi (Brålanda)	Primary (Producer)	Municipal and farm waste in a co-operative co-digestion plant
Founder, company producing biogas from fish processing waste	Primary (Producer)	Biogas from fish processing waste in symbiosis
Sustainability Director, Göteborg Energi (including GoBiGas)	Primary (Producer)	Municipal Waste
Environmental Director for large truck manufacturer	Primary (Consumer)	Involved in strategic development for sustainable freight trucks
Head of Nordic Operations & Project Executions, company selling liquid biogas as a vehicle fuel	Primary (Consumer)	Works with commercial aspects of Nordic market for liquid gas as a vehicle fuel
Project leader and key-note speaker for Biogasakademin	Secondary	Created an organisation promoting separation of food waste in public institutions for biogas production as a citizen who had been impressed by the potential of biogas from waste
Chairman of the environmental committee for Västra Götalands Region	Public	30 years experience working with sustainability and the environment in local, regional and national government
Process Leader for Biogas Väst (part of VGR)	Public	Leads network offering support and promoting development of biogas in the region
Funding officer, Länsstyrelsen	Public	Works with funding applications for local climate-related investment as part of government initiative "Klimatklivet"
Leader of Department for Rural Development, Länsstyrelsen	Public	Spoke at "Biogas för Framtiden" conference in November 2017, works with agriculture in the region
Agricultural Consultant, Länsstyrelsen	Public	Specialist regional advisor in agronomy, agricultural environmental issues and organic farming
Process Leader, Hållbar Utveckling Väst	Public	Responsible for Biogas Väst project, but former CEO of company selling liquid biogas as a vehicle fuel, so also able to offer insights as primary stakeholder from previous role

The organisations that Primary and Secondary stakeholders worked in were private sector, so additional information on these is not provided in order to ensure respect of privacy.

In terms of the broadness of stakeholders interviewed, unfortunately, it was not possible to conduct interviews with primary producers of raw materials (such as farmers or food processing companies), nor smaller organisations or individuals producing biogas. This was because it was difficult to make contact with these kinds of stakeholders. However, the Operations manager at Brålanda had direct contact with such producers, and was able to give some insight into the challenges they faced.

It was interesting to note that all stakeholders seem to empathise well with the challenges faced by others, and seemed to be very open with the limitations of their own roles in the value chain. Although all stakeholders were involved in biogas and no interviews were conducted with actors who were opposed to biogas, many stakeholders reported examples were other technologies were more suitable than biogas. For example, several stakeholders suggested that electric buses were more suited to use in cities as they are quieter than biogas-fuelled buses and can be charged inside buildings; this creates a better experience both for bus users and other people in the same urban environment as the buses. As a whole, interviewees were not guarded about revealing problems with biogas. In general, stakeholders were largely very enthusiastic about biogas and keen to share not only perspectives from their organisation, but also personal opinions on different issues. It may also have been interesting to gauge public perceptions and awareness of biogas in order to gain insights from stakeholders who may not have been in favour of biogas, but this was beyond the scope of this study.

5.2 Interview Process

12 stakeholder interviews were conducted for the purpose of this study. The use of semi-structured interviews was felt to be an appropriate method for gaining the information needed for this study. However, it was found that in some cases, the expectations of stakeholders about the format of interviews was sometimes misaligned with the approach taken. This may have hindered the initial parts of the interviews at times. Nonetheless, this did not seem to affect the overall outcomes of the interviews, as stakeholders tended to adapt quite quickly to the setting and were keen to contribute to the study. In general it was found that stakeholders were very open to sharing their views, as well as passionate and enthusiastic about the potential implications of the results of the study. Almost all of the stakeholders asked to be sent a copy of the finished report.

5.3 Interview Analysis

By interviewing stakeholders from different parts of the biogas value chain, it was possible to gain a range of perspectives on the strengths and weaknesses of biogas in terms of increased regional development. In order to highlight aspects which

stakeholders found important, information from interviews was broken down into standalone statements. 198 separate statements were identified; these are presented in Appendix A. These were analysed as outlined below.

5.3.1 SWOT Analysis

In the majority of cases, the statements clearly fitted into a single category of the SWOT, then subsequently into a single theme (and sub-category within the themes where applicable). However, some statements were discarded as it was felt that they did not fall under any category, or particularly add value. Statements which where deemed interesting but not directly relevant to the SWOT were removed from the selection. Although not included in this part of the analysis, these statements were felt to be valuable because they provided more insights into stakeholder passions and concerns for biogas. Additionally, it was felt that these statements could potentially support the findings of the analysis at a later stage. These are summarised as follows:

- "Biogas is socially, economically and ecologically sustainable"
- "Simple solution"
- "Win-win"
- "It is a case of reducing climate impact vs reducing waste vs standard of living vs security of demand"
- "Corporate competition is the mindset, not corporate collaboration, so it is difficult to establish the trust needed for circular economy in a corporate setting"

5.3.2 Categorisation by Thematic Area

Figure 5.1 was made based on the data presented in Appendix B; this is also the case for Figures 5.2 and 5.3 and Tables 5.2 - 5.5 which will be outlined later in this section. As can be seen from Figure 5.1, there was found to be an uneven distribution of statements across the different thematic categories following the thematic categorisation process, with Social aspects dominating, and Value Chain the second biggest thematic category. More detailed observations for each thematic category are outlined below.

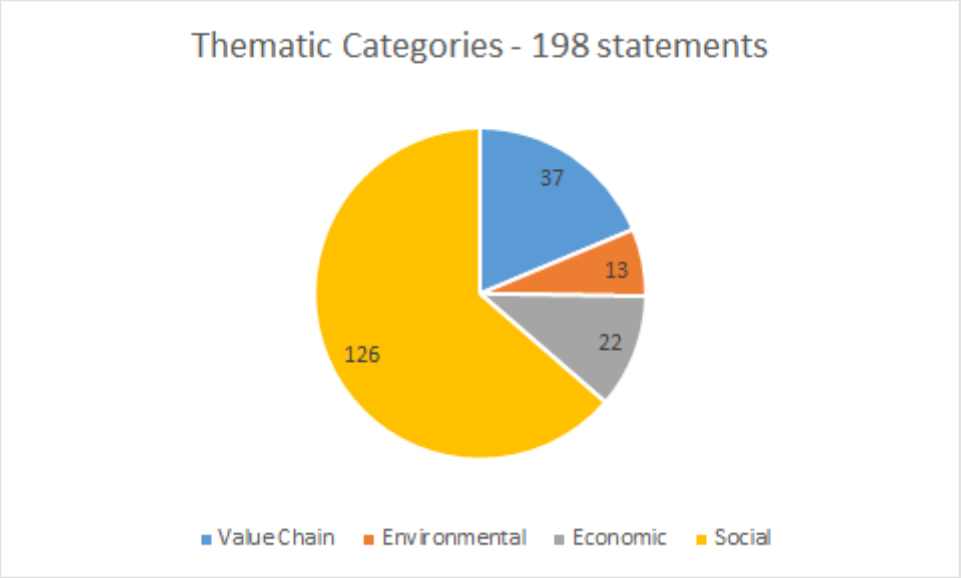

Figure 5.1: Distribution of statements in different thematic categories

5.3.3 Value Chain

As described in Section 3.2.3.2, the Value Chain was split out into the different stages identified when studying the Value Chain (see Figure 4.1 in Chapter 4). Table 5.2 summaries how the statements in the different sub-categories of the Value Chain were split in the SWOT.

Table 5.2: SWOT distribution for sub-categories in the Value Chain thematic area

Sub-category	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**	*Total*
Feedstocks	2	2	3	2	*8*
Upstream Logistics	2	0	0	0	*2*
Biogas Production	0	5	3	1	*11*
Transformation	0	0	0	0	*0*
Downstream Logistics	2	1	2	0	*5*
Products	9	2	12	2	*25*
Total	*15*	*10*	*20*	*5*	

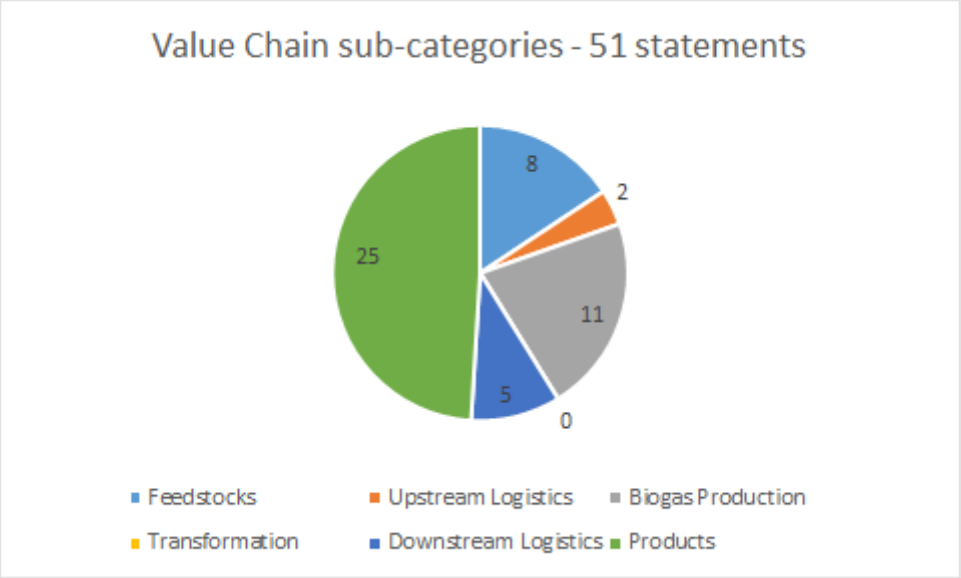

Figure 5.2: Distribution of Value Chain statements in sub-categories

As shown in both Figure 5.2 and Table 5.2, statements related to Products make up almost half of the statements falling under the Value Chain thematic area. Interrogating the SWOT for the Product sub-category presented in Table 5.2 is encouraging; there are 9 Strengths and 12 Opportunities, compared with just 2 Weaknesses and 2 Threats (see Appendix B for a full list of all categorised statements). This implies that there is potential for further development when it comes to using outputs from the biogas value chain, as stakeholders tended to identify topics related to biogas/fertiliser applications.

There were no statements that fell under the Transformation sub-category. This was not because stakeholders had not mentioned the transformation of biogas during interviews, but rather that the statements which included transformation aspects were more related to the final product outcome rather than the transformation itself.

It was found that almost half of the statements related to Products from the value chain. Furthermore, the majority of statements falling under the Products subcategory were classified as Opportunities. This implies potential for growth in terms of applications of biogas and related products in the region. Additionally, no clear SWOT categorisation trends were observed for Feedstocks, Upstream Logistics, Biogas Production or Downstream Logistics. This lack of consistency could be seen as further strengthening the benefit of focusing on the Products part of the Value Chain, where clear trends were seen, suggesting a more effective area to target. This ties in with statements from the stakeholders, such as "New large consumers e.g. shipping and the chemicals industry", "There is increasing demand for bio-fertilisers, but they are difficult to source", "Market still quite open in terms of new actors and applications", "Public procurement to create large, reliable consumers (e.g. by using biogas-fuelled vehicles)", "Alternative to natural gas which can be substituted into existing systems", and "Biogas is needed for

renewable molecules, e.g. hydrocarbons for bioplastics".

Social
Table 5.3 and Figure 5.3 show that within the Social thematic category, statements related to the sub-categories Relevant Actors (i.e. those with direct involvement in the biogas value chain) and Society (i.e. those who may be affected by biogas development in a much broader sense) were reported most frequently.

Table 5.3: SWOT distribution for sub-categories in the Social thematic area

Sub-category	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**	*Total*
Relevant Actors	7	11	15	18	50
Political	3	4	8	11	25
Society	8	10	13	11	42
Public Sector	0	1	7	1	9
Total	*18*	*26*	*43*	*41*	

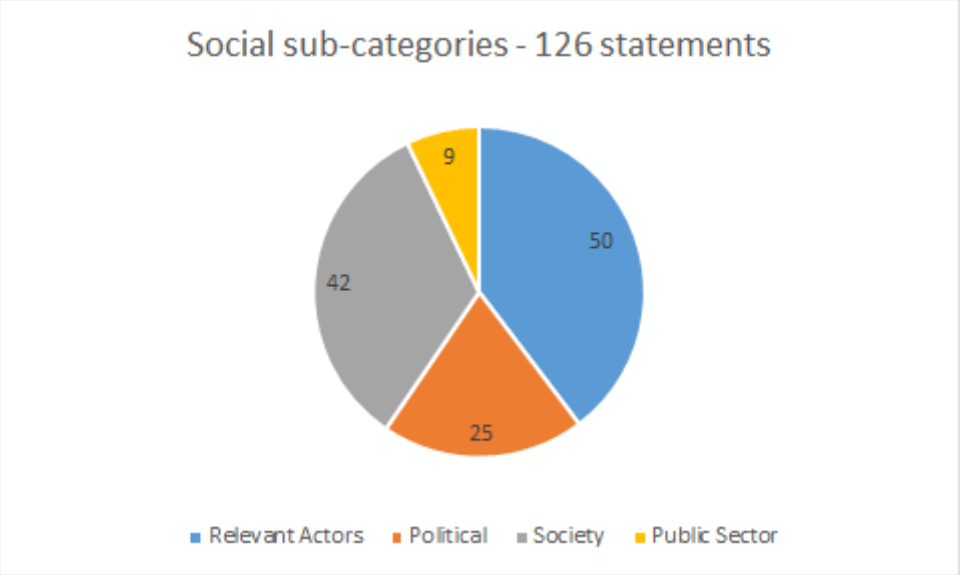

Figure 5.3: Distribution of Social statements in sub-categories

As stated earlier, and as shown in Figure 5.3, over half of the statements given by stakeholders fell within the Social thematic area, making it by far the biggest category from a theme perspective. Considering Figure 5.3, it can be observed that Biogas Value chain is the thematic area with the most statements, closely followed by Society. Cross-comparing with Table 5.3, there appear to be a significant number of both opportunities and threats falling within these two sub-categories. Overall, there are 41 Threats and 43 Opportunities within the Social category, with almost 30 of each from both the Biogas Supply Chain and Society sub-categories. Looking more deeply into the statements for these sub-categories, as included in Appendix B, behaviours and interactions seem to be common

themes for both Opportunities and Threats. Risk and trust are frequently cited, but may be difficult to address. This indicates that human factors have the greatest influence overall on the development of biogas in the region. In terms of overcoming barriers and promoting enablers, it is proposed that a more formalised approach with supportive policies is needed in order to address the identified Social factors.

Environmental
Looking at Figure 5.1, it can be seen that the Environmental category was the smallest considered, with only 16 statements. This may have been because the Environmental aspects of biogas production and use are often inherent. Furthermore, they do not tend to deliver a direct benefit (or indeed directly cause pain) to stakeholders. As such, this could explain why fewer of the statements given by stakeholders were concerned with Environmental matters. Considering the breakdown of statements in the Environmental category into the SWOT categories (as shown in Table 5.4), it is felt that statements included in the Environmental category could be used as a support in promoting enablers for biogas, as none of the Environmental statements were Weaknesses and there was only one Threat. Therefore, the stakeholders interviewed perceive that there are predominantly Strengths and Opportunities with regard to the Environmental dimensions of biogas.

Although statements relating to circular economy were mainly included in the Environmental category (see Tablre 5.4 below), "Inexperience with circular economy - collaboration threat in value chain and society" was included as a Social rather than Environmental statement, under the sub-category Biogas Value Chain, as this clearly relates the the human influence on circularity as opposed to the environmental aspects.

Table 5.4: SWOT distribution for the Environmental category

Category	Strengths	Weaknesses	Opportunities	Threats
Environmental	11	0	4	1

Circular economy was a theme which emerged from in several of the statements given by stakeholders. Although it could arguably have fallen under the Value Chain category, it was felt that many of the reasons for adopting circular economy were environmental. This is because more efficient resource use can lead to reduced pollution from emissions to air, water and soil. It can also lead to reduced consumption of raw material which may need to be extracted from the natural environment. Circular economy affects the Value Chain by changing the flow of raw materials, and may also bring about economic and social effects, but the it was felt that the environmental effects were most significant. Furthermore, many stakeholders had mentioned the importance of environmental sustainability, suggesting that the environmental credentials of a technology can also be a driver in social or economic decision-making.

In terms of the Environmental thematic categories, it was found that many stakeholders valued the circularity aspects of biogas (9 stakeholders said "Biogas enables a circular economy"). As a whole, it was felt that stakeholders saw the inherent environmental benefits of biogas, within which many also identified social and economic benefits ("Biogas unites rural and urban communities", "Additional source of revenue for farmers"). The value that stakeholders place on these environmental aspects is encouraging, particularly in light of the statement "Revenues from biogas are seen as too low, but many value the environmental aspects enough to tolerate the poor economic turnover".

Economic
As shown in Figure 5.1, Economic statements made up the second smallest thematic category. As can be seen from Table 5.5, of the 22 statements included in the Economic category, the largest proportion of these were Threats. When looking more closely into the content of these statements (see Appendix A for a full list), it can be observed that some of these Threats could be overcome by addressing biogas policies, as many of these related to lack of drivers from a political level, poor clarity in terms of long-term aspirations for biogas and challenging economic situations that could be improved through changes in taxation. However, all of these factors are beyond the control of actors in the biogas value chain. From looking at the Economic thematic area, it could be argued that one way to promote enablers in the region (thereby supporting the biogas value chain) would be to appeal to political decision makers who could change policies in order to overcome the identified Economic threats.

Table 5.5: SWOT distribution for the Economic Category

Category	Strengths	Weaknesses	Opportunities	Threats
Economic	5	5	4	8

Looking at statements in the Economic thematic categories, it was found that Threats were predominant in terms of SWOT categorisation, implying that many of the barriers to development of biogas stem from the current economic conditions. It was noted that policy changes could be used as an approach for overcoming some of these Economic Threats, but that this is not something that actors within the Västra Götaland biogas value chain can control, particularly as it was identified that policies could only be implemented at a national level. However, lobbying for more favourable policies could be one way to improve the economic viability of biogas production in the region. This is also reflects the findings of the case study into European biogas policies; it was found that Sweden is fairly unique in offering financial incentives to those purchasing biogas, but lacking economic support for biogas producers (Lantz, 2013). The economic importance of having appropriate policies in place was also raised during the initial stakeholder interviews. The following related statements were each given by one stakeholder: "Policies are dictated by trends and it is impossible to forecast what

the trends will be", the threat of the "Complexity of biogas taxation system" and "Subsidies for electric vehicles but not biogas vehicles". These statements indicate that stakeholders feel that the current policies in place are not helping the biogas value chain to overcome economic challenges.

5.3.4 Statement Prioritisation

Once the statements from Appendix A had been categorised by both SWOT and thematic area, it was still necessary to further refine the data considered due to the large number of statements. Weighting was assigned to each statement by counting the number of stakeholders who had given that statement and taking the number of stakeholders as the weighting. It was found that out of the 198 original statements, only 55 had been given by 2 or more stakeholders. Tables 5.6 - 5.9 present a summary of these statements for each SWOT category respectively, including the number of stakeholders who mentioned the statement (shown in the #SH column in Tables 5.6 - 5.9) and thematic categories. A full list of all statements, separated into both SWOT and thematic areas, can be found in Appendix B.

Table 5.6: Strengths identified by multiple stakeholders, with thematic categorisation

Statement (Identified Strength)	**#SH**	**Thematic Category**	**Sub-Category**
Resilient, especially compared to other renewable technologies (has experienced set-backs in the past but still remains in market)	2	Value Chain	Products
Biogas production already exists in wastewater treatment plants	2	Value Chain	Feedstocks
Biogas unites urban and rural communities	2	Social	Society
Biogas can be combined with natural gas and used in existing systems	2	Value Chain	Downstream Logistics
Biogas enables circular economy	9	Environmental	N/A
Provides security of supply for fuels and nutrients	2	Social	Society
High emission reduction potential per investment	3	Economic	N/A
Produces excellent organic fertiliser - same amount of nutrients in 40% less volume, plus less odour	3	Value Chain	Products
Renewable alternative to fossil fuels	2	Environmental	N/A

Table 5.7: Weaknesses identified by multiple stakeholders, with thematic categorisation

Statement (Identified Weakness)	**#SH**	**Thematic Category**	**Sub-Category**
Development reliant on multi-disciplinary collaboration	2	Social	Relevant Actors
Need for systems view to understand the complex value chain	2	Social	Relevant Actors
Complex network at both local and international level	2	Social	Relevant Actors
Need for more stable and mature market	4	Social	Relevant Actors
It is slow to plan, construct and commission a new biogas plant	2	Value Chain	Biogas Production
Need for long-term strategy	2	Social	Political
Biogas production costs are relatively high and need to be reduced	2	Economic	N/A
Economically challenging for small-scale producers	5	Economic	N/A

Table 5.8: Opportunities identified by multiple stakeholders, with thematic categorisation

Statement (Identified Opportunity)	**#SH**	**Thematic Category**	**Sub-Category**
Willingness for collaboration between large-scale biogas producers and consumers	2	Social	Relevant Actors
New large consumers e.g. shipping and the chemicals industry	3	Value Chain	Products
50% growth in freight transport is forecast by 2030	3	Value Chain	Products
Consumers want to buy sustainable biogas - could use more environmental branding to promote this	2	Value Chain	Products
Ongoing development of biogas-fuelled vehicles	5	Value Chain	Products
Sweden has potential to be a market leader, and VGR has potential to lead in Sweden	2	Social	Relevant actors
Potential to focus on different aspects of biogas supply chain in terms of communication, marketing and wider perspectives	2	Social	Relevant Actors
Digestate from sewage is not used as a fertiliser locally, but can be exported as fertiliser, combusted or used as construction soil	2	Value Chain	Products
There is increasing demand for bio-fertilisers, but they are difficult to source	2	Social	Society
Public procurement to create large, reliable consumers (e.g. by using biogas-fuelled vehicles in the public sector	5	Social	Public Sector
Regional focus is mainly on fossil-free alternatives, but biogas is a special case with high politial interest	2	Social	Political
Circularity aspects make biogas a regional priority	3	Environmental	N/A
Government support for capital investments through KlimatKlivet	2	Economic	N/A
Better waste and emissions management	4	Environmental	N/A

Table 5.9: Threats identified by multiple stakeholders, with thematic categorisation

Statement (Identified Threat)	**#SH**	**Thematic Category**	**Sub-Category**
Poor marketing and communication from producers of biogas and biogas-fuelled vehicles	3	Social	Relevant Actors
Lack of trust between actors	4	Social	Relevant Actors
Mindsets of different actors	3	Social	Relevant Actors
Lack of long-term agreements and planning	7	Social	Relevant Actors
Competition for use of organic waste	2	Value Chain	Feedstocks
Societal change of resource use over time	2	Value Chain	Overall Value Chain
Inconsistency in supply and demand	9	Social	Relevant Actors
Inefficient production technologies	2	Value Chain	Biogas Production
Difficult to know who is benefitting most in a collaboration, so there are issues with power and risk	2	Social	Relevant Actors
Existing co-operatives do not dare take the risk of expanding, even though there is potential to do so	4	Social	Relevant Actors
Negative media coverage	2	Social	Society
Lack of national biogas strategy	2	Social	Political
Politicians are not prepared to make "unpopular" decisions and risk not being re-elected	2	Social	Political
Lack of long-term governmental policies	3	Social	Political
Lack of competence in political decision-making - desire for a simple solution that will solve everything	2	Social	Political
Focus on electric vehicles by manufacturers and politicians	3	Social	Society
Difficulties in changing behaviours without economic drivers - economic and mindset threat in value chain and society	3	Social	Society
Inexperience with circularity - collaboration threat in value chain and society	2	Social	Society
Lower cost of biogas imported from Denmark - need for neutrality between Swedish and Danish taxation systems	7	Economic	N/A
Economic difficulties for small-scale producers	3	Economic	N/A

Considering the approach taken to conducting the SWOT analysis, it is interesting to note that the keywords identified for Strengths and Opportunities were distinctly different from each other, mostly because Strengths generally related to the current situation whilst Opportunities tended to be more relevant to future potential which could be realised. For example, the inherent Strength that biogas "Provides security of supply for fuels and nutrients" is closely related to the Opportunity that "There is increasing demand for bio-fertilisers, but they are difficult to source", but the Opportunity directly addresses a need which could be achieved with biogas production, whilst the Strength simply states an argument that could be used to encourage more biogas production. On the other hand, there were several keywords (difficult, risk, need for/lack of) which were applicable to both Weaknesses and Threats. For example, the Weakness of "It is difficult to attribute costs/profits to deserving parties across the supply chain" and the Threat of "Difficult to know who is benefiting most in a collaboration, so there are issues with power and risk". Here, the Weakness states an inherent problem with trying to introduce co-operatives into the value chain, whilst the Threat reinforces the Weaknesses by identifying the the potential conflicts due to power and risk cause this difficulty. This suggests that Weaknesses may strengthen Threats more than Strengths support Opportunities, implying that overcoming barriers could prove a bigger (and arguably more important) challenge than promoting enablers. Positive or negative adjectives were used to help with SWOT categorisation on the basis of the criteria proposed earlier in this section. As per the criteria, the adjectives identified for Strengths and Weaknesses were concrete or inherent properties, while the adjectives for Opportunities and Threats were more actionable or behaviour based, such as "Consumers want to buy sustainable biogas - could use more environmental branding to promote this" as an Opportunity, and "Difficulties in changing behaviours without economic drivers - economic & mindset threat in value chain and society" as a Threat.

It was found that in general, Opportunities tended to be enablers whilst Threats were barriers. The Strengths and Weaknesses often supported what had been identified, but by definition were not concretely actionable points. Using the thematic categories enabled trends for the most relevant aspects affecting the development of biogas to be identified. Because the prioritisation of statements was done on the basis of the number of stakeholders who gave that statement, it is possible that valuable or important points may have been eliminated. This could have been due to lack of knowledge (or even access to specific information) by some stakeholders, who therefore would not have been able to identify such statements. However, as all of the statements are recorded in Appendix A, it is still possible to pursue these further as avenues of inquiry.

In terms of Primary, Secondary and Public stakeholders (as described by Preble (2005), see Section 3.2), when considering the biogas supply chain in Västra Götaland it can be seen that Public stakeholders span the whole of the value chain, whilst Primary and Secondary stakeholders dominate upstream and downstream sections respectively. Based on this, it could be argued that Public stakeholders

have potential to support and unite the whole supply chain. This reflects the illustration of the value chain provided in Figure 4.1 in Section 4. It is proposed that this could be achieved through continued and possibly extended collaborative support, as is already being provided through the Biogas Väst network.

Key trends for each category within the prioritised SWOT (outlined in Tables 5.6 - 5.9) are summarised as follows:

Strengths

The broad distribution of different types of Strength included in the interview statements indicates that the perceptions on the strengths of biogas tends to be closely linked to the perspective of each interviewee, depending on their insights through their role. Additionally, this highlights the wide range of benefits connected to biogas. From an economic perspective, biogas is viewed to have a "High emission reduction potential per investment", and could also work as an "Additional source of revenue for farmers", whilst simultaneously providing farmers with their own source of fertiliser, as the process "Produces excellent organic fertiliser [...]". Building upon the latter statement, rural development was also emphasised as a benefit, as "Biogas unites urban and rural communities". These statements were typically mentioned by Public stakeholders who were involved in rural development and regional affairs, whilst Primary stakeholders from a more commercial background tended to be more concerned with technological promises, such as biogas being "Resilient, especially compared to other renewable technologes [...]" and the possibility in that "Biogas can be combined with natural gas and used in existing systems". In spite of the wide range of Strengths mentioned, there seems to be a consensus among the interviewees on the importance of circularity, as "Biogas enables circular economy" was mentioned 9 times, effectively singling out this aspect as a positive focus for actors throughout the value chain.

Weaknesses

The statements viewed as Weaknesses mostly centered around social aspects, with many based networking and collaboration between people, as illustrated by statements such "Development reliant on multi-disciplinary collaboration", "Need for systems view to understand complex value chain" and "Complex network [...]". However, while collaboration was a recurring theme, the statements mentioned most frequently in the interviews concerned economical circumstances both in it being "Economically challenging for small-scale producers" (brought up by 5 stakeholders) and that there is a "Need for a more stable and secure market" (raised by 4 stakeholders). As such, there seems to be a general perception that collaboration in an industrial setting is difficult to achieve, but a stronger consensus on the Weaknesses of biogas in relation to economics.

Opportunities

The statements identified as Opportunities mostly revolved around securing future demand for biogas, as highlighted in statements such as “New large consumers e.g. shipping and the chemical industry” and “Ongoing development of biogas-fueled vehicles”. The latter statement was the second most frequently mentioned Opportunity, reflecting the focus on biogas for the transport sector highlighted in "Kraftsamling Biogas" (Västra Götalandsregionen and Länsstyrelsen, 2016), which was developed by regional decision-makers to steer the direction of biogas development in Västra Götaland. The other most frequently mentioned opportunity encouraged use of “Public procurement to create large, reliable consumers [...]”, once again addressing potential options for increasing demand and use. In this case, the focus is on the potential of the public sector to drive creation of stable demand, indirectly making the most of the multiple benefits that biogas can bring to society through. There was recurrence of circularity in Opportunities, as had been the central theme in Strengths, highlighted through statements that “Circularity aspects make biogas a regional priority”, and “Regional focus is mainly on fossil-free alternatives, but biogas is a special case with high poitical interest”. However, it was evident that the majority of Opportunities raised by interviewees connected to increased use of biogas in the region, with far fewer statements relating to the potential for biogas production.

Threats

Three of the top five most frequently mentioned statements from stakeholder interviews were categorised as Threats. This indicates a that there is consensus on the main barriers among stakeholders from different parts of the biogas value chain. The most commonly recurring statement in the Threat category was “Inconsistency of supply and demand” (stated by 9 stakeholders, closely followed by “Lower cost of biogas imported from Denmark [...]” and the “lack of long-term agreements and planning” (both raised by 7 stakeholders). The latter statement could also be connected to concerns over “lack of long-term governmental policies” and “Lack of national bigas strategy”, which can be further reinforced by the identified Weakness of “Need for long-term strategy”. It could be argued that these statements indicate that the biogas value chain in Västra Götaland relies heavily on political influences, and that many actors expect politicians to take responsibility for improving the situation for biogas in the region. There was also mention of political focus in a way which was unfavourable for biogas, such as “Focus on electric vehicles [...]”, “[...] desire for a simple solution that will solve everything” and that “Politicians are not prepared to make "unpopular" decisions and risk not being re-elected”. It could be said that these statements derive from concerns over ever-changing political, economic and societal environments, further supported by the Threats of “Competition for use of organic waste” and “Societal change of resource use over time”, which were both raised by two different stakeholders. The interviewees also described difficulties stemming from “Negative media coverage” and “Poor communication and marketing [...]” for biogas in the region. However, statements related to mindset and collaboration were more prominent, including “Lack of trust between actors” (given by 4 stakeholders), “Mindset of different actors” (3 stakeholder raised this) and it being “Difficult to

know who is benefitting most in a collaboration [leading to] issues with power and risk". In summary, the stakeholders interviewed highlighted a wide range of threats, but placed the greatest emphasis on the three statements mentioned at the beginning of this appraisal of Threats in the SWOT analysis; this indicates that the greatest perceived Threats relate to the balance between supply and demand, and long-term agreements.

Some of the statements presented in Tables 5.6 - 5.9 could be seen as spanning SWOT-categories and thematic sub-categories. However, to simplify the data handling process, this was not accounted in the data analysis. Nonetheless, it was considered valuable to present these observations alongside the final categorisation. The summary below highlights what were considered to be the most significant examples:

- The organic fertiliser that is a by-product of the anaerobic digestion was mentioned as a Strength, with three stakeholders claiming that is it an "[...] excellent fertiliser [containing the] same amount of nutrients in 40% less volume, plus less odour", and two stakeholders saying that it could also provide additional revenue for the farmers (it was raised by several stakeholders that many farmers in the region struggle economically). Statements connected to fertiliser were also raised twice in the Opportunities category, with stakeholders saying that "There is an increasing demand for bio-fertilisers, but they are difficult to source" and that while "Digestate from sewage sludge is not used as a fertiliser locally, [it] can be exported as fertiliser, combusted or used as construction soil". This latter statement can be seen as a mitigation to one of the Weaknesses presented, namely that there is "Ethical debates/poor public perceptions of use of sewage sludge on arable land". Consequently, when considering the statements classified within the SWOT analysis, fertiliser produced as part of biogas production can be seen to help actors in the value chain make the most of a Strength of biogas, as well as grasping two opportunities, whilst also counteracting an identified Weakness.
- Circularity was a recurring positive theme throughout the SWOT, most notably that "Circularity aspects make biogas a regional priority", thereby presenting an Opportunity for the biogas value chain. In the Opportunities category of the SWOT analysis, it was stated by four interviewees that biogas production could result in "Better waste and emissions management" which was attractive due to "Large volumes of organic waste in the region" according to two of the interviewed stakeholders, supporting another opportunity in that "Sweden has potential to be a market leader, and VGR has potential to lead Sweden" (suggested by two stakeholders). Circularity aspects also occurred in Strengths, both through the statement "Biogas enables circular economy" (one of the two statements raised by 9 different stakeholders, making this statement considered among the most important in the SWOT), but also that biogas production "Provides security of supply for fuels and nutrients". This second statement means that biogas can help the

region become independent of the need to import fuels and agricultural nutrients from elsewhere; several stakeholders discussed the importance of addressing the need for local self-sufficiency when considering instability in global politics and the potential implications for availability of vital raw materials in the future.
- While it was considered an Opportunity that the government offers "[...] support for capital investments through Klimatklivet", that support does not address the economic hardships for producers, mentioned in both Weaknesses (by 5 stakeholders) and Threats (raised by 3 stakeholders), nor does it offer a solution for the production costs that "[...] are relatively high and need to be reduced", also mentioned in the Weaknesses category as a barrier to being able to sell biogas at a competitive price. However, it was noted that Klimatklivet could address one Weakness, namely that "It is difficult to plan, construct and commission a new biogas plant"; it is possible to apply for Klimatklivet support for this kind of work, and there is also technical support available via Länsstyrelsen and Hushållningssällskapet.

However, this was still considered too many statements to include within the scope of the study, so further filtering was carried out so that the three most reported statements were selected as a focus point for further research. Two statements given by 9 stakeholders were identified and two statements from 7 stakeholders. 3 of the statements were Threats, so the fourth statement, the Strength of "Biogas enables circular economy" which was identified by 9 stakeholders, was discarded at this point as it was felt that the Threats were both more actionable and more aligned with the Research Question. Additionally, the 3 Threats were more consistent with each other, which enabled a defined focus for further research. The 3 identified Threats are presented in Table 5.10.

Table 5.10: Most Highly Reported statements

Statement	**Category**	**Number of Stakeholders**
Inconsistency in supply & demand	Social	9
Lack of long-term agreements and planning	Social	7
Lower cost of biogas imported from Denmark - need for neutrality between Swedish and Danish taxation systems	Economic	7

As shown by the Threats presented in Table 5.10, it can be argued that the most commonly identified threats to the development of biogas in Västra Götaland affect the entire value chain rather than a single actor or group of actors. Furthermore, "Inconsistency in supply & demand" connects closely with "Lower cost of biogas imported from Denmark - need for neutrality between Swedish and Danish taxation systems" because at present the production of Swedish biogas outstrips demand, and is then further undermined by Swedish consumers opting for cheaper Danish biogas (Westman Svenselius, 2017; Steinwig, 2017; Avfall Sverige, 2017a). As such, "Inconsistency in supply & demand" could be seen as a

result of unbalanced competition between Swedish and Danish biogas producers. This is further compounded by the "Lack of long-term agreements and planning", as consequently there has been little focus on establishing such agreements due to an overall lack of stability in the biogas market in Västra Götaland. It is proposed that these three identified threats can be viewed as characterising the main barriers which need to be overcome in order to enable development of biogas in the region.

Consequently, it was concluded that the most important areas for ongoing research in this study were the causes of imbalance of supply and demand in the current biogas value chain, as well as policies which could support the overall value chain in the region more reliably in the long-term. This should include how to make biogas competitive locally in order to overcome the threat of cheap imports from the international market. Policies could support upstream, downstream and biogas producing actors, thereby increasing the integrity of the overall value chain. It is felt that there is potential for success using a policy-based approach due to the strong political interest in circularity, reflecting many of the frequently cited statements listed in Tables 5.6 - 5.9. To address these identified barriers, Chapter 6 will present a case study on different European biogas policies, first assessing the cause of imbalance between policies in Sweden and Denmark and additionally appraising policies across Europe that hindered or helped the development of biogas in their respective countries.

6

Case Study: Biogas Policies in Europe

Based on the outcomes of the Västra Götaland biogas value chain case study and analysis of the stakeholder interviews, biogas policy was selected as an area for focused research that could support development so that the full potential of biogas in the region may be reached. Firstly, current biogas policies for the region were studied to give a basis for assessment of the situation at present. As one of the three main identified Threats made specific reference to the need for balance between Swedish and Danish biogas policies, the current situation in Denmark is also explored in some detail.

Suggestions for beneficial changes were then developed by highlighting the hindering differences between Swedish and Danish biogas policies, as well as appraising the current and historic biogas policies across Europe to find other policies that have proven successful. It should be noted that in the following sections, "biomethane" refers to upgraded biogas (generally for either direct injection to the grid or use as a vehicle fuel) (Wilkie, 2018). This has been included in order to represent information in international legislation more accurately.
Mentions of "feed-in tariffs" refer to either direct injection of upgraded biogas to the natural gas grid, or transfer of electricity generated from biogas to the electric grid; whether the tariff refers to biogas or electricity will be made clear where relevant. Furthermore, it should be noted that the tariff is awarded to the producer of the biogas (or electricity) as opposed to the waste producer or grid owner (Sterner, 2003). "Feed-in premium" refers to a form of tariff which positively discriminates in favour of biogas. The premium awarded depends on the country, but is always higher than the tariff in that country (where applicable).

The case study was carried out as follows:

- Literature review - to collate relevant background information
- Development of proposal for changes - based on appraisal of information found through the literature review
- Follow-up discussions with stakeholders - to assess whether proposals were felt to be practical and beneficial for the biogas value chain in Västra Götaland

This chapter explores a case study of policies for biogas in Europe.

6.1 Current Biogas Policies in Sweden

At present, the biogas value chain in Västra Götaland is governed by centralised policies and there are no biogas policies that are specific to the region (Avfall Sverige (2017b)). This is in terms of the activities permitted and the financial incentives available. This section outlines the situation for biogas in Sweden from a policy perspective in order to ensure that any recommendations for policy change would be appropriate within the existing legislature. Familiarity with the current policy structure also eliminates the risk of making recommendations that are already in place. Policies which are already in place but not widely practiced could be also identified as unrealised opportunities.

The production and use of biogas in Sweden is affected by numerous policy instruments that address what feedstock is used in production, or how the biogas or other products are used. According to Lantz (2013), many other biogas producing countries in Europe use feed-in tariffs and Sweden is unusual in not offering this kind of support. Furthermore, Avfall Sverige (2017b) claims that Sweden is the only country in Europe where policies and support have been aimed at use of biogas; in other European countries support has instead been aimed at biogas production. The support in place in Sweden aims to increase the use of upgraded biogas as vehicle fuel, with the purpose of increasing the overall demand for biogas as a raw material (Avfall Sverige, 2017b). Table C.1 in Appendix C summarises the policy instruments currently implemented under the Swedish system, as identified through a literature review.

6.1.1 Support Aimed at Production

Most of the production support presented in Appendix C is provided through capital investment support from Klimatklivet. However, Klimatklivet does not specifically target production, and as such this support (i.e. all investment support in Table C.1) will be accounted for as part of the "Other" policies outlined in Section 6.1.4.

Although not strictly a policy, there is a national environmental target for a minimum of 50% of municipal waste to be treated biologically by 2018 (Lantz, 2013). Combined with the landfill bans outlined in Appendix C, this suggests a probable future increase in the availability of feedstock for biogas producers. However, there is currently no legislation enforcing treatment of agricultural residues such as manure, even though they are an ideal feedstock for biogas production and a significant contributor to GHG emissions if left untreated. As such, there is little incentive for agricultural production of biogas aside from the environmental benefits gained through anaerobic treatment of associated waste. Additionally, farm-scale biogas production from agricultural waste suffers from quite harsh economic conditions under the Swedish system due to poor profit margins, so further actions are needed to support agricultural biogas production. There have been some efforts to improve this situation, including the 2009

implementation of a subsidy for biogas production using manure as its major feedstock ("Gödselgasstödet"). This is still in place and the programme is planned to run through 2023 (Avfall Sverige, 2017b). Biogas produced from co-digestion of manure and sewage sludge is not eligible for financial support, and the amount granted is based on availability of allocated state budgets. Support is also not available for biogas production from any sources other than manure, and in order to be awarded any sort of support, facilities must be approved in line with regulations appropriate to the handling of animal by-products. Support can be given to cover a maximum of 40% of total project expenditures, and the highest support available is 40 million SEK, provided it is intended for capital investment. Expenditures must be at least 100 000 SEK in order to qualify for such support (Avfall Sverige, 2017b).

The remaining scheme covered under Production in Appendix C considers tax exemptions. Since biogas is considered a renewable technology/fuel/resource, both production and use are exempt from tax. Producers of liquid and gaseous biogas can benefit from tax exemption, as in the Swedish system, both are classified as energy products by the tax authorities. As such, both the fuel and the power used in producing the biogas are exempted CO_2 and energy taxes, as well as sulfur tax (where applicable). Consequently, the tax exemptions do not only apply to the digestion, but also any pre-treatment of the raw materials or purification/upgrading of the biogas, plus any changes to the state of the biogas. However, for this tax exemption to be valid, the biogas must be used either for heat/electricity generation or as a vehicle fuel. Again, it is worth noting that these tax exemptions are not unique to biogas and are applicable to all renewable technologies (Avfall Sverige, 2017b; Lantz, 2013).

6.1.2 Support Aimed at Distribution

As is evident from Appendix C, the only support given in terms of distribution is investment support for construction of either fuelling stations or the natural gas grid itself; there is no specific support available for providing the stations or grid with biogas. This could be seen as a gap, since injection of upgraded biogas to the natural gas grid is one way for local producers to reach a regional market, thus decreasing their dependence on the local market and strengthening competitiveness of their product. However, there are some associated technical issues, such as adjusting the heating value of the biogas to match that of natural gas. This means that biogas needs to be blended with LPG in order to meet the required standards, resulting in additional costs and environmental impact (Avfall Sverige, 2017b). A further complication for direct injection is that any activities related to the natural gas grid in Sweden are strictly regulated by Naturgaslagen (the Natural Gas Law; Naturgaslag 2005:403), which dictates both what can be approved for injection into the gas grid and also who is allowed to operate it (Regeringskansliet, 2017).

Approval for injection of biogas into the grid must be in line with Naturgaslagen

(Regeringskansliet, 2017), but this is restricted to "when it is technologically possible"; based on this on this ambiguous phrasing, the actual requirements for direct injection remain somewhat unclear. The decisions on what can be injected also have to be non-discriminatory, so there is no preferential treatment of biogas in comparison to natural gas. Naturgaslagen also states that the company owning the grid is not allowed to produce or buy/sell natural gas in order to maintain neutrality in the operation of the grid (biogas is included within the terminology "natural gas" under this law). However, the Swedish government has shown interest in changing this, proposing in June 2017 that the owner of the gas grid could be required by law to, without delay, provide terms and conditions of connection and injection to the grid in writing on demand (Regeringen, 2017). These terms and conditions would include requirements about the quality, odour and pressure of the gas, and it is also desirable that the owner makes these requirements transparent and open to the public. According to Regeringskansliet's record of adjustments of this law, the changes were approved by the Swedish Riksdag and set in motion in January 2018 (Regeringskansliet, 2018b).

6.1.3 Support Aimed at Use

There are no tax exemptions supporting biogas specifically, however, it is covered under general tax exemptions for renewable technologies. This is why tax exemptions occur in different Use and Production situations in Appendix C. The energy tax is targeted at consumers and was originally implemented with the intention of generating funding for the state. However, it has subsequently developed into a means for steering production and use of energy towards alignment with current targets by taxing different fuels at different rates, depending on the amount of emissions generated and the type of end-use (Naturvårdsverket, 2012).

Another policy that targets the consumer is the reduction in fringe-benefit tax available to those who drive a biogas-fuelled vehicle for work purposes (Avfall Sverige, 2017b; M. Larsson, Grönqvist, and Alvfors, 2016). A 40% subsidy to the cost of the vehicle is offered (although this is capped at 10 000 SEK and only applies to relatively expensive vehicles). The result is that the cost of the vehicle is brought into line with that of a comparable vehicle run on fossil fuels. This ultimately means that the consumer does not have to pay as much fringe-benefit tax as they would if they had an equivalent fossil-fuelled vehicle.

There are specific environmental targets focusing on the transport sector, with the Swedish government aiming to have a fossil-independent national vehicle fleet by 2030. In order to meet these targets, renewable vehicle fuels must fulfill certain sustainability criteria before they are able to receive the tax exemptions. These criteria relate to the location and characteristics of the feedstocks used to produce the fuel, as well as the reduction in GHG emissions achieved by substituting the fuel in place of a conventional fossil-fuel. The GHG emission reduction target was initially set at 35%, with an increase to 50% in 2017. As the GHG emission reduction factor

is about 71% on average for biogas, compared to 38% for biodiesel (Lantz, 2013); this suggests that biogas could become a preferred option in terms of renewable vehicle fuels, as it is more likely to be eligible for tax exemption once emission reduction criteria become more stringent.

6.1.4 Other Types of Support

Most of the capital investment support available in Sweden is granted through Klimatklivet, a programme led by Länsstyrelsen and Naturvårdsverket (the Swedish Environmental Protection Agency) which grants support to projects which they assess to have potential of achieving high environmental benefit per capital investment (Naturvårdsverket, 2018). Because Klimatklivet is run jointly by these two organisations, the funding is provided at a national level, but the sum allocated to Västra Götaland is distributed within the region. As Klimatklivet does not prioritise a specific technology, the support they offer can cover different aspects of production, distribution and use of biogas. However, they only offer financial support for capital investments, including upgrades and maintenance to existing facilities. Despite Klimatklivet accepting a wide range of projects, biogas projects are given the most support in the programme – over half of the budget 2016 was granted to biogas-related projects, with the majority of these projects linked to biogas fuelling stations. There were a relatively small number of applications related to production facilities, and there was a high rate of approval for funding among those (Avfall Sverige, 2017b).

6.2 Current Biogas Policies in Denmark

As it was identified that favourable tax conditions in Denmark compared to Sweden was a threat to biogas production in Västra Götaland, it was considered important to investigate current biogas policies in Denmark with the same level of attention as those in Sweden. This section outlines both Danish legislation for biogas and the import-export market for biogas between Sweden and Denmark, as it was found that differences in regulations between these two countries was directly impacting biogas producers in Västra Götaland. Table D.1 in Appendix D summarises the policies governing the biogas market in Denmark. In an article featured in NyTeknik in Autumn 2017, a representative from Avfall Sverige claims that the threat from imported biogas may potentially render futile existing investments from the state, municipalities and private actors into Swedish biogas and biofertiliser production (from wastes and residues). These investments aim to fulfill the environmental targets, but in reality end up supporting imported biogas whose producers have already benefited from subsidies in their country of origin, most notably with Danish biogas (Steinwig, 2017).

Under the current Swedish system, producers of imported biogas ultimately receive compound subsidies, firstly for production in their country of origin, and then additional subsidies through tax exemption when being sold on the Swedish market; Danish biogas producers benefit greatly from this (Avfall Sverige, 2017a).

In contrast, the biogas produced in Sweden gets the tax exemption for users, but not comparable production support, which results in locally produced biogas being more expensive than foreign (most notably Danish) biogas. Avfall Sverige (2017a) and Steinwig (2017) also claim that the trend preference towards electric vehicles for use in public transport poses a threat to biogas in Sweden, and that recommendations for public procurement must better reflect accumulated environmental benefits in order for biogas to be perceived as a favourable option. However, long-term decisions are needed urgently as current tax exemptions will expire after 2020; there needs to be consideration of policy instruments in other industries and countries in order to better inform decisions and prevent clashes caused by the impact of policy changes on the international biogas market (Avfall Sverige, 2017b; Steinwig, 2017; Avfall Sverige, 2017a).

6.2.1 Support Aimed at Production

Producers of biogas in Denmark are eligible for a subsidy if their gas is sold for use in the transport sector. There is also a feed-in premium for electricity produced from biogas. While there are no other policies directly affecting the producers of biogas, they indirectly benefit from the policies in place for distribution. This is because direct injection to the natural gas grid expands the market for the biogas (see Appendix D for more details).

6.2.2 Support Aimed at Distribution

As shown in Table D.1 in Appendix D, policies aimed at distribution in Denmark concern injection to either local grids for transport applications, or to the natural gas grid. These policies are aimed at upgrading and purification facilities with the criteria that the gas ultimately becomes sufficiently high quality to be injected. This widens the market for the gas, so much so that a large part of the Danish biogas production becomes available for export to Sweden. Biogas in Denmark has two main applications. 46% is used in "direct heat and power", with 54% going directly to "grid injection 'other'" and a negligible amount is injected into grids "for transport purposes" (Boesgaard, 2017). The 54% injected to grid for purposes other than transport is of interest when looking from a Swedish perspective, as this is assumed to account for biogas which is sold on to Sweden via the grid. Avfall Sverige (2017a) claims that the total import of Danish biogas to Sweden in 2016 was 0.155 TWh, whilst in just the first quarter of 2017 (January-March), the import was already 0.140 TWh. Extrapolating this suggests that the annual import of biogas during 2017 could have been around 0.560 TWh. Assuming that the Västra Götaland regional production did not alter significantly from the 2016 figures (about 0.380 TWh, see Section 4.1.1.2), this means that the import of biogas from Denmark would have been larger than the regional production. Although data on import is provided on a national basis, it can be assumed that a large part is imported to Västra Götaland as it is one of only two Swedish regions with access to the grid, thereby making imports from Denmark feasible in exclusively these areas of Sweden

(ENTSOG, 2018).

6.2.3 Support Aimed at Use

In Denmark, there are direct policies addressing the use of biogas, which include financial support to organisations using the biogas for processing or industrial purposes and/or for heat production. There is also an indirect policy aimed at use for heating as those users are eligible for tax exemption due to avoided fossil fuel use. Apart from this, Danish biogas producers and consumers are not exempted from the energy and CO_2 tax in the country (Boesgaard, 2017).

Considering the distribution of use of Danish biogas highlighted earlier, it could also be argued that the demand for biogas as a fuel is not as prominent in Denmark compared to Sweden. Biogas in Denmark is mostly used for heat and power, if the assumption that a large part of the biogas applied via "injection to grid other" is in fact exported to Sweden is correct (Boesgaard, 2017). Furthermore, there seems to be little demand for upgraded biogas in Denmark, but instead there are existing policies encouraging both biogas production and injection to grid, specifically the natural gas grid (see Appendix D),(Avfall Sverige, 2017b). It could be said that the policies in Denmark and Sweden are indeed unbalanced, with Danish policies indirectly encouraging export, and Swedish policies indirectly encouraging import.

6.2.4 Other Types of Support

No other kinds of support were identified within the Danish system, but some decisions have proven to be beneficial to the development of the biogas market.

- In 2013 and 2014, the economic support systems were improved for the biogas sector in Denmark. The improvement meant *removing the limitation that support could not be given for both investment and operation.* This lead to greater governmental financial support across different stages of the value chain, reducing risks to investors as this created a guarantee of compound funding.
- Subventions dependent on use are given either as a minimum price (guarantee) or an addition to the price for which the biogas is sold. This means that producer are guaranteed to make more than their production costs.

(Avfall Sverige, 2017b)

6.3 Appraisal of Current and Historic Biogas Policies Across Europe

Aside from trying to achieve better alignment between biogas policies in Sweden and Denmark, it is proposed that by identifying European policies that helped or hindered development of biogas in other countries, suggestions can be made for

policies that could potentially induce positive change in Västra Götaland. It could also serve as a warning by highlighting approaches which could negatively impact on biogas development, or cause other problems. This approach was adopted to further develop the Hungarian biogas sector; after developing a strategy based on examples from European frontrunners Germany, Austria and the Netherlands, Hungary's biogas sector experienced significant growth (Strauch, Krassowski, and Umsicht, 2012). As such, the approach of taking the best elements from policies in different countries can be seen as a way to inform good decision making with regard to policy reform, particularly as the shortcomings of the existing legislation have already been identified. It is acknowledged that differences in the socio-technical regimes between countries, including cultural and political differences, may affect the effectiveness of implementing the same policy in different countries. However, this will be taken into consideration when making suggestions. Issues related to this were also addressed during the follow-up interviews.

There are EU initiatives in place to promote and support biogas through Intelligent Energy Europe (IEE), such as FABbiogas and bioteam (Gabauer and Bochmann, 2018; Gaast, Russolillo, and Montalto, 2018). These schemes are helping knowledge sharing between EU countries in order to strengthen biogas as a technology in Europe by creating networks between different countries. A further project called "Green Gas Grids", also funded by IEE, has created a network of 13 European countries (including Sweden, which was considered to be a biogas frontrunner along with Austria, Germany, the Netherlands and Switzerland), aiming to nurture the European biogas market, as well as enhance knowledge sharing (Strauch, Krassowski, and Umsicht, 2012).

Through the Green Gas Grids project, it has been identified that there are difficulties in establishing a common European market due to differences in infrastructure, political situations and general attitudes to and dependencies on natural gas. However, the project (along with an assessment by the European Commission which presented "Optimal use of biogas from waste streams" (Kampman et al., 2017)) does provide good background information on the conditions in the different countries, as well as the policy approaches taken by different European governments and their resulting effects on the development of biogas in their respective countries (Strauch, Krassowski, and Umsicht, 2012). The findings from these documents were supplemented by a review of other sources in order to ensure that the information reviewed was up to date. The tables presented in Appendix E collates a review of whether these policies were felt to have helped or hindered the development of biogas in the countries in which they were implemented. As some of the sources reviewed were very recent and others were more historic, it was possible to observe the effectiveness of these policies over time, including the consequences if a policy was withdrawn during the period studied.

Considering the helping and hindering aspects outlined in Appendix E, a number

of trends have been identified. Notably, uptake of biogas production has typically been highest in countries where there is high dependency on natural gas, particularly if it is imported (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017). This is most often the case if there is widespread existing infrastructure for natural gas distribution (Strauch, Krassowski, and Umsicht, 2012). Furthermore, it is evident that most countries have put financial support in place aimed at production, upgrading and distribution of biogas (Kampman et al., 2017). Conversely, current Swedish economic incentives are by and large aimed at biogas users. Compared with the 13 countries considered in Appendix E, plus Denmark (Appendix D, Sweden is one of the only countries that does not offer any form of feed-in tariff for either direct injection of upgraded biogas to the grid or of electricity produced from biogas (the same is true in Norway and Switzerland) (Strauch, Krassowski, and Umsicht, 2012). This echoes what was found during research into Swedish biogas policies. Furthermore, in terms of comparison between what stakeholders said during interviews and the information summarised in Appendix E, it would appear that having longer guarantee periods for support schemes does increase the growth of biogas production, and that fossil fuel prices impact the value of biogas (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017). It also seems that difficulties for smaller producers are fairly widely acknowledged across most countries, as additional financial support for smaller producers is frequently available. As a whole, it was found that the issues and opportunities raised by stakeholders during interviews aligned quite closely with the observed effects of policies in other countries. Furthermore, Sweden is arguably better off in a socio-technical sense with regard to biogas than countries with limited waste collection/treatment infrastructure, and Västra Götaland also could benefit from access to the gas grid (ENTSOG, 2018).

6.3.1 Support Aimed at Production

Feed-in tariff schemes aimed at supporting producers were quite common across most of the countries considered, with some countries granting support according to specified criteria regarding the conditions for biogas production. In several countries (Austria, France, Hungary, Italy and the UK), different rates are offered depending on the scale of production, with smaller producers being offered more generous tariffs. Although in most countries the additional support for smaller producers was found to be beneficial for development, in Poland such schemes were unsuccessful. This was primarily due to micro-scale plants being targeted with the offers of low interest loans for producers providing biogas energy for single or multi-family households (Kampman et al., 2017).

In Croatia, France and Hungary, higher or premium tariffs are awarded to producers using specific types of waste as a feedstock (typically agricultural residues or manure). France also offers their premium tariffs to urban production facilities (Kampman et al., 2017), and in Germany and Finland additional incentives are given for plants with high efficiency. However, Finland does not

provide tariffs for plants which receive another form of governmental grant (or in some cases only receiving the tariff at a reduced rate). Hungary and Slovakia also have this practice, and along with Austria and Croatia use an element of decision-making on a case-by-case basis for grant/tariff eligibility (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017; Biogas Action, 2017). This has been noted to act as a deterrent to development of new plants, as prospective producers are unsure as to whether they will be able to benefit from governmental financial support (Strauch, Krassowski, and Umsicht, 2012).

Guaranteed tariffs over longer periods (15-20 years) have resulted in rapid increase of the expansion of biogas in the countries where this has been implemented (Strauch, Krassowski, and Umsicht, 2012). Conversely, if feed-in tariffs or other continuous financial support schemes are made less favourable then this has lead to an immediate decrease in the number of plants being constructed (this was the case in Austria, Italy and Germany) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017).

Furthermore, it was identified that many biogas successes were linked to production from energy crops in these countries (Strauch, Krassowski, and Umsicht, 2012). Considering the interviews held with stakeholders in Västra Götaland, and the pillars of sustainability (Circular Ecology, 2018), as well as the potential for using waste streams in the region that was frequently reported during stakeholder interviews, this is not proposed as an approach to be taken here, as production of biogas from existing organic waste streams has greater potential for GHG emission reduction and improved nutrient cycling. In order to promote this, certification for biogas may be considered, as use of origin certification and biogas registers has helped boost consumer confidence in many countries, particularly when highlighting that biogas has been produced from organic waste (Strauch, Krassowski, and Umsicht, 2012). These kinds of schemes would work in heightening confidence in producers as well.

6.3.2 Support Aimed at Distribution

In all countries where direct injection to the grid was an option, this was subject to meeting safety and quality requirements. In some cases, biogas produced from certain feedstocks (generally wastewater and landfill gas) was not permitted for direct injection, however, it appeared that some countries had later relaxed this prohibition with no negative consequences. It is sometimes a requirement for the producer to odourise the gas prior to injection. In most countries, the producer has to pay for connection, but in other cases funding is available for this (Italy, Slovakia and Germany). There is also discrepancy over who maintains and operates the injection points; sometimes it is the biogas producer, other times it is the grid operator. Germany, Italy and Slovakia have the most favourable conditions for biogas producers wishing to feed directly into the grid (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017). For connections to the gas grid, biogas producers in Germany pay 25% of the connection cost and the grid

provider contributes the remaining 75%, provided that it is less than 10km from the plant to the connection point. There is also a 250,000 euro cap for the costs that the producer must cover; beyond this the grid provider must cover the costs. However, if the connection is greater than 10km then the producer must pay in full. The grid operator then owns the connection point and takes on all associated costs. The quality requirements for biogas as a natural gas substitute for injection are slightly lower in Germany in terms of calorific value than for other types of gas. Slovakia has also adopted the German 25% : 75% grid connection cost-split approach (Strauch, Krassowski, and Umsicht, 2012; Stephanblome, 2011).

6.3.3 Support Aimed at Use

In Austria, a 5 point action plan to encourage and expand the use of natural gas (including biogas) as a transport fuel was launched in 2006. The branding "Bio-CNG" has been used on a fuel which is composed of 20% biomethane leading to growth in the gas-fuelled vehicle sector. This fuel is also exempt from mineral oil tax. There are also grants available for use of renewable transport fuels that reduce GHG emissions by at least 45%. Switzerland boasts a tax policy which is favourable for gas-fuelled vehicles. In Germany, the UK and the Netherlands there is a quota that means all petrol/diesel sold must contain a specified percentage of biofuel, with fines for fuelling station operators who fail to fulfill this criteria. There are also subsidies for use of biogas in CHP and electricity production in these countries (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017).

In Germany, a building regulation introduced at the start of 2009 meant that all newly constructed buildings must be heated by renewable energy. If 30% of this heat demand is met by biogas used in CHP then the requirement is considered to be fulfilled, creating a good incentives for construction firms to design biogas-fuelled heating systems. Under Slovakian regulations, replacement of inefficient solid-fuel boilers with biogas-based CHP can make projects eligible for investment grants (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017).

Some countries (Croatia and France) do not grant specific benefits to use of biogas as a transport fuel or in heating/electricity production, although do exempt consumers of biofuels (including biogas) from having to pay excise tax (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017).

6.3.4 Other Types of Support

In Germany, the combination of targets to reduce CO_2 emissions by 40% by 2020 and plans for rapid decommissioning of nuclear power plants resulted in ambitious strategic plans for expansion of biomethane production to feed into natural gas grids. Switzerland also experienced a surge in biogas production following plans to

decommission nuclear power plants (Strauch, Krassowski, and Umsicht, 2012; Stephanblome, 2011). This arguably shows how political will regarding environmental challenges can impact the development of alternative technologies, even if policy is not directly aimed at benefitting particular technology. In this case, it would seem that plans to decommission nuclear power plants in a country could benefit biogas (and other renewable technologies) by extension. There has previously been a referendum on nuclear decommissioning in Sweden (Bergenäs, 2009). Although this did not result in the closure of nuclear power plants, it does indicate that there could potentially be appetite for such actions in future. There are discriminatory laws in place, designed to discourage use of nuclear power, which combined with policies supporting renewable technologies indicates a potentially promising future for biogas in Sweden (World Nuclear Association, 2018). This will not be discussed further due to the scope of this study.

6.4 Appraisal of Swedish and other European biogas policies

The comparison between Swedish biogas policies affecting Västra Götaland and the policies in place elsewhere in Europe revealed differences that could be helpful in addressing the barriers and enablers identified in the region. In collating information on current policies in Sweden and Denmark, it was clear that there were significant financial incentives for Danish biogas producers to export to Sweden, thereby meaning that it is effectively possible to receive 2 different production subsidies in Denmark and also benefit from increased profit margins from sales through a third subsidy which is granted to Swedish biogas consumers. Meanwhile, Swedish biogas producers do not benefit from any production subsidies, leaving them unable to compete on price with Danish imports (Avfall Sverige, 2017a). This supports one of the main issues raised by stakeholders during interviews ("Lower cost of biogas imported from Denmark [...]"), and was also reinforced as being a barrier during the follow-up discussions with stakeholders.

Based on the 15 countries for which biogas policy was reviewed as part of this study, it was found that Sweden was in a minority (along with Switzerland and Norway) by not offering any form of feed-in tariff for biogas (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017; Lantz, 2013). Likewise, it was found that although it is currently possible to inject biogas directly into the Swedish gas grid, poor transparency means that it is generally not known that this can be done (Regeringskansliet, 2017). Conversely, in countries such as Germany, Italy and Slovakia, there are generous subsidy schemes where the grid operator takes on part of the costs of connection to the grid (provided the distance from the producer to the grid is below a certain threshold). In some cases, the gas grid operator then has full financial and practical responsibility for the grid connection (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017); this is not the case in Sweden. Since injection of upgraded biogas to the natural gas grid is one way for producers to reach a regional market, and strengthen the competitiveness of their

product, the lack of support for grid connections in Sweden could be seen as a gap. However, there are some associated technical issues, such as adjusting the heating value of the biogas to match that of natural gas (Avfall Sverige, 2017b).

Experiences from other European countries support the benefits of economic incentives for use of biogas-fuelled vehicles. Countries including Austria, France, Italy and Switzerland have experienced development in their biogas-fuelled vehicle markets since introducing financial incentives; similar trends have been observed in Sweden (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017). Therefore there should be continued support for biogas as a vehicle fuel in Sweden, as this has been proven to be an effective way of creating consumer demand for biogas.

6.5 Development of Suggested Changes to Biogas Policy in Västra Götaland

This section proposes suggested changes that could be beneficial to the development of biogas in Västra Götaland, based on comparison and appraisal of the biogas policy information.

6.5.1 Proposed Support Aimed at Production

At present, there are no biogas feed-in tariffs available in Sweden, despite availability of grants for gas grid construction. Introduction of long-term feed-in tariffs (minimum 10 years, as suggested by stakeholders in interviews) is proposed as a way which could lead to regional biogas development, based on the success of schemes elsewhere in Europe (Kampman et al., 2017). To reduce the risk of failure (as in the case of Poland, where the policy favoured micro-scale production (Strauch, Krassowski, and Umsicht, 2012)), it is suggested that a plant minimum size threshold is set, possibly based on what has previously been successful in the region.

Based on observing discussions between regional biogas actors at a seminar, it was felt that there were misconceptions about what grants were available for (Västra Götalandsregionen and Biogas Väst, 2018). This could potentially have direct implications on the development of new biogas plants, as relevant actors are not aware of the financial support available to them. Consequently, if a feed-in tariff scheme were to be launched, existing capital support schemes could be advertised in parallel, as this may encourage more actors in the value chain to consider their potential to develop biogas plants or upgrading facilities. As mentioned, in Germany and Finland additional incentives are given for plants with high efficiency (Kampman et al., 2017; Nordic Energy Research, 2010). This approach could be adopted in order to nurture the development of more modern, reliable biogas plants.

In Croatia, Austria, Slovakia and Hungary, there is an element of decision-making on a case-by-case basis for grant/tariff eligibility (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017). This has been noted to act as a deterrent to development of new plants, as prospective producers are unsure as to whether they will be able to benefit from governmental financial support. Therefore it is proposed that clear criteria should be outlined in order to boost the confidence of potential new producers by ensuring that they are aware of whether or not they would be eligible for support, even in the early stages of planning a new plant.

Interestingly, in Switzerland, many upgrading plants for direct injection of biogas into the grid were developed in spite of there not being financial support available for such schemes (Strauch, Krassowski, and Umsicht, 2012). Furthermore, a certification scheme could be used to raise the profile of biogas and help clarify the criteria that should be met in order for biogas to be considered of an acceptable standard. This reflects statements given by stakeholders about the value which consumers place on buying sustainably produced biogas; this could also help to fundamentally support the regional biogas value chain by fulfilling consumer demands for sustainable products.

6.5.2 Proposed Support Aimed at Distribution

It is proposed that policies targeting direct injection of upgraded biogas could be beneficial for Västra Götaland due to the focus on use of biogas as a vehicle fuel. This approach also enables larger users, such as the chemicals industry, to increase their biogas consumption. Furthermore, this reflects the value placed on biogas-fuelled vehicles and larger consumers (shipping, chemicals) during the stakeholder interviews. It was found that countries which have strong gas distribution infrastructure and a high dependency on natural gas (particularly if this is imported) have tended to experience stronger development of the biogas sector (Strauch, Krassowski, and Umsicht, 2012). Although Sweden as a whole does not have much reliance on natural gas as a fuel, the existing gas grid which covers the West Coast of Sweden from Stenungsund down to Trelleborg means that Västra Götaland has relatively good accessibility to the grid and therefore good potential for direct injection (ENTSOG, 2018). Use of origin certification and biogas registers has helped boost consumer confidence in many countries (Strauch, Krassowski, and Umsicht, 2012). In addition to supporting the value chain by meeting with consumer demands as previously mentioned, if the Swedish gas grid provider were to set the criteria for certification, and a biogas register was set up for Västra Götaland, this could help with regulating direct grid injections in a way which the gas grid operator was willing to accept.

6.5.3 Proposed Support Aimed at Use

As the current regulations regarding use of biogas in Västra Götaland are very favourable, it is proposed that these should be kept in place, in order to support the consumer demand creation aspect of the biogas value chain in the region.

6.5.4 Proposed Other Types of Support

Environmental targets for both Sweden and Västra Götaland indicate strong desire to support further development of use of renewable technologies (Regionen, n.d.). This was frequently echoed during stakeholder interviews. When considering the likelihood of biogas policy changes being put into place, the environmental credentials of biogas could be used to add weight to lobbying. This echoed a statement given by 3 public stakeholders during the initial interviews that "Circularity aspects make biogas a regional priority".

6.5.5 Overall Proposal for Reformed Biogas Policies in Västra Götaland

Based on the comparison of Swedish biogas policies with those in 14 other European countries, as outlined in Sections 6.1 to 6.3, the following suggestions are proposed:

- There should be a feed-in tariff for direct injection of biogas to the grid. This should be guaranteed for a minimum of 10 years and kept consistent.
  - Tariffs should be scaled so that smaller producers have greater incentives than larger ones
  - Tariffs should be preferential towards biogas production which leads to the greatest reduction in GHG emissions
  - Premium tariffs should be offered to producers who operate at high efficiency (at least 60%)

- It should be possible for biogas producers (including upgrading facilities) to have access to the grid for connection. Use of a certification system would allow grid operators to ensure that quality and safety standards are met.
  - The cost of connection to the grid should be partially covered by the grid operator, with a cap for the maximum amount that the biogas producer must pay
  - The grid provider should be responsible for constructing, operating and maintaining the connection. This ensures that their quality and safety standards are met, and enables specialist work to be carried out by people who already have the necessary skills

- The financial support available for investment in and use of biogas-fuelled vehicles should continue
- Better promotion of all types of financial support available to those producing and upgrading biogas

One of the weaknesses in taking a policy-based approach to further the development of biogas is that it is an issue which lacks clear leadership at a political level. This was mentioned as a statement in the stakeholder interviews ("Fits into multiple government departments with no obvious owner"), and was

also identified by the Green Gas Grids project as a hindrance to the development of biogas in Croatia. Although there are socio-technical differences between Sweden and Croatia (principally that Croatian infrastructure for waste collection and treatment is relatively underdeveloped, which is not the case in Sweden (Strauch, Krassowski, and Umsicht, 2012)), this highlights that the acknowledgement of issues surrounding political ownership.

Current Swedish policies appear to be effective in some parts of Sweden, as growth has been identified in Stockholm and the Skåne (Eriksson and Harrysson, 2017). Reflecting on both this and the consistent reports from stakeholders that competition from cheaper biogas imports from Denmark suggests that legislations at present are not suited to Västra Götaland. The comparison between the policies in place in Sweden and Denmark showed a stark contrast in conditions which was clearly much more favourable towards the Danish biogas producers. As Västra Götaland is unique to Sweden in having direct gas grid connections to Denmark, this could explain why the policies which are resulting in biogas growth elsewhere in the country are not effective in the region. It therefore seems that the current Swedish biogas policies are generally appropriate for most of the country, but that Västra Götaland is a special case where a different approach is needed if the ambitious targets to fulfill the potential of the region are to be reached. As such, it may only be necessary to implement the proposed policies in Västra Götaland. This would enable the regional potential to be fulfilled in a manner which would be able to compete with the Danish import market. The strong regional interest indicated through current schemes and policies, along with the passion expressed by stakeholders, many of whom participate in the regional biogas network, suggest that given more favourable conditions for producers, there is real potential for growth of the regional biogas sector. However, it is probable that adopting this approach would be controversial, as it would make conditions for biogas producers in Västra Götaland disproportionately favourable in comparison to the rest of the country. Additionally, no economic analysis was carried out to support these suggestions. It is anticipated that comprehensive cost-benefit analysis would need to be carried out, particularly with regard to policy aspects which place financial onus on gas grid operators.

6.6 Follow-up Discussions with Stakeholders to Appraise Proposal

In order to gauge whether there was potential for the suggested changes to be implemented, and if this could be beneficial, follow-up interviews were held with 4 stakeholders that had been included in the initial interviews for this project, plus one additional stakeholder intended to give an external expert perspective. Sections 6.6.1 - 6.6.3 describe the perspectives expressed by each of the stakeholders involved in follow-up discussions. References to the three focus statements in Sections 6.6.1 - 6.6.3 relate to the identified priority statements from the first set of stakeholder interviews (“Inconsistency in supply and demand”, “Lack of long-term agreements and planning” and “Lower cost of biogas imported

from Denmark [...]"). Section 6.6.4 gives a summary of more general aspects which were common to these follow-up discussions. As previously explained, all stakeholders (with the exception of the technical expert) were kept anonymous.

To provide an external perspective to the appraisal of the suggested changes to biogas policy in Västra Götaland, follow-up discussions were conducted with a smaller sample of stakeholders which were felt to be representative of the biogas value chain. This also enabled the unique insights from stakeholders with very good knowledge of the specific conditions for biogas in the region to be further utilised. The stakeholders selected in follow-up discussions were:

- Public - Process Leader, Biogas Väst (part of VGR)
- Public - Process Leader, Hållbar Utveckling Väst
- Primary (producer) - Sustainability Director, Göteborg Energi
- Primary (consumer) - Environmental Director for large truck manufacturer
- Secondary - Mikael Lantz, Academic expert on biogas and biofuels (broad research with strong socio-technical perspectives)

Prior to the follow-up discussions, stakeholders were provided with a very brief summary of the results from the original interviews, an explanation of the further research and suggestions for policy changes. This summary is presented in Appendix F. This was intended to allow stakeholders time to reflect on the suggestions before giving feedback. The summary was used as a guide during the discussions, with each point in the summary considered systematically with each stakeholder. In this section of the report, use of "proposal" (or similar) relates to the policy proposal formulated during this study; use of "suggestion" (or similar) is indicative of stakeholder input in response to the proposal from the study.

Two public stakeholders were included as it was felt that range roles falling under the public category was broader than for the primary and secondary stakeholder groups. The Process Leader for Biogas Väst was considered to have important insights due to their active involvement with the network of actors working in the biogas value chain in Västra Götaland. The Process Leader for Hållbar Utveckling Väst works within an organisation looking at sustainable energy rather than biogas specifically, thereby giving them insight into how different technologies are perceived within the region. Furthermore, their previous role had been in biogas upgrading, meaning that they could also offer perspectives from the distribution and market parts of the value chain. Additionally, this meant that they had experience of working with biogas in both the public and private sector, giving them quite a unique overview in terms of biogas in Västra Götaland.

Two primary stakeholders were included, in order to give representation for both producers and consumers in the region. It was hoped that a primary stakeholder involved in biogas production at farm-scale could also have been included, but it was not possible to engage with such a stakeholder as part of this study.

The secondary stakeholder (Mikael Lantz) interviewed during the follow-up discussions had not participated during the first set of interviews. However, he was the author of several of the sources used during literature studies. Lantz was the only stakeholder who was not anonymised as it was felt that this would be difficult considering the number of references to his work through the study. Because Lantz was not located in Västra Götaland and had conducted studies that looked at biogas in Sweden as a whole, it did not seem relevant to include this stakeholder during the initial interviews. However, in terms of appraising the suggestions compiled at the end of this study, it was felt to be beneficial to gain insights from an academic expert with good knowledge of biogas within the Swedish socio-technical regime. Lantz would arguably have the most valid contributions in terms of appraisal of the proposals presented by this study, due to his experience of research within the field, which includes technical aspects of biogas production and upgrading, interaction with agricultural producers and relevant policies and socio-technical implications (Lantz et al., 2007; Lantz, 2013).

6.6.1 Public Stakeholder Perspectives

Process Leader, Hållbar Utveckling Väst
The stakeholder recognised the three selected focus statements as barriers, and in particular described that when imports of Danish biogas first started arriving in Sweden, the biogas industry in Västra Götaland felt the effects of this very keenly. It was as if the rules of the game had suddenly changed and this had a large and immediate impact on Swedish producers (even the largest Swedish producers were affected). Not only were the abrupt changes in the Swedish biogas market challenging for local producers, but also the legal implications of reaching agreements between big companies are slow and expensive. As a result, Swedish biogas producers who are struggling due to competition with cheaper imports from Denmark will have to suffer for a long time through the ongoing negotiations before any sort of agreement is reached.

Considering the proposal for a feed-in tariff, the stakeholder felt that this could could be controversial due to the main gas grid pipeline in Sweden only being accessible from Västra Götaland and Skåne. As such, this type of incentive would only benefit biogas producers in this part of the country, which would be unfair. For this reason, there is currently lobbying for liquid biogas (LBG) as this offers better opportunities for all producers to distribute their biogas, regardless of their proximity to the grid, thereby promoting development of a national biogas market. Additionally, LBG has favourable properties as a vehicle fuel, and can also be used in shipping and freight transport. These are areas that are forecast to become major future consumers of biogas. However, at the current production capacity, the potential need in these sectors could not be met; the stakeholder suggested that encouraging LBG production could help create balance between potential demand and future supply capacity. A further benefit of LBG is that the cost of producing and transporting it is comparable to the cost of injecting biogas directly

into the grid (within the current socio-technical regime).

That said, the stakeholder believed that increasing grid accessibility is nonetheless a very important and good suggestion. At present, it is difficult to gain grid connection, and the costs associated with doing so are very high due to a monopoly on grid ownership by Swedegas. This has resulted in both high connection costs and high transmission fees, which have increased significantly during recent years. Consequently, despite the grid having a relatively large capacity for gas distribution, only around 50% of this capacity is currently in use. Furthermore, attempts to negotiate expansion of the grid have been rejected; applications for new natural gas grids are frequently rejected, however the pipeline still goes up to Stenungsund. The pipeline to Gothenburg was closed down around 1988. In a similar vein, in terms of the incentives that are needed to overcome the barriers faced by biogas producers, the stakeholder suggested that investment support should be focused on addressing the lack of infrastructure (largely relating to logistical aspects of the biogas value chain) and the development of LBG.

In order to promote biogas to businesses, the stakeholder suggested that the wide range of benefits that come from biogas should be promoted. This study was identified by the stakeholder as having results which could potentially be helpful both for political lobbying for biogas and when targeting businesses. Furthermore, the stakeholder expressed that allocation of funds for government financial support for biogas should not be a problem in light of the benefits offered. Biogas is quite unique in offering so many benefits simultaneously, particularly as multiple actors often experience these benefits. Subsequently, it was felt by this stakeholder that there were sufficient inherent benefits to be able to justify the need for biogas investment to the government. Following the Paris Agreement, there are drivers to invest in technologies which can help reduce climate effects as governments are aware that they are subject to financial implications in order to fulfill their pledges to the agreement. As such, the stakeholder identified that there is an economic driver for biogas investment, as it could potentially lead to savings elsewhere as a result of reduced costs associated with GHG emission taxes (or similar). They also felt that the interest in biogas applications in transport should be high due to the relatively high proportion of Swedish fossil fuel consumption in this sector; overall, fossil fuels account for around 31% of fuel usage in Sweden, but in the transport sector the figure stands at around 85%. The split between use of fossil fuel consumption in passenger cars and heavy duty vehicles is fairly equal, but at present there is a trend for increasing freight transport. The stakeholder believes that LBG is an ideal fuel for heavier vehicles, and trials are also be carried out for using these fuels in the ferries between the mainland and archipelagos in Västra Götaland. However, the present supplies of LBG available are significantly less than the amount which would be needed for this type of venture; a regular car ferry service in the region requires around 350 GWh liquid biogas annually, and the current production at Lidköping stands at approximately 50 GWh/year.

There was discussion with this stakeholder about the potential effects of a

hypothetical introduction of a biogas quota in natural gas supplies. It was agreed that if in the future some sort of taxation on transmission of fossil fuels were to be introduced (this is not currently planned, but would not come as a surprise considering the increasingly stringent environmental policies that have come into into force in recent years), direct injection of biogas into the natural gas grid could become more favourable, as this could be comparable to the quota amount of biofuels which must be blended with petrol/diesel vehicle fuels in many countries (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017).

Process Leader, Biogas Väst (part of VGR)
This stakeholder felt that the three focus statements did not reflect their personal views. However, they commented that it was interesting to see how their perspectives fitted with those of others. There was agreement with the statement "Inconsistency in supply and demand" and added that it is especially difficult when variations in demand can occur so rapidly whilst increases in production can have a very long response time (i.e. it takes a long time to both construct new plants and adjust the volumes of biogas being produced in existing facilities).

It was raised by the stakeholder that grid issues were not considered by VGR as an organisation because this is not a regional responsibility. Instead, gas grid infrastructure is the responsibility of the government at a national level. Again, it was highlighted that Swedegas has the monopoly on the Swedish gas grid, but in this case it was also acknowledged that Biogas Väst does not work with Swedegas (in spite of involvement with many other regional biogas actors). Similarly, it was identified that the "Lack of long-term agreements and planning" needed to be addressed at a national level. Considerable efforts have already been made at a regional level, but it is apparent that support from higher up is necessary in order to instigate change. For biogas actors in Västra Götaland, it is important to have the guarantee of support for a longer period. Therefore the suggestion to ensure feed-in tariffs for 10 years was felt to be particularly critical. The stakeholder specifically asked if policies for Denmark had been investigated as part of the study, and was pleased that a comparison between Sweden and Denmark specifically had been conducted.

6.6.2 Primary Stakeholders Perspectives

Sustainability Director, Göteborg Energi
(Primary - Producer)

This stakeholder agreed with the main three statements selected as a focus for this study. They also said that it was evident that the study had taken into account many actors across the value chain as both the prioritised statements and the proposals were very reflective of the current situation for biogas in Västra Götaland.

Again, the stakeholder described the difficulties in the relationship between biogas

producers and the natural gas grid. They mentioned that Swedegas (who owns and operates the grid) was previously owned by the state but is now owned by a risk-equity company (EQT), meaning that there there is a monopoly. This has reduced the attractiveness of natural gas, partly due to annual increases in costs that were completely legal under the monopoly. Issues related to the high transmission costs associated with the grid are generally not discussed enough, particularly with a wider audience (this could explain why the Public stakeholders were less aware of these aspects). The stakeholder suggested that it could be beneficial to highlight this problem, potentially by benchmarking costs against comparable charges in other countries. They also felt that a possible mitigation would be to offer a discounted transmission fee for biogas in the natural gas grid.

In the proposal discussed with stakeholders, a 10 year tariff period was proposed because stakeholders had suggested that 5-10 years during the initial set of interviews. This stakeholder felt that this was a conservative suggestion, simply because stakeholders saw it as an improvement on what they have now. However, they pointed out that a longer period would be better; this is reflected by the policies in place elsewhere in Europe (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017). The stakeholder stated that the longer the agreement, the lower the risks, therefore creating better incentives for businesses to invest, which may lead to larger-scale production. It also means that long-term implications are considered, which is more sustainable than short-term solutions.

With regard to the proposal that premium tariffs could be awarded to producers who achieved high process efficiency, this stakeholder identified that it would be difficult to work on an efficiency basis, especially when producing biogas from waste and selling on. The proposal had been inspired by an efficiency scheme in place in Germany, which was probably easier to implement because most of the German biogas was being used directly for either electricity, heating or CHP (Strauch, Krassowski, and Umsicht, 2012). The stakeholder suggested that instead of this, methane slip certification might be a more appropriate measure of efficiency as this corresponds more directly to the climate impact of biogas. However, they also acknowledged that this is quite difficult to calculate and may be too resource-intensive for smaller producers. Whilst exempting smaller producers from this measure could be seen as a supportive mitigation, this does bring about potential debate surrounding where the threshold is set for minimum plant size and the possibility that this clause be abused by actors purposefully constructing plants which are below the threshold. It is harder to control methane slip from smaller plants, and although the climate impact from a single plant is relatively small, the cumulative effect from many small plants could be significant. As highlighted in Section 6.3.1, the favourable conditions for very small biogas plants in Poland lead to complications (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017); this supports the stakeholder statement.

When considering the proposal for universal access to the grid, the stakeholder identified that this is already possible, but needs to be made more transparent

(this echoes with the information found in current Swedish policy see Section 6.1). They also added that injection to grid should be simple and transparent and reduce the hurdle for the producers. The stakeholder felt that the need for a certification scheme could be eliminated by having good transparency in place, however, third party verification would still be needed in order to confirm the claims of the producer that their product fulfills the necessary requirements. However, in lieu of a new certification scheme, producers wishing to be certified for branding purposes could make the most of the schemes already available (for example Svanen (Svanen, 2018)).

In terms of funding for grid connections, the stakeholder felt that the suggestion to have the grid operator paying for connection costs should only be offered to smaller plants; there should be variable caps in place for the maximum price that the producer can pay and this should be based on plant size (as larger plants should be able to fund the connection themselves). They added that placing the onus on the grid operator to take responsibility for the connection would result in financial implications and lack of clarity over responsibilities (both practical and economic). There would be no real incentive for biogas producers to accept this offer as they would still need to pay the grid operator even when they are not producing (or if they have to flare substandard biogas). The stakeholder added that upgrading facilities are much more complex and it is unclear who would cover the costs when the plant is not working, or how joint incentives would work. Furthermore, it is desirable to not have staff onsite at biogas plants, but an upgrading facility with a connection would need constant staffing. The stakeholder felt that a denser network of upgrading facilities would be needed in order to make this viable or even justify the connection investment (especially at smaller scales).

When it came to proposals to retain the current financial incentives for the transport sector and generally promote the available support more widely, the stakeholder felt that it was good to maintain current incentives for users in transport, but that stronger incentives for heavy vehicles should be introduced. Furthermore, this stakeholder suggested that better transparency on how to apply for grants what kinds of projects are eligible for funding is arguably as important as promoting the grant schemes better (they described the current application process as lengthy and complex, and explained that applicants do not know whether they will be granted funded as the conditions for receiving funding lack clarity).

Environmental Director for large truck manufacturer
Primary - Consumer

This stakeholder broadly agreed with the main problems identified in this study, but expressed that biogas imported from Denmark has only become an issue in the last couple of years, and that supply and demand is not a big problem for the vehicle fuel industry; they assume that this is more of a production issue. Additionally, the stakeholder identified that there is a desire for a good market in

the EU, but this is not aided by individual setting national policies in their own favour. They suggested that there is a need to harmonise the markets (in terms of subsidies) at both a national and EU level.

When this stakeholder considered the proposal for a 10 year feed-in tariff guarantee, they felt that it was a good idea to have this long-term perspective to allow the plant investment costs to be paid off, but they felt that this period should not be too long as tax resources need to be allocated in a way which reflects the needs at the time. However, they believed that 10 years seemed like a reasonable compromise between these factors. Interestingly, the stakeholder also felt that the financial support for vehicles should not continue forever, again, because resources need to be allocated effectively. They said that on one hand, the incentives for heavy vehicles would not be needed if the cost of gas was low enough. Similarly, as the interest from the vehicle sector is there it should theoretically be self-supporting. The focus should be on moving away from fossil fuels, so whilst it is good to relate the cost of biogas-based vehicle fuels to fossil fuel pricing/taxes, this creates risk as the future consumption of fossil fuels should decrease. However, if the biogas prices matched diesel prices this could eliminate the need for financial support as it would justify the additional investment costs. Threats from ongoing changes (e.g. electrification and falling demand for fossil-based vehicle fuels). This will ultimately impact biogas production and usage. They felt that it is important to highlight that these changes are happening and then support how this can be integrated with the proposals for biogas. There are uncertainties, although it looks like there will be investment in electrification in cities, but there is identified potential use of biogas for transport outside of cities. However, not many people are thinking this way at present, so this needs to be highlighted. This may result in changes in use of biogas over time.

This stakeholder expressed concerns about potential encouragement of small-scale producers resulting from the policies proposed. In this case, they suggested that whilst there is a lot of interest from farmers due to potential benefits, most notably GHG emission reductions from better management of manure, complications with infrastructure and quality of gas from smaller producers can be an issue. However, the stakeholder felt that as GHG emission reduction is the most important aspect, it is still good to have feed-in tariffs that support this. Another concern that this stakeholder raised was that you need to be able to track the source of energy; biogas has relatively poor traceability compared to other biofuels, and it could be complex to put appropriate monitoring in place. However, this is necessary for environmental protection reasons. A certification system could be helpful, but ultimately better transparency would be needed.

In terms of the main reason to push for improvements in biogas policy, the stakeholder felt that change could be justified because biogas is part of a circular economy. The need for biogas to support circular economy will exist for years to come and this could be used as an argument which helps people to understand the bigger picture, as circularity thinking is very important. However, they

acknowledged that this is a complex issue with many different actors, and therefore different dimensions to consider. In this sense, they noted that it was interesting to see perspectives other than their own through the study. However, they emphasised the difficulties in needing to consider small versus large scale production, use of biogas, efficiency of production and transportation, climate impacts and changes in availability of resources over time as aspects in realising opportunities.

6.6.3 Secondary Stakeholders Perspectives

Mikael Lantz - Academic expert on biogas and biofuels
Mikael Lantz recognised a lot of aspects presented in the proposal from this study from his own work in his group in the division of Environmental and Energy Systems Studies at Lund University. He agreed with the main problems identified, especially with the need for long-term agreements. He feels that the lack of longer-term policy instruments is a major threat to the development of biogas in Sweden. Furthermore, he reported that the inconsistency in supply and demand is mostly a problem due to there being high levels of demand, but potential consumers are not prepared to pay the price of Swedish biogas. He believes that if it was priced in line with the cost of natural gas then Swedish biogas producers might then be able to compete with cheaper Danish imports for supplying industrial consumers.

Lantz' group is currently researching feed-in tariff options. He feels that introducing tariffs to Sweden is a good idea, but is not fully convinced that there should be higher tariffs for smaller producers (as smaller plants tend to experience greater methane slip), acknowledging that this depends on how you define the sizing (Lantz et al., 2007). This is because the current Swedish policy on digestion of manure has been stretched to cover all scales of plant, but this is not necessarily a good approach as the plant size has implications on efficiency; ultimately the environmental credentials of very small plants may be compromised. He felt that the subsidy should reflect GHG-emission reduction, rather than high efficiency; for biogas production, a combination of high recovery rate and low methane losses would be equivalent to high efficiency. This would be similar to the subsidy in place for petrol/diesel (Strauch, Krassowski, and Umsicht, 2012).

Lantz agreed that prioritised access to the grid for biogas would be very good, adding that grid operators should not be allowed to deny this. However, he felt that the proposal for the grid owner covering the cost of connection should be revised to specify a maximum distance that the producer can be from the grid in order for this to be valid. In cases where the threshold distance was exceed, the gas grid operator could bear the financial burden of the capital investment for the additional pipeline, but the producer could pay the transmission fees to cover the additional leg for reaching the main grid. It would also be good if the gas grid owner was responsible for operating the connection point. In terms of investment for grid connections, Lantz felt that there are two major points to consider. Firstly, there

are the capital investment cost and practical construction aspects with regard to new pipelines, pressurising and gas stations. Secondly, a decision must be made about which grid the biogas will be fed into; in Sweden, there are high, medium and low pressure natural gas grids. The low pressure grid is operated at 4 bar, so may seem the most attractive for feed in due to reduced need for biogas pressurisation. However, it should be noted that this grid is the smallest, and that if all biogas plants were to connect to it then supply would be much greater than demand. As it is not possible to transfer gas from low to higher pressure grids, the number of plants delivering biogas to the low pressure grid must be kept within the capacity of the grid, considering the low demands for biogas at this pressure.
In terms of the proposal to keep the current support systems for biogas-fuelled vehicles in place, Lantz felt that support for heavy vehicles in particular is very important, (again, a focus area for his research group at the moment). A temporary production subsidy has been introduced this year (and will only be available during 2018) for biogas that will be used as a vehicle fuel (Regeringskansliet, 2018a). He also added that consideration should be given to whether Sweden should be trying to produce as much biogas as possible, or just focusing on upgrading biogas for use as a fuel on the vehicle market. As such, he suggested that a production subsidy could be combined with specific targets for vehicle fuels (perhaps the current scheme could be extended for a longer period if successful).

With regard to the proposal that there should be better promotion of types of financial support available, Lantz felt that this depends on the focus group for such a promotion. In his opinion, energy and municipal waste companies already have high levels of awareness, but in the agricultural sector there are still misconceptions. Economic fears often act as a barriers for farmers who are considering producing biogas, particularly if they calculated that it would not be profitable for them 5 - 10 years ago, but have not re-calculated the potential financial benefits taking into account revised support schemes; the government could remind producers that this is an option. However, he suggests that most farms are too small to build efficient production plants from which to sell biogas (they are instead at best suited using it for more localised CHP plants). He recommended that it is better to have larger units, although acknowledged that these are expensive and the collaborations required to set them up between multiple farms is challenging. This is partly due to the lack of funding availability for work prior to construction; he suggested that if there was funding available for preliminary studies, it is possible that there would be more co-operatively owned biogas plants due to reduced risks associated with the initial investment.

6.6.4 Overview of Stakeholder Perspectives

Considering the different insights gathered during the follow-up discussions, it is felt that there was overall consensus that the main problems identified during this study were reflective of the current situation for biogas in Västra Götaland.

Broadly speaking, the stakeholders felt that the proposals presented could be beneficial, albeit with some modifications. It was also noted by some stakeholders that the work in this study was valuable because it investigated issues which they and their colleagues had wanted to look into themselves, but did not have the opportunity to do within their own roles. As such, the information collated in this study could be beneficial to regional biogas actors. Furthermore, one stakeholder also suggested that the results of the study should be passed on to EnergiGas Sverige, as this is an organisation which supports the Swedish gas industry and related actors, including work with policy (EnergiGas Sverige, 2018). This implies that the findings of this study could be beneficial to ongoing development of the Swedish biogas industry, thereby bringing inferred benefits to the development of biogas in Västra Götaland. Several stakeholders also reflected that they were glad to have participated in the study, as it has given them new insights into the perspectives of others in the biogas value chain. The discussion with Mikael Lantz suggested that the areas being investigated as part of this studied were closely aligned with the research being undertaken by his group in the division of Environmental and Energy Systems Studies at Lund University on biogas in Sweden. This implies that the chosen focus of the study is valid, and that there are similar issues affecting biogas at both a regional and national level.

6.6.5 Reflection on Stakeholder Perspectives for Policy Proposals

The stakeholders involved in the follow-up discussions were all very interested in the outcomes of the study and were keen to share their perspectives on the proposal which had been presented. Discussing with stakeholders from different backgrounds meant that they had varying levels of knowledge on the topics covered, resulting in some stakeholders feeling more confident in their insights than others. The follow-up discussions were felt to reinforce the stakeholder perspectives which were expressed during the initial interviews. The identified focus points ("Inconsistency in supply and demand", "Lack of long-term agreements and planning" and "Lower cost of biogas imported from Denmark - need for neutrality between Swedish and Danish taxation systems") were agreed to be among the most significant barriers to development of biogas in Västra Götaland by all of the stakeholders involved in follow-up discussions. Notably, the stakeholder all also expressed support for biogas as a result of its multiple benefits, particularly with regard to circularity. This was interesting because "Biogas enables circular economy" was identified by 9 stakeholders but not included in the policy change proposal as it was not felt to be something which could be acted upon in a concrete way. In both the initial interviews and follow-up discussions, it was reported that "Biogas is win-win", not only for actors who are directly involved, but also for the environment and society.

With regard to the threat from Denmark, it was noted by one stakeholder that imported Danish biogas had only become an issue in recent years. Although this may be the case, another stakeholder had reported that the effect of Danish

imports were felt keenly and immediately from when they started by the biogas value chain in Västra Götaland. Lantz (the Secondary stakeholder involved in biogas research) suggested that if biogas were to be priced in line with natural gas then it could be possible for Swedish biogas producers to compete with Danish imports. He also raised that it is the price difference between biogas and fossil fuels which causes inconsistency in supply and demand; this was echoed in what several other stakeholders had reported. The Primary stakeholder represented a large consumer said that there was a need to harmonise markets (in terms of subsidies) at a national as well as EU level. This stakeholder is involved with commercial aspects of biogas-fuelled heavy vehicles at a global level, so perhaps has a more international perspective than some of the other stakeholders. The authors feel that this suggests that progression in the development of biogas needs to driven from a national, if not EU, level. This is because the predominant factors which are causing problems within the regional biogas value chain cannot be controlled from within the region as there are too many external conditions influencing the current situation in the region. As such, guidance at a national level, combined with greater co-operation within the EU, could be key to securing the possibility of Västra Götaland fulfilling its biogas potential in years to come.

In addition to the points previously raised with regard to limitations to grid connection, based on follow-up discussions with stakeholders, it was evident that having financial incentives that are only available in one region (or as would be the case with injection of biogas into the grid, only accessible from certain regions) would not be allowed under Swedish legislation. This fundamentally undermines the suggestion to introduce a feed-in tariff, and arguably also explains why there is not currently a tariff system in place. All stakeholders who were aware of the potential for feed-ins to the natural gas grid expressed concerns about the monopoly that Swedegas has, both because of high costs associated with connection to and transmission via the grid, and due to the lack of transparency about who could connect to the grid and the process for setting up connections. Interestingly, although most stakeholders had felt there were limited possibilities for direct connection to the grid (particularly with regard to potential controversy over lack of universal grid access if a tariff were to be introduced) the same stakeholders nonetheless felt that grid connections should be made easier to set up. Lantz even suggested that grid operators should not be allowed to deny connection access, provided that safety and quality standards are met. One stakeholder suggested that LBG was a better alternative (particularly for vehicle fuels), however, this was not raised by any other stakeholders involved in the follow-up discussions. This could nonetheless be a point for further consideration, particularly in light of potential complications with regard to grid connections.

It was interesting to note that the Public stakeholder from Hållbar Utveckling Väst (who had previously worked in a private company producing biogas-based vehicle fuels) expressed concerns about the lack of accessibility to the grid in different parts of Sweden, whereas the Primary stakeholder from the Production part of the value chain seemed to have much more technical and legal knowledge of the grid

system, but did not raise that direct connection was only an option for those in certain parts of Sweden. Furthermore, the Public stakeholder who was project leader for Biogas Väst stated that issues related to the grid were not considered by VGR. Subsequently, there is no communication by Biogas Väst to their network of regional biogas actors on the potential for direct feed-ins to the natural gas grid. In addition to the lack of transparency surrounding the grid that was highlighted previously, this lack of VGR involvement with matters relating to the gas grid infrastructure does not help to foster awareness of the different options available to biogas producers in the region. It is suggested that a mutual understanding of the Swedish natural gas grid system would be needed by all stakeholders in order for a fair discussion on direct grid connections for biogas producers to be possible.

Scale of production was raised by several stakeholders, especially with regard to whether there would be merit in the proposal for offering higher feed-in tariffs to smaller producers. Primary stakeholders from both the Production and Consumption parts of the value chain raised concerns over the effectiveness of small-scale production. Lantz also had reservations about whether encouraging widespread implementation of small-scale biogas production was a good thing. He suggested that feed-in tariffs should relate to GHG emission reductions rather than plant size. Similarly, both Primary stakeholders identified the lack of system for traceability of biogas origin was a concern, and stated that implementing such a system would be complex (especially for smaller producer, who may lack the resources to handle these kinds of requirements). The same stakeholders emphasised a need for greater transparency in terms of the origin of biogas, particularly if feed-in tariffs were to be introduced.

It was raised by the Primary stakeholder involved in the Production part of the value chain that that there is a general need for greater transparency both on how to apply for government funding and who is eligible. This could be a deterrent for some potential applicants. This stakeholder, along with Lantz, felt that there should be additional financial support available for those wishing to invest in biogas-fuelled heavy vehicles. However, the Primary stakeholder involved in the Consumption part of the value chain felt that subsidies should only be available for a limited time while the market develops enough to become self-sufficient. Instead, tax funds should be allocated where they are needed most. It was interesting to note that although this stakeholder would arguably experience direct benefits of specific economic incentives for investment in biogas-fuelled heavy vehicles, this was not something that they felt was appropriate, whilst at the same time, other stakeholders felt that this was an important type of support to implement.

All stakeholders involved in follow-up discussions felt that better promotion of the financial support available was important. Lantz added that people need to be educated on the options available, and that improvements to the conditions for producers in particular should be highlighted. One stakeholder emphasised that biogas is a complex issue overall, with many uncertainties. Lack of transparency on the type of support available was also frequently cited by stakeholders as an

issue affecting the biogas value chain in Västra Götaland at present. This was very reflective of the statements given during the initial interviews, such as "Poor communication and marketing", "Complex interdependent networks", "High level discussions leave many people mis- or uninformed" and "Local and international market uncertainty".

6.7 Potential Scenarios After Reflection on Stakeholder Perspectives

During the follow-up discussions with stakeholders, it was confirmed that feed-in tariffs and direct gas grid connections would not be possible in Sweden, for the reasons outlined in Section 6.6.5. However, additional ideas that could be implementable in potential future scenarios were discussed with stakeholders. These are outlined as follows:

- One suggestion raised by a stakeholder during follow-up discussions was to implement a lower transmission fee for biogas injection to the natural gas grid. This could be argued to mitigate (to some extent) potential controversy due to lack of universal accessibility to the grid across Sweden.
- One scenario that might justify governmental financial support for direct feed-in of biogas to the natural gas grid would be the introduction of a quota for biogas in natural gas, much like the quota for the percentage of biofuel which must be blended with petrol/diesel (Damberg and Abresparr, 2017; Strauch, Krassowski, and Umsicht, 2012). Although it would still be inappropriate to have a feed-in tariff, a scheme could be introduced which would grant tax levies (or reduce/remove penalties) to the gas grid operator to reward GHG emission reduction stemming from substitution of biogas in place of natural gas.
- One scenario that would encourage large-scale biogas consumers in the region could be some sort of collaboration between Swedegas and the chemical cluster at Stenungsund. In this scenario, direct injection of biogas to the grid (realistically from an industrial-scale biogas producer) could help large industries in the region towards their fossil-free goals (Regionen, n.d.).

Finalised recommendations that take into account the valuable contributions from stakeholders will be presented in Chapter 7.

7

Conclusions & Recommendations

During the early stages of research, it was identified that although there are enablers which could increase the expansion of biogas production and use in Västra Götaland, there are also barriers that must first be overcome in order for these enablers to become effective. It was also established that there is a regional network for biogas actors (Biogas Väst); this is financed by Västra Götalands Region, supporting claims that local politicians are committed to pursuing ambitious targets on biogas production and use. However, there is still a considerable amount of unfilled potential in the Västra Götaland biogas value chain.

Three main barriers were identified through interviews with stakeholders as part of this study, and confirmed through literature review and follow-up discussions. These were inconsistency in supply and demand, lack of long-term planning and agreements at a national level, and current conditions for biogas producers in Västra Götaland making it impossible for them to compete with cheap Danish imports.

To support the development of biogas in the region, it was identified that policy changes are needed in order to balance the biogas markets between Västra Götaland and Denmark. This is needed to allow biogas from Västra Götaland to become competitive in a region of Sweden where importing cheaper biogas from Denmark is a viable option. Based on comparisons of successful biogas policies in the EU, providing guaranteed feed-in tariffs for direct injection of biogas into the natural gas grids seems to be a good way to encourage biogas production. Although biogas producers in Västra Götaland would probably benefit from the introduction of a feed-in tariff, such a policy would be controversial in Sweden as lack of a universal gas grid would mean that many biogas producers in the country would not be able to benefit due to limited accessibility to the grid from most geographical locations. Furthermore, a private monopoly on the gas grid system means that connection and transmission fees are high and have seen rapid increase in recent years; this could prove financially prohibitive to many, particularly smaller, biogas producers in Västra Götaland. The grid owner could be denied the possibility to reject biogas feed-ins (provided safety and quality standards were met) and offer biogas producers discounts on transmission fees, along with support for capital investment in connection points, to prioritise biogas as renewable alternative to natural gas.

A need for greater transparency in opportunities for grid connection was raised as a particular barrier for direct feed-ins. Better transparency on the types of funding available for biogas-related investments and projects, eligibility and the application process was also identified as key in increasing the regional biogas production. Guaranteed funding, granted on a basis of GHG emission reduction potential, was identified by stakeholders as an effective way to encourage sustainable production of biogas, both environmentally and in terms of economic resource allocation. Awarding funding on a GHG emission reduction basis could help promote biogas production in plants at a suitable scale to ensure that environmental benefits are maximised and that producers can make decent profits. Ideally, by developing more larger-scale plants (both co-operatives and individually-owned sites), it will become possible to fulfill the demands of larger consumers, thereby improving stability in market conditions.

In terms of barriers, the overall complexity of issues surrounding biogas, particularly the reliance on multi-actor collaborations, is arguably one of the greatest challenges. There is need for some degree of involvement at a national level (particularly with regard to policy alterations) in order to overcome the current issues with competition from the import market. Overall, transparency between different value chain actors was identified as the biggest potential enabler for biogas in Västra Götaland. The regional focus on circularity was identified as a main opportunity, and is considered to be a driver that could support and encourage transparency and collaboration.

Recommendations for further research include investigation into EU policies and their impact at a more localised level; this could be influential over future developments within the region. Investigation into the cost implications associated with these types of policy proposal could also be undertaken, as during follow-up discussions, some stakeholders felt that it was likely that the government would perceive the benefits of biogas to outweigh the costs, whilst others were concerned that longer-term financial incentives for biogas were not an effective use of taxpayer money. From a technological perspective, it is recommended that more consideration is given to the potential of LBG as a more accessible alternative to direct injection of biogas to the grid; this could mitigate limitations stemming from dependence on producers being in geographical proximity to the grid.

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A

Full list of statements categorised in SWOT

STRENGTHS

- There is already enough demand for there to be competition for what biogas should be used for
- Resilient, especially compared to other renewable technologies (has experienced set-backs in the past but still remains in market)
- Electric cars do not pose a threat to biogas-fuelled vehicles, as both are such a small fraction of the market compared to petrol/diesel vehicles
- Biogas production already exists in wastewater treatment plants
- The technology can easily be spread across Scandinavia
- Existing accumulated technical and business knowledge
- There are existing logistics for organic waste collection in households and institutions
- There is some existing infrastructure (fuel stations), which has already encouraged investment in heavy vehicles
- Support via Hållbar Utveckling Väst and tough targets indicate strong regional interest
- Local production standards are high in terms of ethics, hygiene and safety
- Customers have a climate focus
- Biogas offers a responsible option for consumers to choose
- Additional source of revenue for farmers
- High emission reduction potential per investment
- Could provide boost to local economies
- Good tax incentives for biogas users/consumers
- There are no examples of plants failing after funding was granted
- Biogas production creates jobs
- Biogas production and use offers social benefits
- Biogas production can be both large-scale and rural
- Biogas unites urban and rural communities
- Good performance compared to other renewable technologies
- It is the biofuel with the highest production potential
- Biogas can be combined with natural gas and used in existing systems
- Biogas can be used as a liquid or gas, to suit user needs
- Reduces the environmental impact of agriculture
- Improved nutrient cycling with bio-fertiliser
- Provides security of supply for fuels and nutrients

- Climate impacts
- Improves air quality (when compared to fossil-fuelled vehicles)
- Renewable alternative to fossil fuels
- Better option than electric vehicles due to increased range and 'greener' energy source for fuels (some Swedish electricity is nuclear)
- A future diesel ban would increase demands for liquid biogas as a fuel
- Major biogas actors in the region acknowledge that it is not always the best solution and should only be used where it is a good alternative
- Produces excellent organic fertiliser - same amount of nutrients in 40% less volume, plus less odour
- Environmental issues with extracting natural gas do not exist for biogas
- Solves multiple problems simultaneously (waste management, climate impact, improved nutrient cycling)
- Biogas enables circular economy
- The limitations of biogas are already known because it is an established technology
- Biogas is a necessity in circular economy (industrial symbiosis, nutrient cycling and waste management)
- Difficult to have a sustainable future without biogas
- Development of biogas will be slow but sure
- When politicians show genuine interest in biogas, this boosts confidence in biogas amongst the wider population
- Biogas will take more space in the transport sector as there are so many environmental gains
- Biogas production can be useful as it can address wastewater treatment in symbiotic processes
- It is possible to introduce new substrates into biogas plants once they are already established

WEAKNESSES

- Development reliant on multi-disciplinary collaboration
- Need for systems view to understand the complex value chain
- Complex network at both local international level
- Need for more stable and mature market
- Need for greater collaboration to overcome chicken-and-egg problem
- Unclear direction for future biogas developments
- Need for long-term strategy
- Lack of existing infrastructure
- Cost and complexity/inefficiency of long-distance transportation of biogas
- Biggest potential has been identified in agriculture, but farmers lack the time to gain the additional skills needed to become biogas producers, or to take on additional tasks in their daily work
- Need to identify areas with relatively high concentrations of substrate
- Natural gas is unpopular, which may lead to similar views on biogas
- Social acceptance of waste as a resource is not universal
- Biogas is perceived as having low efficiency

- There are perceptions of unsuccessful business ventures associated with biogas
- Biogas production costs are relatively high and need to be reduced
- It is difficult to attribute costs/profits to deserving parties across the value chain
- Need investment to develop, but this is a risk for investors
- Lack of political knowledge about opportunities for bio-fertiliser production
- Fits into multiple government departments with no obvious owner
- Not the best alternative for any single point of consideration, therefore not an obvious political focus
- Biogas plants are slow to scale-up, but also need to be large in order to get economy of scale
- It is slow to plan, construct and commission a new biogas plant
- Unclear how biogas will become a mainstream technology
- There can be technical issues when using biogas as a vehicle fuel
- Existing biogas plants have been designed for waste treatment rather than biogas production
- Leakages from poorly managed/older plants
- Risk of bacterial contamination from feed (may require additional treatment to ensure product safety)
- Risk of explosions
- Economically challenging for both large- and small-scale producers
- Public institutions are unaware of existing infrastructure for organic waste collection
- Benefits of larger scale biogas plants are sometimes negated by production of excessive amounts of digestate, particular in areas with no local arable land for it to be used on
- Close control and forecasting needed to maintain balance in co-digestion processes
- There is a lot of fluctuation and no reliability in the availability of residues
- Collaborative efforts put a fuel infrastructure in place, but it has not developed as quickly as envisaged
- Biogas has never had much media coverage
- Biogas in Denmark would not necessarily have been a success if they had not neighboured Sweden and benefitted from double subsidies
- Biogas will never be a big renewable technologies like wind and solar
- Political directives on biogas to date have all been too short-term (1-2 years)
- Biogas industry does not market itself well
- Ethical debate about use of digestate from sewage sludge on arable land
- Location is a challenge is near residential areas

OPPORTUNITIES

- Co-operatives are a good way for farmers to produce biogas without being directly responsible
- Long-term contracts reduce risks for both parties
- Willingness for collaboration between large-scale biogas producers and consumers

- Growing needs for energy and freight transport
- There is increasing demand for bio-fertilisers, but they are difficult to source
- Big consumers could contribute indirectly by creating products which run on biogas
- Demand from big companies for sustainably produced biogas
- Potential for growth of biogas in transport
- New large consumers e.g. shipping and the chemicals industry
- Consumers are looking for biofuels
- Using biogas to power manufacturing can help make it carbon-neutral
- 50% growth in freight transport is forecast by 2030
- Consumers want to buy sustainable biogas - could use more environmental branding to promote this
- Ongoing development of biogas-fuelled vehicles
- Liquid biogas improves logistical options in terms of getting from waste producers to biogas users
- Market still quite open in terms of new actors and applications
- Potential both in the region and in the developing Nordic market
- Sweden has potential to be a market leader, and VGR has potential to lead in Sweden
- Business perspectives can boost economic viability
- VGR currently has the biggest production potential but lowest actual production of biogas in Sweden
- Learning from import/export with other Nordic countries
- Knowledge sharing and education within networks and organisations
- Farmers interested in innovation and new developments
- VGR is supporting and connecting actors and co-operatives
- VGR is acting as a neutral facilitator between stakeholders
- Biogas Väst supports both actors with difficulties and actors with interest
- Support from Energigården (sustainable energy production/use) and Agro Väst/kommunalforbund (for agriculture)
- Government support for capital investments through Klimatklivet
- Benefits from engaging young people/the right people in organisations - can promote overall change throughout an organisation
- Educate the public on circularity in everyday life
- Educate farmers about going organic and move away from reliance on chemical fertilisers
- Demonstrating benefits to overcome mindset barriers
- Motivational speakers/inspiring discussions
- Potential to focus on different aspects of biogas value chain in terms of communication, marketing and wider perspectives
- Greater expansion in Norway was due to positive attitudes, demonstrating the importance of mindset
- “Authorities should encourage local food production”; local biogas production could be a side venture
- There are examples of success following good political engagement
- Focus on circularity

- Environmental targets
- SDGs
- Government pre-studies on biogas subsidies
- Regional investment in biogas thanks to confidence in future profitability
- VGR is supporting new and ongoing biogas projects
- Need for security in fuel supply (global political concern)
- Better waste and emissions management
- Organic arable farmers can produce biogas from the clover grass which they have to grow to get organic status, but which has no other purpose
- Production in rural areas
- Good for rural development
- Examples of bottom-up success
- Public procurement to create large, reliable consumers (e.g. by using biogas-fuelled vehicles)
- Alternative to natural gas which can be substituted into existing systems
- Potential production from sea algae
- Large volumes of organic waste in region
- GoBiGas proved that politicians could be daring with technological investment
- Politicians see biogas as a bridging technology
- Politicians do not think there is a single technological solution, leaving potential for biogas to be integrated alongside other technologies
- Viewed by VGR as a technology which will diffuse faster than electric vehicles
- Regional focus is mainly on fossil-free alternatives, but biogas is a special case with high political interest
- Circularity aspects make biogas a regional priority
- Presence of the gas grid makes VGR strategically important for biogas
- Digestate from sewage is not used as a fertiliser locally, but can be exported as fertiliser, combusted or used as construction soil
- Proximity to the gas grid can reduce losses from biogas plant from 6-7% down to 2%, making it economically viable
- Biogas is needed for renewable molecules, e.g. hydrocarbons for bioplastics
- Financial support for digesting manure can help farmers
- Revenues from biogas are seen as too low, but many value the environmental aspects enough to tolerate the poor economic turnover
- In terms of renewably-fuelled vehicles, heavy vehicles tend to run on biogas whilst smaller vehicles will be electric
- Potential interest from waste producers and industries who are interested in the environment
- Easier to create collaboration between organisations if key actors have already had strong roles in these companies and have established trust
- Education/site visits for the public can help to improve perceptions of biogas prior to construction of new plants

THREATS

- Poor multi-disciplinary collaboration
- Poor collaboration between large organisations and rural actors

- Complex interdependent networks
- Poor communication and marketing
- Large powerful industries and very small biogas producers
- Actors in network are also in competition with each other
- Overall value chain needs fine-tuning
- Lack of widely-accepted collaborative business models
- Lack of trust between actors
- Mindsets of different actors
- Lack of long-term agreements & planning
- Competition for use of organic waste
- Societal change of resource use over time
- Inconsistency in supply and demand
- Local and international market uncertainty
- Lack of investment due to fears over the chicken-and-egg problem
- Lower cost of biogas imported from Denmark
- Need for a lot of investment in large-scale infrastructure
- Demand for very consistent quality products is hard to meet
- Inefficient production technologies
- Better suited technologies are available for some applications
- Economic difficulties for small-scale producers
- Relatively high cost of biogas as a fuel
- Fluctuating oil prices
- Electric vehicles viewed by some as the only solution
- Risk of lock-ins
- Consumers do not see the bigger picture
- Some actors are critical of government support as they feel that the biogas industry should be self-supporting
- Poor public perception, including confusion between biogas and fracking
- Reducing climate impact vs reducing waste vs standard of living vs security of demand
- Negative media coverage
- High level discussions leave many people mis- or uninformed
- Transport providers do not want to subsidise waste management by offering financial support for biogas production
- Anti-biogas/pro-fossil fuel lobbying
- Neglect of rural areas due to focus on Gothenburg
- Lack of national biogas strategy
- Politicians are not prepared to make “unpopular” decisions and risk not being re-elected
- Ever-changing political environment
- Lack of long-term governmental policies
- Complexity of biogas taxation system
- Lack of competence in political decision-making
- Focus on electric vehicles by manufacturers and politicians
- Difficulties in changing behaviours without economic drivers - economic & mindset threat in value chain and society

- Inexperience with circularity - collaboration threat in value chain and society
- Biogas no longer a focus for Göteborgs Energi
- Long-term effects of medicines in sewage sludge on agricultural land are unknown
- Reliance on availability of residues inhibits circular economy
- Difficult to know who is benefitting most in a collaboration, so there are issues with power and risk
- There are huge administrative burdens with joint ventures for investment
- Conflicts occur when organisations are trying to protect themselves from losses
- Risk associated with investment
- Policies are dictated by trends and it is impossible to forecast what the trends will be
- Need for focused policy on liquified biogas as a vehicle fuel
- Subsidies for electric vehicles but not biogas vehicles
- Lack of ambition to succeed with biogas from energy companies and politicians
- Existing co-operatives do not dare to take the risk of expanding, even though there is potential to do so
- Politicians are not giving clear directives on what role biogas should play in a fossil-free transport sector

B

Full summary of statements by SWOT and thematic categories

Table B.1: Full SWOT and Thematic Categories

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
There is already enough demand for there to be competition for what biogas should be used for	1	Strength	Value Chain	Products
Resilient, especially compared to other renewable technologies (has experienced set-backs in the past but still remains in market)	2	Strength	Value Chain	Products
Electric cars do not pose a threat to biogas-fuelled vehicles, as both are such a small fraction of the market compared to petrol/diesel vehicles	1	Strength	Value Chain	Products
Biogas production already exists in wastewater treatment plants	2	Strength	Value Chain	Feedstocks
The technology can easily be spread across Scandinavia	1	Strength	Social	Relevant Actors
Existing accumulated technical and business knowledge	1	Strength	Social	Relevant Actors
There are existing logistics for organic waste collection in households and institutions	1	Strength	Value Chain	Upstream Logistics
There is some existing infrastructure (fuel stations), which has already encouraged investment in heavy vehicles	1	Strength	Value Chain	Downstream Logistics
Support via Hållbar Utveckling Väst and tough targets indicate strong regional interest	1	Strength	Social	Political
Local production standards are high in terms of ethics, hygiene and safety	1	Strength	Social	Society
Please turn page for continuation of Table B.1				

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
Customers have a climate focus	1	Strength	Social	Society
Biogas offers a responsible option for consumers to choose	1	Strength	Social	Society
Additional source of revenue for farmers	1	Strength	Economic	N/A
Could provide boost to local economies	1	Strength	Economic	N/A
Good tax incentives for biogas users/consumers	1	Strength	Economic	N/A
There are no examples of plants failing after funding was granted	1	Strength	Economic	N/A
Biogas production creates jobs	1	Strength	Social	Society
Biogas production and use offers social benefits	1	Strength	Social	Society
Biogas production can be both large-scale and rural	1	Strength	Social	Society
Biogas unites urban and rural communities	2	Strength	Social	Society
Good performance compared to other renewable technologies	1	Strength	Value Chain	Products
It is the biofuel with the highest production potential	1	Strength	Value Chain	Products
Biogas can be combined with natural gas and used in existing systems	2	Strength	Value Chain	Downstream Logistics
Biogas can be used as a liquid or gas, to suit user needs	1	Strength	Value Chain	Products
Biogas enables circular economy	9	Strength	Environmental	N/A
Reduces the environmental impact of agriculture	1	Strength	Environmental	N/A
Improved nutrient cycling with bio-fertiliser	1	Strength	Environmental	N/A
Provides security of supply for fuels and nutrients	2	Strength	Social	Society
High emission reduction potential per investment	3	Strength	Economic	N/A
Climate impacts	1	Strength	Environmental	N/A
A future diesel ban would increase demands for liquid biogas as a fuel	1	Strength	Value Chain	Products

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	#SH	SWOT Category	Thematic Category	Sub-Category
Major biogas actors in the region acknowledge that it is not always the best solution and should only be used where it is a good alternative	1	Strength	Value Chain	Products
Produces excellent organic fertiliser - same amount of nutrients in 40% less volume, plus less odour	3	Strength	Value Chain	Products
The limitations of biogas are already known because it is an established technology	1	Strength	Social	Relevant Actors
Biogas plants are slow to scale-up, but also need to be large in order to get economy of scale	1	Weakness	Value Chain	Biogas Production
Biogas development will be slow but sure	1	Strength	Social	Relevant Actors
Biogas will continue to take more space and grow (especially in transport) as there are so many environmental benefits	1	Strength	Social	Relevant Actors
Biogas production can be used to address needs for wastewater treatment in symbiotic processes	1	Strength	Value Chain	Upstream Logistics
New substrates can be introduced to existing plants	1	Strength	Value Chain	Feedstocks
When politicians show genuine interest in biogas, confidence is boosted among the wider population	1	Strength	Social	Political
Improves air quality (when compared to fossil-fuelled vehicles)	1	Strength	Environmental	N/A
Renewable alternative to fossil fuels	2	Strength	Environmental	N/A
Better option than electric vehicles due to increased range and "greener" energy source for fuels (some Swedish electricity is nuclear)	1	Strength	Environmental	N/A
Environmental issues with extracting natural gas do not exist for biogas	1	Strength	Environmental	N/A
Solves multiple problems simultaneously (waste management, climate impact, improved nutrient cycling)	1	Strength	Environmental	N/A
Development reliant on multi-disciplinary collaboration	2	Weakness	Social	Relevant Actors

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	#SH	SWOT Category	Thematic Category	Sub-Category
Need for systems view to understand the complex value chain	2	Weakness	Social	Relevant Actors
Complex network at both local and international level	2	Weakness	Social	Relevant Actors
Need for more stable and mature market	4	Weakness	Social	Relevant Actors
Need for greater collaboration to overcome chicken-and-egg problem	1	Weakness	Social	Relevant Actors
Unclear direction for future biogas developments	1	Weakness	Social	Relevant Actors
Lack of existing infrastructure	1	Weakness	Social	Relevant Actors
Cost and complexity/inefficiency of long-distance transportation of biogas	1	Weakness	Value Chain	Downstream Logistics
Biggest potential has been identified in agricultural, but farmers lack the time to gain the additional skills needed to become biogas producers, or to take on additional tasks in their daily work	1	Weakness	Value Chain	Biogas Production
Need to identify areas with relatively high concentrations of substrate	1	Weakness	Value Chain	Feedstocks
Difficult to have a sustainable future without biogas	1	Strength	Social	Relevant Actors
It is slow to plan, construct and commission a new biogas plant	2	Weakness	Value Chain	Biogas Production
Unclear how biogas will become a mainstream technology	1	Weakness	Social	Relevant Actors
There can be technical issues when using biogas as a vehicle fuel	1	Weakness	Value Chain	Products
Existing biogas plants have been designed for waste treatment rather than biogas production	1	Weakness	Value Chain	Biogas Production
Benefits of larger scale biogas plants are sometimes negated by production of excessive amounts of digestate, particularly in areas with no local arable land for it to be used on	1	Weaknesses	Value Chain	Products
Close control and forecasting needed to maintain balance in co-digestion processes	1	Weakness	Value Chain	Biogas Production

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
There is a lot of fluctuation and no reliability in the availability of residues	1	Weaknesses	Value Chain	Feedstocks
Collaborative efforts have put a vehicle fuel infrastructure in place, but it has not developed as quickly as envisaged	1	Weakness	Social	Relevant Actors
Biogas will never be a big renewable technology like wind and solar	1	Weakness	Social	Relevant Actors
Biogas industry does not market itself well	1	Weakness	Social	Relevant Actors
Need for long-term strategy	2	Weakness	Social	Political
Natural gas in unpopular, which may lead to similar views on biogas	1	Weakness	Social	Society
Social acceptance of waste as a resource is not universal	1	Weakness	Social	Society
Biogas is perceived as having low efficiency	1	Weakness	Social	Society
There are perceptions of unsuccessful business ventures associated with biogas	1	Weakness	Social	Society
Lack of political knowledge about opportunities for bio-fertiliser production	1	Weakness	Social	Political
Fits into multiple government departments with no obvious owners	1	Weakness	Social	Political
Not the best alternative for any single point of consideration, therefore not an obvious political focus	1	Weakness	Social	Political
Leakages from poorly managed/older plants	1	Weakness	Social	Society
Risk of bacterial contamination from feed (may require additional to ensure product safety)	1	Weaknesses	Social	Society
Risk of explosions	1	Weakness	Social	Society
Public institutions are unaware of existing infrastructure for organic waste collection	1	Weakness	Social	Public Sector
Biogas has never had much media coverage	1	Weakness	Social	Society

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
Political directives on biogas to date have all been too short-term (1-2 years)	1	Weakness	Social	Political
Ethical debates/public perceptions of use of sewage sludge on arable land	1	Weakness	Social	Society
Location is a challenge if near residential areas	1	Weakness	Social	Society
Biogas production costs are relatively high and need to be reduced	2	Weakness	Economic	N/A
It is difficult to attribute costs/profits to deserving parties across the value chain	1	Weakness	Economic	N/A
Need investment to develop, but this is a risk for investors	1	Weakness	Economic	N/A
Economically challenging for small-scale producers	5	Weakness	Economic	N/A
Economically challenging for both large- and small-scale producers	1	Weakness	Economic	N/A
Biogas in Denmark would not necessarily have been a success if they had not neighboured Sweden and benefitted from double subsidies	1	Weakness	Economic	N/A
Co-operatives are a good way for farmers to produce biogas without being directly responsible	1	Opportunity	Value Chain	Biogas Production
Long-term contracts reduce risks for both parties	1	Opportunity	Social	Relevant Actors
Willingness for collaboration between large-scale biogas producers and consumers	2	Opportunity	Social	Relevant Actors
Big consumers could contribute indirectly by creating products which run on biogas	1	Opportunity	Value Chain	Products
Demand from big companies for sustainably produced biogas	1	Opportunity	Value Chain	Products
Potential growth of biogas in transport	1	Opportunity	Value Chain	Products
New large consumers e.g. shipping and the chemicals industry	3	Opportunity	Value Chain	Products
Consumers are looking for biofuels	1	Opportunity	Value Chain	Products

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	#SH	SWOT Category	Thematic Category	Sub-Category
Using biogas to power manufacturing can help make it carbon-neutral	1	Opportunity	Value Chain	Products
50% growth in freight transport is forecast by 2030	3	Opportunity	Value Chain	Products
Consumers want to buy sustainable biogas - could use more environmental branding to promote this	2	Opportunity	Value Chain	Products
Ongoing development of biogas-fuelled vehicles	5	Opportunity	Value Chain	Products
Liquid biogas improves logistical options in terms of getting from waste producers to biogas users	1	Opportunity	Value Chain	Downstream Logistics
Market still quite open in terms of new actors and applications	1	Opportunity	Social	Relevant Actors
Potential both in the region and in the developing Nordic market	1	Opportunity	Social	Relevant Actors
Sweden has potential to be a market leader, and VGR has potential to lead in Sweden	2	Opportunity	Social	Relevant actors
Business perspectives can boost economic viability	1	Opportunity	Social	Relevant Actors
VGR currently has the biggest production potential but lowest actual production in Sweden	1	Opportunity	Social	Relevant Actors
Learning from import/export with other Nordic countries	1	Opportunity	Social	Relevant Actors
Knowledge sharing and education within networks and organisations	1	Opportunity	Social	Relevant Actors
Farmers interested in innovation and new developments	1	Opportunity	Value Chain	Feedstocks
Potential to focus on different aspects of biogas supply chain in terms of communication, marketing and wider perspectives	2	Opportunity	Social	Relevant Actors
"Authorities should encourage local food production", local biogas production could be a side venture	1	Opportunity	Value Chain	Biogas Production
Need for security in fuel supply (global political concern)	1	Opportunity	Social	Relevant Actors
Alternative to natural gas which can be substituted into existing systems	1	Opportunity	Value Chain	Downstream Logistics

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	#SH	SWOT Category	Thematic Category	Sub-Category
Potential production from sea algae	1	Opportunity	Value Chain	Feedstocks
Politicians do not think there is a single technological solution, leaving potential for biogas to be integrated alongside other technologies	1	Opportunity	Social	Relevant Actors
Proximity to the gas grid can reduce losses from biogas plants from 6-7% down to 2%, making it economically viable	1	Opportunity	Value Chain	Biogas Production
Biogas is needed for renewable molecules, e.g. hydrocarbons for bioplastics	1	Opportunity	Value Chain	Products
In terms of renewably-fuelled vehicles, heavy vehicles tend to be run on biogas whilst smaller vehicles will be electric	1	Opportunity	Value Chain	Products
Potential interest from waste producers and industries who are interested in the environment	1	Opportunity	Social	Relevant Actors
Presence of the gas grid makes VGR strategically important for biogas in Sweden	1	Opportunity	Social	Relevant Actors
Digestate from sewage is not used as a fertiliser locally, but can be exported as fertiliser, combusted or used as construction soil	2	Opportunity	Value Chain	Products
Easier to create collaboration between organisations if key actors have already had strong roles in these companies ad have established trust	1	Opportunity	Social	Relevant actors
Growing needs for energy and freight transport	1	Opportunity	Social	Society
There is increasing demand for bio-fertilisers, but they are difficult to source	2	Opportunity	Social	Society
VGR is supporting and connecting actors and co-operative	1	Opportunity	Social	Public Sector
VGR is acting as a neutral facilitator between stakeholders	1	Opportunity	Social	Public Sector
Biogas Väst supports both actors with difficulties and actors with interest	1	Opportunity	Social	Public Sector

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
Support from Energigården (sustainable energy production/use) and Agro Väst/kommunalforbund (for agriculture	1	Opportunity	Social	Public Sector
Benefits from engaging young people/the right people in organisations - can promote overall change throughout an organisation	1	Opportunity	Social	Society
Government pre-studies on biogas subsidies	1	Opportunity	Social	Political
VGR is supporting new and ongoing biogas projects	1	Opportunity	Social	Public Sector
Projection in rural areas	1	Opportunity	Social	Society
Good for rural development	1	Opportunity	Social	Society
Examples of bottom-up success	1	Opportunity	Social	Society
Public procurement to create large, reliable consumers (e.g. by using biogas-fuelled vehicles in the public sector	5	Opportunity	Social	Public Sector
GoBiGas proved that politicians could be daring with technological investment	1	Opportunity	Social	Political
Politicians see biogas as a bridging technology	1	Opportunity	Social	Political
Viewed by VGR as a technology which will diffuse faster than electric vehicles	1	Opportunity	Social	Public Sector
Regional focus is mainly on fossil-free alternatives, but biogas is a special case with high politial interest	2	Opportunity	Social	Political
Circularity aspects make biogas a regional priority	3	Opportunity	Environmental	N/A
Education/site visits for the public can help to improve perceptions of biogas prior to construction of new plans	1	Opportunity	Social	Society
Government support for capital investments through KlimatKlivet	2	Opportunity	Economic	N/A
Regional investment in biogas thanks to confidence in future profitability	1	Opportunity	Economic	N/A

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
Financial support for digesting manure can help farmers	1	Opportunity	Economic	N/A
Revenues from biogas are seen as too low, but many value the environmental aspects enough to tolerate the poor economic turnover	1	Opportunity	Economic	N/A Sector
Better waste and emissions management	4	Opportunity	Environmental	N/A
Organic arable farmers can produce biogas from the clover grass which they have to grow to get organic status, but which has no other purpose	1	Opportunity	Environmental	N/A
Long-term effects of medicines in sewage sludge on agricultural land are unknown	1	Threat	Environmental	N/A
Poor multi-disciplinary collaboration	1	Threat	Social	Relevant Actors
Poor collaboration between large organisations and rural actors	1	Threat	Social	Relevant Actors
Complex interdependent networks	1	Threat	Social	Relevant Actors
Poor marketing and communication from producers of biogas and biogas-fuelled vehicles	3	Threat	Social	Relevant Actors
Large powerful industries and very small biogas producers	1	Threat	Social	Relevant Actors
Actors in network are also in competition with each other	1	Threat	Social	Relevant Actors
Overall value chain needs fine-tuning	1	Threat	Social	Relevant Actors
Lack of widely-accepted collaborative business models	1	Threat	Social	Relevant Actors
Lack of trust between actors	4	Threat	Social	Relevant Actors
Mindsets of different actors	3	Threat	Social	Relevant Actors
Lack of long-term agreements and planning	7	Threat	Social	Relevant Actors
Competition for use of organic waste	2	Threat	Value Chain	Feedstocks

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	#SH	SWOT Category	Thematic Category	Sub-Category
Societal change of resource use over time	2	Threat	Value Chain	Overall Value Chain
Inconsistency in supply and demand	9	Threat	Social	Relevant Actors
Local and international market uncertainty	1	Threat	Social	Relevant Actors
Lack of investment due to fears over the chicken-and-egg problem	1	Threat	Social	Relevant Actors
Demand for very consistent quality products is hard to meet	1	Threat	Value Chain	Products
Inefficient production technologies	2	Threat	Value Chain	Biogas Production
Better suited technologies are available for some applications	1	Threat	Value Chain	Products
Biogas is no longer a focus for Göteborgs Energi	1	Threat	Social	Relevant Actors
Reliance on availability of residues inhibits circular economy	1	Threat	Value Chain	Feedstocks
Difficult to know who is benefitting most in a collaboration, so there are issues with power and risk	2	Threat	Social	Relevant Actors
There are huge administrative burdens with joint ventures for investment	1	Threat	Social	Relevant Actors
Conflicts occur when organisations are trying to protect themselves from losses	1	Threat	Social	Relevant Actors
Existing co-operatives do not dare take the risk of expanding, even though there is potential to do so	4	Threat	Social	Relevant Actors
Electric vehicles viewed by some as the only solution	1	Threat	Social	Society
Risk of lock-ins	1	Threat	Social	Society
Consumers do not see the bigger picture	1	Threat	Social	Society
Some actors are critical of government support as they feel that the biogas industry should support itself	1	Threat	Social	Society
Poor public perception, including confusion between biogas and fracking	1	Threat	Social	Society

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
Negative media coverage	2	Threat	Social	Society
High level discussions leave many people mis- or uninformed	1	Threat	Social	Society
Transport providers do not want to subsidise waste management by offering financial support for biogas production	1	Threat	Social	Public Sector
Anti-biogas/pro-fossil fuel lobbying	1	Threat	Social	Society
Neglect of rural areas due to focus on Gothenburg	1	Threat	Social	Political
Lack of national biogas strategy	2	Threat	Social	Political
Politicians are not prepared to make "unpopular" decisions and risk not being re-elected	2	Threat	Social	Political
Ever-changing political environment	1	Threat	Social	Political
Lack of long-term governmental policies	3	Threat	Social	Political
Lack of competence in political decision-making - desire for a simple solution that will solve everything	2	Threat	Social	Political
Focus on electric vehicles by manufacturers and politicians	3	Threat	Social	Society
Difficulties in changing behaviours without economic drivers - economic and mindset threat in value chain and society	3	Threat	Social	Society
Inexperience with circularity - collaboration threat in value chain and society	2	Threat	Social	Society
Policies are dictated by trends and it is impossible to forecast what the trends will be	1	Threat	Social	Political
Need for focused policy on liquified biogas as a vehicle fuel	1	Threat	Social	Political
Lack of ambition to succeed with biogas from energy companies and politicians	1	Threat	Social	Society
Politicians are not giving clear directives on what role biogas should play in a fossil-free transport sector	1	Threat	Social	Political

Please turn page for continuation of Table B.1

Continuation of Table B.1

Statement	**#SH**	**SWOT Category**	**Thematic Category**	**Sub-Category**
Lower cost of biogas imported from Denmark - need for neutrality between Swedish and Danish taxation systems	7	Threat	Economic	N/A
Need for a lot of investment in large-scale infrastructure	1	Threat	Economic	N/A
Economic difficulties for small-scale producers	3	Threat	Economic	N/A
Relatively high cost of biogas as a fuel	1	Threat	Economic	N/A
Fluctuating oil prices	1	Threat	Economic	N/A
Complexity of biogas taxation system	1	Threat	Economic	N/A
Risk associated with investment	1	Threat	Economic	N/A
Subsidies for electric vehicles but not biogas vehicles	1	Threat	Economic	N/A

End of Table B.1

C

Summary of biogas-related policies in Sweden

Table C.1 was created through literature research presented in Section 6.1. Each policy has been categorised into Production, Distribution and Use depending on what the policy addresses. References used to source the data are listed beneath Table C.1.

Table C.1: Policies related to biogas in Sweden

Production	**Distribution**	**Use**	**Other (or several)**
National environmental target of biologically treating 50% of all municipal waste by 2018	Restricted by Naturgaslagen	Investment support when converting from fossil fuels to use of biofuels	Investment support for projects resulting in great environmental benefits in terms of GHG-emission reduction through Klimatklivet
Please turn page for continuation of Table C.1			

Continuation of Table C.1

Production	**Distribution**	**Use**	**Other (or several)**
Tax on landfilling implemented in 2000 → Ban on landfilling biologically digestible materials implemented in 2005	N/A	Complete tax exemption for vehicle fuel (Energy- and CO_2-tax), corresponds to about 685 SEK/MWh compared to petrol and 548 SEK/MWh compared to diesel, of which about 235 SEK/MWh is due to exemption from CO_2-tax. The exemptions needed approval from the EU-commission, and this approval is valid through 2018 for liquid biofuels and through 2020 for biogas as a fuel	N/A
Tax exemption during production phases if fulfilling some criteria regarding the end use of the biogas	N/A	No excise tax on biogas	N/A

Please turn page for continuation of Table C.1

Continuation of Table C.1			
Production	**Distribution**	**Use**	**Other (or several)**
Subvention of fertiliser that has been treated in a biogas facility; Financial support of max 42 SEK/MWh produced biogas from manure, in order to reduce the environmental impacts from methane releases related to manure handling. The budget was calculated for 2014-2023, but has been increased for the period 2016-2019	N/A	About 40% reduction of "förmånsvärdet" – the value of a benefit given to an employee by an employer which decides the level of a tax they are required to pay due to this benefit (e.g. when having a car at work which it is considered a benefit or privilege) – to the end of 2020, limited to 10 000 SEK. However, this also applies to natural gas, as it depends on the definition of an environmentaly friendly vehicle (swedish: miljöbil), and not specifically vehicles fueled by biogas	N/A
N/A	N/A	Support for using residue heat	N/A
N/A	N/A	Support for destruction of methane from landfills, WWTW and biogas facilities	N/A
N/A	N/A	Subvention on biogas used in CHP	N/A
N/A	N/A	Subvention for direct use in transport	N/A
End of Table C.1			

References used in Table C.1:Lantz, 2013 and Avfall Sverige, 2017b

D

Summary of biogas-related policies in Denmark

Table D.1 provides a summary of the policies in Denmark relevant to biogas. Table D.1 is explained in more detail in Section 6.2 in the project report.

Table D.1: Policies related to biogas in Sweden

Production	**Distribution**	**Use**	**Other (or several)**
Subsidies given to producers who sell their biogas so that its end use is in transport	Subventions to owners of upgrading facilities that inject biogas to the natural gas grid	Financial support to organisations that use the biogas in processing or industrial purposes	N/A
Feed-in premium for electricity production from biogas	Subventions to owners of facilities that purify biogas and inject to local grid ("city-grid")	Financial support to operations that use the biogas for heat production	N/A
N/A	N/A	Indirect subsidy of biogas used for heating due to tax exemption as a result of avoided fossil fuel use	N/A

Data in Table D.1 taken from Avfall Sverige (2017b) and Kampman et al. (2017).

E

Summary of current and historic policies across Europe

The following tables summarise the biogas-related policies from 13 countries across Europe used in this study to develop recommendations for Swedish policy. The policies are categorised into Production, Distribution and Use depending on what part of the value chain each particular policy affects. Other kinds of support, or support spanning over several parts of the value chain, were labeled as Other.

Table E.1: Austrian biogas policies

Production	**Distribution**	**Use**	**Other**
Helping			
Introduction of 13 year tariff scheme in 2007 lead to rapid development of energy crop biogas plants	Upgrading plants inject directly to grid or fuelling stations	Launch of 5 point action plan to encourage and expand use of natural gas (including biogas) as a transport fuel. Use of branding to promote this and subsequent growth in the vehicle sector.	Grants available to cover up to 25% of capital investment costs for environmentally relevant projects, plus an additional 5% if using for transport fue l
Higher basic tariff for smaller agricultural plants	30% reimbursement available for electricity feed-in due to avoiding fossil fuels (if not getting other tariffs)	Investment and operating grants available for vehicle fleets using 50% biogas/biomethane	Certificates of origin
15 year tariff period, which can be extended to up to 20 years	N/A	N/A	Research grants available
Please turn page for continuation of Table E.1			

Continuation of Table E.1

Production	**Distribution**	**Use**	**Other**
60% annual fuel efficiency is required for tariffs to be granted, with bonuses given for running at higher efficiencies. Additionally, feedstocks must be at least 30% agricultural residues/manure or penalties are incurred	N/A	N/A	N/A
To fulfill sustainability criteria, raw materials must be sourced from within 10km of production plants	N/A	N/A	N/A
CHP bonus, including for self-supply	N/A	N/A	N/A
Hindering			
Removal of financial support for operational costs for producers using energy crops hampered progress of the biogas market, after an initial period of rapid development	If connecting to the grid, biogas producers have to cover the costs of injection, including the initial connection. The feed-in tariffs are relatively low and producers are responsible for odourising their gas	N/A	Lack of clarity for eligibility criteria, so risk for some types of investment which may not benefit from governmental financial support

Please turn page for continuation of Table E.1

Continuation of Table E.1			
Production	**Distribution**	**Use**	**Other**
Poor market and political conditions have resulted in unfavourable electricity feed-in tariffs, heating and transport with biomethane	N/A	N/A	N/A
End of Table E.1			

Biogas policy summary for Austria (considered a European frontrunner) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017)

Table E.2: Croatian biogas policies

Production	**Distribution**	**Use**	**Other**
Helping			
Better feed-in tariffs offered to agricultural producers than landfill/sewage (and increases in line with inflation)	For injection into the grid, the national grid operator constructs and operates injection equipment	No excise tax for biofuels	Some financial subsidies for renewable energy projects
Interest-free or low-interest loans are available for renewable energy producers	Efforts made to put appropriate legal infrastructure in place to support biogas, as well as pre-studies to increase development	N/A	N/A
Market premium rather than feed-in tariffs and contracts with national regulatory body lead to huge increase in biogas production	N/A	N/A	N/A
Hindering			
Please turn page for continuation of Table E.2			

Continuation of E.2			
Production	**Distribution**	**Use**	**Other**
No clear legislation for construction of new plants, so application process is very slow	Standards for injection to grid formulated on a case-by-case basis - slow and may results in more stringent requirements for biogas Producer has to pay for grid connections	No subsidies for biogas as a vehicle fuel (whilst other biofuels do receive subsidies)	Government support for biogas declared in over 40 legal documents, but spans multiple departments so there is a lack of ownership No explicit mention of biogas as a renewable technology eligible for grants
End of Table E.2			

Biogas policy summary for Croatia (considered high potential but under-developed at present) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017; Biogas Action, 2017)

Table E.3: French biogas policies

Production	**Distribution**	**Use**	**Other**
Helping			
Specific targets for increased heat and electricity production from biogas by 2020	N/A	Large fleet of gas-fuelled public service vehicles	Guarantee of origin status
Bonus scheme for biogas production from manure	N/A	Regional initiatives for substantial financial subsidies (50-70% of additional costs) have successfully support the growth of biogas in transport	N/A
Higher feed-in tariff for smaller producers	N/A	N/A	N/A
Bonus scheme for producing higher quality biogas	N/A	N/A	N/A
Yearly updates on tariff rates	N/A	N/A	N/A
Please turn page for continuation of Table E.3			

Continuation of E.3			
Production	**Distribution**	**Use**	**Other**
Permanent tax exemption for agricultural biogas plants	N/A	N/A	N/A
Biogas producers have the right to set up contracts with any gas suppliers for 15 years; the supplier receives compensation for the price increase compared to natural gas (the compensation is funded by all gas consumers)	N/A	N/A	N/A
Government guarantee to buy gas if no other consumer	N/A	N/A	N/A
Both feed-in and premium tariffs (depends on size and location; priority given to urban plants)	N/A	N/A	N/A
Price of electricity from agricultural co-digestion plants increased in 2015 to improve profitability for farm-scale producers	N/A	N/A	N/A
Hindering			
N/A	Very few gas-fuelling stations are open to the public	No national scheme in place to promote/support biogas use in transport	
N/A	Plant owners have to pay for connection to the grid	N/A	N/A
End of Table E.3			

Biogas policy summary for France (moderate conditions under current regime) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017; Buddensiek, 2016; Reizine, 2015)

Table E.4: German biogas policies

Production	**Distribution**	**Use**	**Other**
Helping			
Rapid and widespread adoption of agricultural biogas production thanks to consistent supporting policies	N/A	2009 amendment of law to allow biomethane to fulfil quota for legal requirement of minimum fraction of biofuel to be included in petrol/diesel (and fines for fuelling station operators if this is not met) If the quota is exceeded, then operators are able to gain additional revenues by trading allowance	The combination of targets to reduce CO2 emissions by 40% by 2020 and plans for rapid decommissioning of nuclear power plants resulted in ambitious strategic plans for expansion of biomethane production to feed into natural gas grids
Guarantee feed-in tariff for 20 years from initial plant start-up	N/A	Loans for low-emission vehicles	All building constructed after 1st January 2009 must be heated by renewable energy. If 30% of the heat demand if met by biogas used in CHP, this requirement is considered to be fulfilled (but must have 100% heat utilisation to qualify)
Please turn page for continuation of Table E.4			

Continuation of E.4			
Production	**Distribution**	**Use**	**Other**
For connections to the gas grid, the biogas producer pays 25% and the grid provider 75%, provided that it is less than 10km from the plant to the connection point, with a 250,000 euro cap for the costs that the producer must cover. However, if the connection is greater than 10km then the producer must pay in full. The grid operator then owns the connection point and takes on all associated costs. The quality requirements for biogas as a natural gas substitute for injection are slightly lower than for other types of gas.	N/A	N/A	Biogas register for certification of origin
	N/A	N/A	Provision of flexibility surcharge
Hindering			
Changes to the 2011 tariff scheme significantly decreased the number of new plants being constructed as the incentives were far less attractive	N/A	N/A	N/A
End of Table E.4			

Biogas policy summary for Germany (considered a frontrunner) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017; Stephanblome, 2011)

Table E.5: Hungarian biogas policies

Production	Distribution	Use	Other
Helping			
Variable feed-in tariffs for biogas from sources, operation times, plant size and technology	N/A	N/A	Capital investment grants available
Compulsory premium for the certain sized plants (0.5-1MW)	N/A	N/A	N/A
15 year tariff period (unless benefitting from other grants)	N/A	N/A	N/A
Hindering			
Tariffs periods may be shortened if other investment grants also used	Producers must pay for connection to the grid	N/A	Low priority from a political perspective
Eligibility determined on a case-by-case basis	N/A	N/A	N/A
Tariff amount and period are determined on a case-by-case basis	N/A	N/A	N/A
Lowest tariffs in the EU (average of 99.5 euros/MWh compared to 237 euros/MWh in Germany)	N/A	N/A	N/A
End of Table E.5			

Biogas policy summary for Hungary (considered high potential but under-developed at present) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017)

Table E.6: Italian biogas policies

Production	**Distribution**	**Use**	**Other**
Helping			
Favourable electricity from biogas feed-in tariffs (most support in Europe)	Grid operator responsible for ensuring that connections to the grid conform with standards and are financially viable. They have to cover connection costs and must accept any gas which meets requirements	Investment in developing network of gas fuelling stations has resulted in the highest uptake of gas-fuelled vehicles in Europe	N/A
Small-scale electricity from biogas producers entitled to choose either the feed-in or premium tariff (hourly electricity price - basic feed-in tariff)	N/A	N/A	N/A
Plants with capacity below 100kW have automatic access to incentives	N/A	N/A	N/A
Tendering process for plants larger than 5MW to be granted premium tariff rate	N/A	N/A	N/A
20 year tariff periods	N/A	N/A	N/A
Hindering			
Please turn page for continuation of Table E.6			

Continuation of E.6			
Production	**Distribution**	**Use**	**Other**
Substantial drop in the amount of additional installed capacity each year following the 2012 revision of feed-in tariffs - focus has now shifted to how the existing plants will be managed in a sustainable under the agreed guaranteed tariffs	Slow to create regulations around biogas upgrading/injection	N/A	Weak role of government and weak links between government-industry-research caused a lot of problems, along with differing perspectives between stakeholders.
100kW- 1MW capacity plants must be on the national register before they are able to qualify for financial support	Poor management of leachate was a big issue.	N/A	N/A
Removal of tariff system in 2016 - awaiting new law	N/A	N/A	N/A
Tariff and tax system caused problems.	N/A	N/A	N/A
Complaints from local residents also problematic.	N/A	N/A	N/A
Had to stop producing food to grow energy crop to maintain plants, then needed to import food.	N/A	N/A	N/A
End of Table E.6			

Biogas policy summary for Italy (considered high potential but under-developed at present) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017; Ricci-Jurgensen, 2018; Bianca, 2016)

Table E.7: Dutch biogas policies

Production	Distribution	Use	Other
Helping			
Feed-in subsidies cover the difference between the cost of producing biogas and the average prices for energy (premium tariff)	N/A	There will be an obligatory quota for 10% biofuels in transport fuels by 2020	Provision of expert advice as well as financial support when establishing new schemes
Tariffs are guaranteed for 12 years	N/A	N/A	N/A
The government initially covered the costs of the premium tariff different schemes, but it was later funded from profits from public gas and electricity	N/A	N/A	N/A
Hindering			
Feed-in tariffs are granted on a first-come-first-served basis, so those applying at certain times of the year are unlikely to get support due to insufficient funds	N/A	No specific quota for biogas in transport	
Tariff is variable, depending on wholesale price of fossil fuels	N/A	N/A	N/A
End of Table E.7			

Biogas policy summary for The Netherlands (considered a frontrunner) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017)

Table E.8: Polish biogas policies

Production	Distribution	Other	Ref.
Helping			
N/A	Biogas producers can inject directly into the grid provided that quality standards are met. There are 2 different gas grids (one high-methane, one high-nitrogen), increasing opportunities for biogas producers.	N/A	Certification system for agricultural biogas
Hindering			
Limited support (i.e. low interest loans) available for very small producers	N/A	No financial support for biogas as a vehicle fuel	Lack of long-term legislation or financial incentives hindered the progress of biogas development for some time
End of Table E.8			

Biogas policy summary for Poland (considered high potential but under-developed at present) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017)

Table E.9: Slovakian biogas policies

Production	Distribution	Use	Other
Helping			
Two-fold feed-in tariff (compensation to match with electricity market price and surcharge) - dependent on plant size	Electricity from biogas given priority in terms of connection to the grid, along with other benefits and support	N/A	Funds available for using biogas to replace less efficient fossil fuel technologies
Please turn page for continuation of Table E.9			

Continuation of E.9			
Production	**Distribution**	**Use**	**Other**
Specific CHP support available	75% of grid connection are paid by grid operator provided plant is within 4km of the grid (but the producer must cover all connection costs if the distance is greater)	N/A	Favourable tax policies
15 year period for tariff support	N/A	N/A	N/A
Grants and tariffs available for plants which help EU GHG emission goal to be met	N/A	N/A	N/A
Hindering			
No tariffs if other government grants are awarded	Technical and legislative infrastructure is not matched by appropriate financial incentives	N/A	Subsidies awarded on a case-by-case basis
End of Table E.9			

Biogas policy summary for Slovakia (considered high potential but under-developed at present) (Strauch, Krassowski, and Umsicht, 2012; Kampman et al., 2017)

Table E.10: Swiss biogas policies

Production	Distribution	Use	Other
Helping			
N/A	Upgrading plants for direct injection have been developed in spite of a lack of supporting government scheme	Favourable tax policies for biogas-fuelled vehicles, along with good marketing	Decommissioning of nuclear power plants raised the profile of biogas to be considered as an important contributor to Swiss energy requirements
N/A	N/A	Certification and branding to sell biogas as a household fuel	N/A
Hinderingg			
No government schemes such as tariffs or subsidies/grants for biogas production	N/A	N/A	N/A
End of Table E.10			

Biogas policy summary for Switzerland (considered a frontrunner) (Strauch, Krassowski, and Umsicht, 2012)

Table E.11: British biogas policies

Production	Distribution	Use	Other
Helping			
Option for smaller producers (50 kW - 5 MW) to choose between feed-in tariff and quota system	N/A	Fixed tariffs for heat production from biogas	Exemption from fossil energy tax
Scheme for compensation for difference between a set price and the market price for biogas from all sources	N/A	Quota system for biogas in transport, with additional incentives if biofuels are made from waste or residues	N/A
Biogas production also supported through landfill tax	N/A	N/A	N/A
Please turn page for continuation of Table E.11			

Continuation of E.11			
Production	**Distribution**	**Use**	**Other**
Hindering			
Caps on the maximum tariffs that can be received	N/A	N/A	Some schemes terminated in 2017
End of Table E.11			

Biogas policy summary for The UK (moderate conditions under current regime) (Kampman et al., 2017)

Table E.12: Finnish biogas policies

Production	**Distribution**	**Use**	**Other**
Helping			
Plants with efficiency above 50% get "Energy aid" grants for new capital investments over 5 millions euros and research projects	N/A	No excise taxes for biogas in any application	N/A
12 year guaranteed premium tariff for electricity from biogas	N/A	N/A	N/A
Hindering			
Plants which have previously received financial support from the state are not eligible for tariffs	N/A	N/A	N/A
End of Table E.12			

Biogas policy summary for Finland (moderate conditions under current regime) (Kampman et al., 2017)

Table E.13: Norwgian biogas policies

Production	Distribution	Use	Ref.
Helping			
Grants for capital investment	Larger fuel pumping stations legally obliged to sell an alternative fuel alongside fossil fuels	Tax exemption for biogas-based fuels	N/A
Subsidies for treatment of manure	N/A	N/A	N/A
Hindering			
Waste is often exported to Sweden and Denmark, leaving limited resources for local production	N/A	Low dependency on natural gas imports means that biogas as an alternative to natural gas is not really a driver	N/A
End of Table E.13			

Biogas policy summary for Finland (moderate conditions under current regime) (FREMSYN, 2017; Boesgaard, 2017)

F

Document sent to stakeholders prior to follow-up discussions

Suggestions following masters thesis project on biogas
The aim of this project was to suggest strategies for overcoming barriers and promoting enablers for the development of biogas in the Västra Götalands region. Analysis of information gained through interviews conducted with 14 stakeholders from different parts of the biogas supply chain suggested that the following aspects were most in need of being addressed:

- Inconsistency in supply and demand
- Lack of long-term agreements and planning
- Lower cost of biogas imported from Denmark - need for neutrality between Swedish and Danish taxation systems

Based comparison of Swedish biogas policies with those in 14 other European countries, the following suggestions are proposed:

- There should be a feed-in tariff for direct injection of biogas to the grid. This should be guaranteed for a minimum of 10 years and kept consistent.
  - Tariffs should be scaled so that smaller producers have greater incentives than larger ones
  - Tariffs should be preferential towards biogas production which leads to the greatest reduction in GHG emissions
  - Premium tariffs should be offered to producers who operate at high efficiency (at least 60%)

- It should be possible for biogas producers (including upgrading facilities) to have access to the grid for connection. Use of a certification system would allow grid operators to ensure that quality and safety standards are met.
  - The cost of connection to the grid should be partially covered by the grid operator, with a cap for the maximum amount that the biogas producer must pay
  - The grid provider should be responsible for constructing, operating and maintaining the connection. This ensures that their quality and safety standards are met, and enables specialist work to be carried out by people who already have the necessary skills

- The financial support available for investment in and use of biogas-fuelled vehicles should continue

- Better promotion of all types of financial support available to those producing and upgrading biogas

We would be interested to have your views on whether these changes would be beneficial for the development of biogas in the region. In particular, any suggestions which you feel are particularly good/bad and why would be very helpful to the conclusions for our project.
Thank you again for your support.
Sara & Alice