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Bridging Local Constraints and Global Priorities:
The Shaping of Swedish Biogas Markets

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POPULÄRVETENSKAPLIG SAMMANFATTNING

Biogas är ett hållbart alternativ till fossila bränslen och kan dessutom främja cirkularitet och lokal ekonomisk tillväxt. Därför har biogasen alltmer prioriterats av beslutsfattare i Sverige och EU. I Sverige anses dock biogasmarknaden vara underpresterande när det gäller storlek och räckvidd. Biogas är ett socioteknisk system som har krävt omfattande stöd från stat och lokala regioner för att etableras på grund av konkurrensen från fossila bränslen men också till följd av dess materiella restriktioner. Det primära syftet med denna avhandling är att undersöka hur samspelet mellan olika politiska, samhälleliga och marknadsmässiga inramningar har format biogasmarknaden. Studien fokuserar på biogasmarknaden i Sverige, med särskild tonvikt på olika geografiska regioners roll.

En longitudinell fallstudie har gjort det möjligt att observera vilken central roll tolkningar av uppdrag och visioner har spelat för att motivera lokala aktörer att framgångsrikt utveckla biogasmarknaderna i utvalda regioner. Lokala policy-tolkningar visade sig i hög grad bygga på lokala problem och resurser som finns tillhands. Detta innebar också att klimatproblemen i en global kontext inte alltid var i fokus. Den lokala policytolkningen visade sig vidare vara en del av värdeskapandet, där värdet kopplades nära den regionala materiella och sociala kontexten. Dessa värdeskapandeprocesser visade också tydligt att biogas och biogödsel är objekt som är både naturligt och socialt konstruerade. Analysen visade den bristande förmågan att skilja på det naturliga och det sociala i komplexa system som spänner över flera sociala sfärer.

De socio-materiella egenskaperna hos biometan och biogödsel är viktiga för utformningen av biogasmarknaden. Ett tydligt exempel är den nära relationen mellan biometan och fossilgas som har visat sig ha både för- och nackdelar för biogasmarknadens utveckling. En fördel är att biometan genom att använda fossilgasinfrastruktur lätt kan expandera. Narrativet om fossilgas som en brygga till fossila-fria samhället kan ses som en nackdel eftersom det har lett till tvivel om biogasens roll. Det finns en uppenbar risk för att biogasen genom fossilgaskopplingen bara anses göra fossilgas mer accepterad.

Att biogödselns ställning på biogasmarknaden håller på att förändras påverkar också biogasproduktionens förutsättningar. Det som tidigare betraktades som en biprodukt till produktionen av förnybar energi och ett problem för producenterna kan numera användas som en tillgång. I likhet med effekterna av samspelet mellan fossil gas och biometan rör detta sig om en förändring av de sociala ramarna snarare än en materiell förändring. Att detta förändrade synsätt varit av central betydelse är en observation som är viktig både ur en empirisk och teoretisk synvinkel. Det visar att det går att förändra uppfattningen om ett objekt. Om objektet ska förstås som värdefullt eller hållbart krävs emellertid omfattande insatser. Det rör sig om ett samspel mellan de sociala, materiella och tekniska aspekter som (om)formar produkter och marknader.

Slutligen, användningen av begreppet ”marketisation” bidrog till att synliggöra biogasmarknadens problem. Analysen visar att biogasmarknaden fortfarande utvecklas

och är vad som, brukar kallas en ”het marknad. Gränserna för marknaden, inklusive vad som betraktas som externa effekter, håller fortfarande på att definieras. Även om detta inte helt förklarar den långsamma tillväxten, gör det möjligt för intressenter att använda denna kunskap för att påverka utformningen av marknaden. När biogasmarknaden förändras, tillsammans med andra faktorer såsom rollen för fossilgas, effekten av materiella förändringar med flytande biogas, och expansionen av den koncentrerade biogödselmarknaden, är det tydligt att narrativen kommer att behöva förändras. Avhandlingen bidrar till den empiriska litteraturen om förnybar energi genom att visa hur regioner genom lokalt förankrade narrativ motiverat hur biogassatsningarna, skapat värde för medborgarna. Dessa narrativ kommer att behöva anpassas för att återspegla de nya materiella verkligheterna.

ABSTRACT

Biogas offers a sustainable alternative to fossil fuels, promoting circularity and local economic growth. It is, therefore, increasingly prioritised by decision-makers within Sweden and the EU. Despite its advantages, the Swedish market is perceived as underachieving in terms of scale and penetration. Biogas, a socio-technical system, has necessitated state and regional support for its establishment and expansion, given its competition with entrenched fossil fuels and its inherent material limitations. This thesis primarily seeks to explore how the interplay of political, societal, and market perspectives has influenced the biogas market. The research zeroes in on the Swedish biogas market, with a special focus on the impact of geographical regions on market shaping.

Using in part a longitudinal case study revealed that historically, successful regions have relied heavily on translations of missions and visions for developing the biogas markets. These translations were found to build heavily on local concerns and local resources. The consequence of this meant that the global context of the climate problem was not always the focus of policy and strategies. The significance of local interpretation was further unveiled as a component of value creation, where value is closely tied to the material and social conditions of local geographies. Value creation for intricate systems like biogas, which are multifunctional and span various social domains, indicates that biogas and biofertilisers are entities that are both naturally and socially constructed, underlining the impossibility of separating the natural from the social.

The socio-material properties were important for biogas market shaping, as shown by tracing both biogas and biofertilisers. The connections between methane and fossil gas were found to be positive and negative for the biogas market. The reliance on fossil gas has created conditions that allow the biogas market to expand. However, the narrative of fossil gas as a bridge has, at times, led to doubts about biogas, and there is a risk that instead of biogas greening fossil gas, fossil gas has a 'browning' effect on the biogas market. For biofertiliser, the socio-material was found to be in a phase of change. It was found that the biogas market has been built for the energy market, but increasingly, it is important to consider the role of biofertiliser in this market. What was previously considered to be a by-product and a problem for the producers, is increasingly seen as an asset. Similar to the findings of the connection between fossil gas and biomethane, this is a change in social framings more than a change in the material. The movement from waste to by-product to an asset can be an important view both empirically and theoretically to foreground that for an object to be understood as valuable or sustainable, work is needed. This highlighted that markets do not simply appear, and objects are not inherently valuable or sustainable. It is instead an interplay between the social, material, and technical, which (re)shapes products and their markets.

Lastly, this thesis, through the lens of marketisation, traced the concerns of the biogas market. It found that the biogas market is still evolving often referred to as a

hot market. The boundaries of the market, including what is considered an externality, are still being defined. While this doesn't fully account for the slow growth, it does enable stakeholders to use this understanding to influence the market's development. As the biogas market changes, along with other factors such as the role of fossil gas, the impact of material changes with liquified biogas, and the growth of the concentrated biofertiliser market, it's evident that the narratives will shift. This thesis adds to the empirical literature on renewable energy by emphasising that regions that depend on creating value for their citizens by promoting a local narrative will need to adapt to reflect the new material realities. This will influence both how valuation processes are conducted and the use of missions and visions by both the public and private sectors.

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As noted by others, the acknowledgment section follows a specific format (Magnusson, 2013). However, starting a PhD when I did was not a part of any typical sequence of events, so this will be no different. I will start by thanking my two wonderful children, Louis and Mathilda. You have supported me through this latest project and a journey that began with my first master's in 2011. You tolerated textbooks all over the house, stressful exam periods, rushed dinners, and me studying during football and riding practices. You have both supported, encouraged, and enabled this whole journey. I love you both very much.

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1 Introduction

"Through ignorance or indifference, we can do massive and irreversible harm to the earthly environment on which our life and well-being depend. Conversely, through fuller knowledge and wiser action, we can achieve for ourselves and our posterity a better life in an environment more in keeping with human needs and hopes." (UN, 1972).

It has been 50 years since the first global conference to address the problem which we now know is a climate emergency (Wilkinson & Clement, 2021). We can conclude that knowledge alone has not prevented humanity's situation. If we wish to turn knowledge into wiser action, we need new tools and perspectives. The estimates of the amount of time we have to drastically reduce greenhouse gas emissions show that we are running out of time (Raftery et al., 2017). Hence, the decisions we make to reduce emissions are becoming increasingly vital (Hansen et al., 2013). Although this urgency has led Swedish policymakers to aim for an energy transition, the way in which this will be achieved is not always clear. The urgency of the problem means it is crucial to understand how an energy transition can best be brought about.

Ending our dependency on fossil fuels is critical for the transition, and moving to renewables for energy production is considered to be vital for achieving the Paris Agreement's emission targets (Jackson et al., 2019). In Sweden, 95% of electricity production is fossil-free and the country aims to produce 100% of its electricity using renewables by 2040 and a net zero-carbon economy by 2045 (IEA, 2019). However, industry and transport are more difficult to decarbonise. Domestic transportation is for example responsible for one-third of Sweden's greenhouse gas (GHG) emissions (Trafikverket, 2023). In the quest for sustainable energy sources and a more circular

economy, local biogas production has attracted attention as a small, but essential role in providing an alternative to fossil fuels.

Biogas is produced when organic matter decomposes in an anaerobic environment. The energy produced can be used for heat and power, or as raw gas. When biogas is cleaned of impurities, it is referred to as biomethane (CBG). This fuel can be used interchangeably with compressed fossil gas (CNG). In Sweden, biogas has long been part of the municipalities' waste management approach for treating wastewater. More recently, biogas was also produced via landfill gas recovery. In recent decades, organic waste from households, industry and agriculture has been added to the input streams of biogas production(Lantz, 2013). Biogas can be utilised in diverse ways, but the most common use in Sweden is biomethane as a transport fuel. In Sweden, 67% of all biogas is used as upgraded biomethane for transportation, while 10% is used as a heating source (Energigas Sverige, 2023). In 2022, of the biomethane used for transportation purposes, almost half of all biogas was used by buses (SCB, 2023). However, this is expected to change with the increasing electrification of public transport. Currently, the three most densely populated regions, Skåne, Stockholm and Gothenburg, are all planning or have already progressed with significant moves towards electrified public transport (Lundström et al., 2019). While the primary biogas market faces threats, other significant transformations are also underway.

Organic waste material is the primary input for biogas, but the economical transportation of this input is limited by distance due to its weight (Scarlat, Dallemand, & Fahl, 2018). Additionally, the digestate, the nutrient-rich humus matter remaining after gas extraction, has a high water content and is typically considered to be economical within a 10-30 km radius (Vestman, Liljemark, & Svensson, 2014). In its compressed form (CBG), fossil gas pipelines or trucks are required for biogas distribution, with economic restrictions on geographical reach. With the introduction of liquified biogas gas (LBG), transport costs are dramatically reduced (Gustafsson et al., 2020). In addition, interest from centralised sources such as shipping and industry has begun to grow, strengthened by the current price and uncertainty of fossil LNG (Ahlström et al., 2020; Jivén et al., 2022). However, even if, from an economic perspective, the distribution has fewer geographical constraints, the connection to local sources of substrates means that economic constraints on production sites remain (Feiz et al., 2022).

Considering a broad environmental context, there has been an emphasis on the importance of initiatives at the local and regional level for driving transformative change, particularly in alignment with the UN sustainable development goals (Fenton & Gustafsson, 2017). It has been argued that the local level is where powerful transitions against existing systems or 'regimes' have occurred (Späth & Rohracher, 2010). Although increasing attention is being paid to the spatial dimensions of energy transitions, there is still a lack of understanding of the precise dynamics in the regions within transitions (Hansen & Coenen, 2015). Biogas systems in Sweden have developed as local and regional systems, and consequently been associated with locally bounded visions of local futures built on local resources (Mutter & Rohracher, 2022). This has been attributed in part to the high transportation costs of both the substrate and digestate (Mol, 2014). The regional perspective can be vital, as biogas is

a "regional speciality" (Finne et al., 2021, p. 28), which requires coordination between both public and private regional actors (Lundmark et al., 2021).

As local actors in different regions try to understand how best to support the increased production and consumption of biogas, the creation and shaping of biogas markets is an important perspective. Biogas can be analysed as a socio-technical system where social values and institutions are entwined with the material dimensions of biogas and its infrastructure. One aspect of the connection between the social and the material is understood through the concept of a sustainability object. Corvellec (2016) described biogas as an example of a 'sustainability object'. This concept, which builds on a general theory of performativity (Latour, 1986), posits that objects become sustainable by being systematically defined as such. For this reason, it can be fruitful to unpack the values and qualities contributing to the classification of biogas as a sustainability object. While biogas is often heralded for its ability to solve numerous societal problems and contribute to multiple UN sustainable development goals (Hagman & Eklund, 2016), this feature also makes describing and calculating the benefits complex and difficult, as it belongs to and affects multiple spheres. As national and regional policymakers attempt to expand the biogas market, illuminating the benefits of biogas becomes a pressing matter, as understanding the value of biogas solutions becomes important for market growth.

1.1 The Case for a Market Perspective

Although the Swedish biogas market has been attracting considerable attention, notably less scrutiny has been placed on approaching the biogas market through the lens of a 'social studies of marketisation' (Çalişkan & Callon, 2009), enabling the examination of markets. This approach considers the role of the societal and the material, and focuses on their impact upon how markets are created and shaped. Rather than solely critiquing neoclassical economics, it has been argued that the future of the field can be helped by focusing attention on actual markets and considering input from economic geography with its focus on the importance of local contexts (Berndt & Boeckler, 2023). Traditional economics, the understanding of markets, is often reduced to understanding prices within a supply and demand framework controlled by a rational actor, where value is directly linked to price. However, building on the marketisation approach (Caliskan & Callon, 2010; Çalişkan & Callon, 2009; Callon, 1998b), this thesis assumes that markets are not found, but created and shaped by actors and devices and depend on these social and material interactions. When considering market shaping instead of market 'finding', we can trace how economic value becomes entangled with a broader concept of value. Furthermore, this approach is suitable for markets deemed to constitute 'concerned markets', such as sustainable and circular economy products. This view refuses to accept the assumed dichotomy that the economy and society are two different entities, but brings out how the concerns of society interact with markets.

It has been argued that biogas provides a sustainable alternative to fossil fuels, while at the same time promoting circularity and local economic growth. It is increasingly being prioritised by decision-makers in Sweden and the EU (European Commission,

2022). However, despite the benefits, the market is considered to be underperforming in terms of its size and reach (Gustafsson & Anderberg, 2023). After a period of stagnation, biogas use increased in 2021 and then declined again in 2022 (Energigas Sverige, 2023). It has been estimated that production is approximately 20% of what is feasible (SOU, 2019). Nevzorova and Kutcherov (2019) identified multiple significant barriers, both political and economic, to its development that are specific to Sweden. It has been argued that the challenges associated with building the biogas market are mainly related to profitability, which was linked to the limited scope of incentives (Lantz et al., 2007; Martin & Coenen, 2015). These challenges facing the biogas market are compounded by the rise of electrification to replace fossil fuels in the transport sector (Mutter & Rohracher, 2022).

One strategy to expand the market involves integrating societal benefits into policy decision-making and support. These benefits may include the monetary value of all effects of increased biogas production and consumption, e.g. reduced emissions or reduced eutrophication. However, incorporating socio-economic values into policymaking is a complex matter, especially for nature-related issues. One of the primary advantages of biogas is the value of avoided emissions (Brännlund, Nilsson, & Söderholm, 2010). However, as the emissions market is problematic and underdeveloped (Green, 2021; MacKenzie, 2009) and does not yet include industries like agriculture, this benefit, or cost, cannot be accounted for using traditional market logic. Similarly, the biofertiliser produced through biogas systems has economic and social value (Dahlin, Herbes, & Nelles, 2015). However, to fully recognise its value, the economic benefits of avoiding mineral fertilisers must be evident to consumers or turned into a socialised benefit with positive externalities internalised.

Based on the local relevance of biogas and the literature that highlights the role of local actors and public sector input in market development, it is essential to examine how local conditions, such as regional assets and constraints, have influenced both the shaping of the biogas markets and the perceived value of biogas, expressed through narratives and policy formulation. We can begin by asking the question: what is the value of biogas for a Swedish region? This could be answered by naming the price per litre, the energy-carrying amount or the increase in regional GDP. However, when we look at biogas as a market supported by public actors and entangled in hopes of transforming the energy system, we are forced to use an expanded notion of the word 'value'. Since the Stern review of 2006, the economic value of acting to prevent the effects of climate change has been recognized, which has brought about a significant change within policy. The problem with this view is that it is deeply entrenched in neoclassical economics, and the concepts of value remain linked to the commensurability of all things to a monetary value (Barker, 2008). Bringing in concepts of value from outside neoclassical economics will assist in approaching this renewable market through a new lens, and can assist in understanding practices and processes which are not apparent when viewing the market through the lens of political policy, solely or exclusively through concepts such as supply and demand.

1.2 Aim and Research Questions

The broad aim of this thesis is to understand how political and market framings intersect and influence each other to further develop the biogas system markets. More specifically, this thesis considers how value-adding and attending to concerns have occurred among both regional public actors and the private sector. The biogas market, as a locally bounded configuration, is particularly sensitive to the actions of regional actors. By bringing out new perspectives on the practices used in market shaping, the goal is to improve the knowledge base of these essential and often black-box processes in building publicly supported renewable markets. To achieve this, the thesis project considered actors within three regions in Sweden and recognised the multi-level governance structure in Sweden, which meant including the public and private actors at municipal, regional and national levels. The following research questions guided the project:

Research Question 1: How have actors in different regions used visions and valuations as a part of policy formation regarding biogas market development?

Research Question 2: How have the socio-material properties of the biogas system affected the dynamics of biogas market development?

Research Question 3: What tensions exist within the biogas market?

The first question seeks to create an understanding of the motivations and strategies used at the regional level and to distinguish how these actions have impacted the biogas market. The aim is to reveal how regional actors have positioned themselves in terms of engagement in the biogas market and what visions are produced by the regions which have contributed to the shaping of the biogas market. The second question begins with the awareness that the biogas system is comprised of multiple facets (societal, economic, technical and political), and looks to trace how the socio-material properties of a biogas system have affected market shaping. This knowledge would facilitate a better understanding of the biogas market. Lastly, the third question is based on the premise that biogas markets, including the biofertiliser markets, are developing and evolving markets, this question aims to understand what tensions, concerns and controversies exist within the markets which impact the progression. Understanding the market aspects that introduce uncertainty and shape the market can assist market actors, including the public sector, in managing and adapting to market aspects, while at the same trying to expand the market. To do this, the values and concerns that impact market shaping were foregrounded by studying market framings for biogas and biofertiliser.

The questions were approached using a comparative case study to enhance my comprehension of the variations and commonalities across regional markets. This was followed by considering the private sector's influence more explicitly through interviews, media and document analysis. The overarching objective was to deepen the understanding of the interplay between biogas markets and the efforts relating to market shaping. By acknowledging the multifaceted nature of biogas systems, I sought to trace how the socio-material attributes of these systems impact market

Research Question	Paper I	Paper II	Paper III	Paper IV
How have actors in different regions used visions and valuations as part of strategy formation regarding biogas market development?	X	X		
How have the socio-material properties of the biogas system affected the dynamics of biogas market development?	X	X	X	X
What tensions exist within the biogas market?			X	X

Table 1.1: Research questions

shaping. An overview of the questions with an indication of which paper addressed each question is shown in table 1.1

The purpose of the kappa is to address the research questions by synthesising the results from the four papers. Second, this kappa also aims to reflect upon the contribution that can be made from the example of biogas to the theories of marketisation. Biogas is an example of a market that, from a regional perspective, is part of a multi-market structure. It is formed as part of energy, food, and waste markets. As such, it can provide an interesting example of market shaping theory.

The thesis is comprised of four articles and a comprehensive summary. The comprehensive summary begins with this introduction. Following this introduction, Chapter 2 outlines the background of biogas markets and describes the specificity of the Swedish market. This chapter outlines the existing literature and research gaps. Chapter 3 presents the main theoretical concepts and perspectives used in both the design and analysis phases of this thesis. Chapter 4 describes the methods used, including the rationality of the case selection and a short discussion of my own researcher reflexivity of the research process. Chapter 5 summarises the four articles on which this thesis is based. Chapter 6 presents a discussion of the thesis findings, focusing on the research questions outlined in Table 1.1 This is followed by a concluding chapter on the results of this project, along with my reflections for further research.

2 The Biogas Market in Sweden

The following section gives an introduction to the Swedish biogas market. This includes a brief presentation of the development and current situation of biogas in Sweden and relevant previous research. This is followed by an overview of the policy landscape as it pertains to biogas in Sweden. This chapter concludes with a brief discussion of the research gaps which have been identified and are addressed by this work.

Sweden lacks significant fossil energy reserves, but it has developed considerable potential for renewables in terms of hydropower, biomass and wind. With its focus on research and development, it has been a frontrunner in the modern development of renewables since the 1990s (Nilsson et al., 2004). Sweden was heavily impacted during the 1970s oil crisis, leading to advancements in replacing oil, notably in energy-intensive industries such as pulp and paper (Bergquist & Söderholm, 2016; Nilsson et al., 2004). During the first decade of this century, as Sweden began to commit itself to further climate and environmental goals, there was a push to utilise the ability to produce local biogas for energy (Lantz et al., 2007). Biogas production has existed and has been produced in Sweden since the 1960s, although this thesis focuses specifically on the market from 2006 onwards (See Ulmanen (2013) for a complete presentation of the Swedish biogas history). This boundary was based on data as shown in Figure 2.1, which suggested that this was the start of the biogas system dominated by co-digesters, despite earlier developments in some regions [1].

[1] 'Co-digestion' is the process of mixing a variety of organic wastes, known as substrates, together. Compared with anaerobic digestion, which is based on single

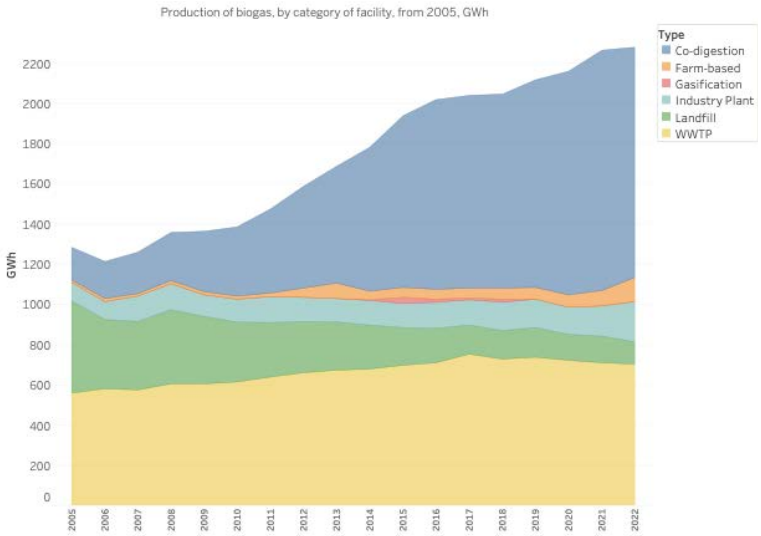

Figure 2.1: Production of biogas by facility type

Data obtainedd from Energimyndigheten (2024)

Biogas represents a small proportion of the energy mix in Sweden. In Sweden, energy gases amount to 4% of the total energy supply in Sweden. Despite this low quantity, the biogas potential is significantly higher and, as a regional product, it has attracted considerable attention from local actors in both the public and private sectors. Consumption of biogas in Sweden has increased ever since large-scale production began in the late 1990s and, in 2018, the country consumed 3.8 TWh of biofuel energy, with 63% of this biogas being upgraded to biomethane and used as transport fuel (Energigas Sverige, 2023). Figure 2.2 shows the uses for biogas in Sweden from 2005-2022. The high percentage of upgraded biogas is a unique market arrangement, as most European countries use much of their biofuel in heating and cooling systems (Dahlgren, Kanda, & Anderberg, 2019).

In contrast to many other European countries, Sweden has limited gas grid access, as Figure 2.3 shows. The lack of a gas grid has meant that the fuel has to be transported by road to where it will be consumed, such as refuelling stations or industrial users.

In Sweden, biogas has traditionally been produced from household and industrial food waste and sewage sludge. The last 20 years have seen significant developments in co-digestion plants. Biogas production has historically been operated by municipal waste and wastewater organisations and, most large municipalities have invested in biogas plants. However, this situation is changing, with an increasing proportion of the investments originating from the private sector over the past decade, often with support from programmes such as Climate Leap (Klimatklivet). In 2022, a total of

sources, the methane content and nutrient mix are considered to be significantly improved by co-digestion (Energigas Sverige, 2011; IEA, 2019)

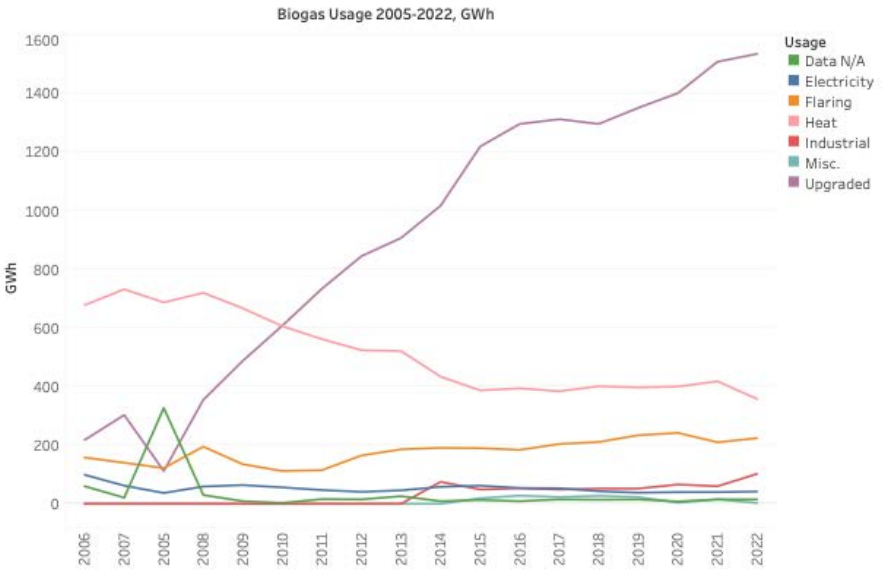

Figure 2.2: Biogas usage 2005-2022.

Data obtained from Energimyndigheten (2024)

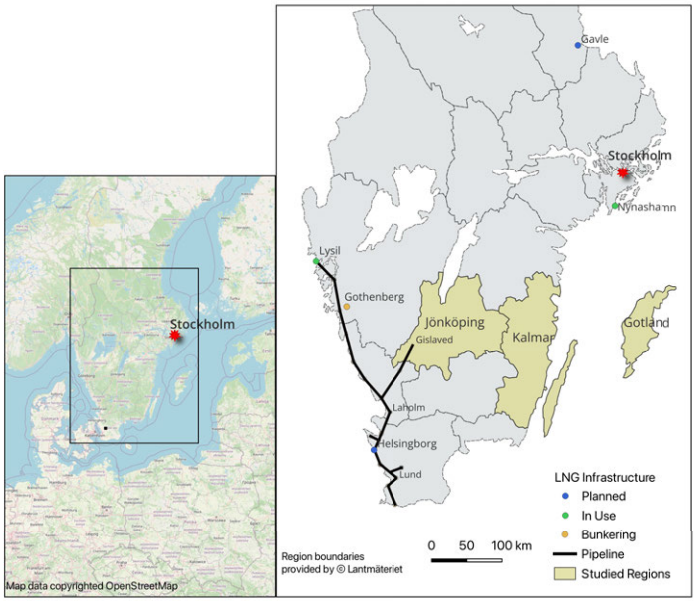

Figure 2.3: Fossil gas infrastructure in Sweden.

Data obtained from Energimyndighet(2020) and Energimarknadsbyrå (2024)

SEK 1.8 billion was invested in biogas, which represented 40% of all the funding from the programme (Swedish Energy Agency, 2023). It is expected that the majority of future capacity expansion will come from the private sector (Klackenberg, 2023). Much of the public sector involvement in recent years has taken place via public sector procurements through the prioritised use of biogas for public buses (Aldenius & Khan, 2017; Fallde & Eklund, 2015; Lundmark et al., 2021). However, this strategy for building the market through consumption has changed rapidly over the last few years, as electrification has taken on a more prominent role in the procurement of public transport (Lundmark et al., 2021; Mutter & Rohracher, 2022).

In 2019, the White Paper entitled "More Biogas!" found that producing 7 TWh of biomethane from anaerobic digestion by 2030 was feasible from both a technical and an economic perspective. This would entail a significant increase from the 2.3 TWh which was produced in 2022 (Energigas Sverige, 2023). Despite its potential, the biogas market in Sweden is considered to be underperforming in terms of its potential size, and it is believed that 7 GWh is feasible, even though it would require considerable coordination between policy instruments and public and private sector efforts (Gustafsson & Anderberg, 2022). One issue for the biogas market has been the uncertainty surrounding the markets, leading to suboptimal investment (Martin, 2015). In 2013, it was found that the economic viability of biogas plants was under threat and that the poor economic viability of biogas plants was having a significant impact on market expansion. The report concluded that poor economic viability was due to the lack of substrate availability, the high cost of production and distribution, and the lack of biofertiliser valorisation (Bisaillon et al., 2013).

Although biogas systems are often visualised as a farm-based circular system, small-scale or decentralised solutions account for approximately 9% of all the biogas produced in Sweden (Energigas Sverige, 2023). Considering the specific conditions of farm-based and small-scale biogas plants, a report in 2015 found that, on average, the plants operated at a loss of SEK -4/kWh gas produced (Ahlberg-Eliasson, 2015). The report found that the problem was the low price of electricity, along with a lack of opportunity to sell the gas. A further study found that these problems are to some extent alleviated when biogas plants combined other substrates with the manure (Ahlberg-Eliasson et al., 2017) A more recent study considered the return on investment and found that a decentralised farm had generated an approximate return of 5% after 20 years. However, as Ahlberg-Elisason found, co-digesting manure with other materials significantly improved this figure (Vaneeckhaute et al., 2018). Long-term thinking, which is essential for generating a return on investment, was missing from policy support, which has had a negative effect on the biogas market. When considered from a regional perspective, this seriously impacts the ability of farm-based biogas plants to invest. This barrier was found to be compounded by observations that policy at the national level often does not accommodate regional variations (Niskanen & Magnusson, 2021).

The rise of liquefied fossil gas has further transformed the biogas market. Liquified methane, which has been produced since the 1960s, gained momentum in the early 2000s. It is formed by cooling methane gas to -162'C, transforming the gas to its liquefied form. Liquefied methane has a more efficient volume-to-energy ratio and

therefore removes the requirement for pipelines for economically viable distribution (Gustafsson et al., 2020). The market is supported through measures such as the TEN-T blue network, which has been designated an LNG corridor. This requires an LNG refuelling station every 400km along selected European highways. According to EU policy, compressed methane (CBG/CNG) is feasible for urban areas. However, LNG should be viable for longer distances (Osorio-Tejada, Llera, & Scarpellini, 2015). More recently, the use of LNG in shipping has gained traction in Europe. However, due to the cost and hesitation in retrofitting existing ships, the uptake in this sector is likely to be gradual (Sharples, 2019). This development in the LNG market is significant for biogas, as the compressed liquefied versions (LNG and LBG) can be interchanged or blended. In 2021, there were three LBG production facilities in Sweden, which generated 95 GWh. It is anticipated that new production sites will focus on LBG (Klackenberg, 2023).

2.1 Policy Landscape

The policy landscape has been shown to be important for energy transitions. Weber and Rohracher (2012) found that numerous failures can be encountered when considering transitions. One of these failures is policy incoherence. Policy incoherence can exist between different policy levels, such as regional and EU level, or between other policy sectors, such as agriculture and energy. Building on this, Huttunen, Kivimaa, and Virkamäki (2014) found in Finland that, although it created a situation that spurred innovation to overcome barriers, the lack of policy coherence was potentially limiting the diffusion of technology to the market in the long term. One root cause of this policy incoherence was the fact that biogas was part of multiple policy domains. This resulted in a situation where policy objectives could be aligned between different spheres, such as agriculture, waste, transport, and energy, but the instruments to operationalise the policies were often not synchronised. When considering EU countries, Gustafsson and Anderberg (2021) found that biogas is connected to environmental, water, economy and construction policy arenas, in addition to the aforementioned areas. The authors concluded that, when biogas finds itself caught between a variety of policy arenas, there is a risk that no single actor will take responsibility for ensuring its success.

The economic instrument which has been cited as being the most impactful has been the exemption from energy and carbon tax (SOU, 2019). Sweden has both an energy and carbon tax on fuels, from which biogas have been exempted from. Fossil gas is also exempted from the energy tax, but is subject to carbon tax based on emissions (Holmgren, 2012). This policy tool has been attributed to building the consumption market, including for imported biogas, but had no effect on stimulating Swedish production (SOU, 2019). Due to EU regulations, tax exemptions are based on the production price compared with fossil fuels in order to avoid unfair competition for fossil fuels and disrupting the common energy market in Europe. Sweden has had to apply at regular intervals to the EU for this tax exemption for biogas, which has been granted from 2003 through until the present day. However, each extension was preceded with a period of uncertainty, which has contributed to slow growth of the biogas market (Karltorp & Gosens, 2016).

To boost investment in production and infrastructure, the Swedish Government has, since 1998, provided investment support for biogas production through local investment programmes and climate investment programmes which have been involved in supporting the construction of several biogas plants. These programmes were initially aimed at larger projects and encouraged the early involvement of municipalities in the construction of plants (Lantz et al., 2007). These programmes have been designed to help business make investments which lead to emission reductions. The focus on investment support as opposed to production cost has been preferred by actors who do not wish to rely on support which could change in the future (Lönnqvist et al., 2019). Despite the support, it was noted that some projects have not been completed due to uncertainties relating to future production support and an inability to secure additional private financing (SOU, 2019).

Smaller schemes which are targeted specifically at biogas have also been introduced. One example is the economic support for energy production based on manure, which is part of a methane reduction plan and began in 2015 (Jordbruksverket, 2022). Although this has been important for small-scale farm-based plants, it has suffered from the same problem of a lack long-term predictability(SOU, 2019). This support is linked to the price of fossil fuel production, meaning that when the production price of fossil fuels goes up, there is a risk biogas producers will receive less or even no support to avoid overcompensation. In addition to this uncertainty, the number of applicants and the quantity of gas they generate, the budget might not cover the full allowable compensation (Jordbruksverket, 2022).

2.2 Research Gap

As outlined in the preceding section, the academic literature has shown that considerable barriers exist in the biogas market, many of which have been known for more than 15 years. The barriers were found to be primarily policy and economic in nature. In order to deepen our understanding of how this has caused the biogas market to underperform, in spite of the political support, this thesis will focus on a holistic view which combines the economic, political and societal interpretations of the biogas market.

3 Theory

This theoretical chapter introduces concepts that are used in the design and analysis of the research project and to determine how the concepts help us to understand market shaping. The first section focuses on strategies and visions and how they are used by the regional actors to both react to the market and proactively shape the market. This is followed by an introduction to theories of market shaping and marketisation based largely on the writings of Michel Callon. The chapter concludes with a discussion of the theoretical notions of value and how valuation practices impact our use of valuation and are affected by matters of concern.

3.1 Missions and Market Shaping

Mission-oriented innovation policies are public policies that are aimed at stimulating innovation that addresses grand societal challenges. It is argued that governments use dynamic capabilities to leverage private investments in industrial development (Spencer, Murtha, & Lenway, 2005) and new market creation (Mazzucato, 2016), and depend on purposeful and systematic interventions which aim to stimulate major sociotechnical changes (Weber & Rohracher, 2012). As opposed to traditional missions such as putting a man on the moon, missions relating to major challenges such as climate change need to acknowledge that problems cannot be solved through technological change alone, but require a board range of wider transformations (Coenen, Hansen, & Rekers, 2015).

"Missions require a vision about the direction to drive an economy, focusing investment in particular areas" (Mazzucato, 2018, p.809). Energy transitions are playing an

increasingly vital role in addressing major challenges and tackling complex 'wicked problems' within policy design (Kaldewey, Russ, & Schubert, 2020; van der Helm, 2009), and energy visions are part of developing and operationalising an energy strategy. The use of visions to promote an agenda or ideology in the public sector is neither new nor specific to renewable energy policy. Although it cannot be said that visions are in place to present a homogenous voice or to silence others, it has been noted that visions can indeed mask the potential conflicts in the aim for the utopian vision (Späth & Rohracher, 2010; Trutnevyte, 2014). The use of visions as a market-building activity has been demonstrated to be important in the Swedish biogas sector (Ottosson & Kindström, 2016), as strong visions provide the stability to attract investment and innovation (Winquist et al., 2019).

Guiding visions or narratives are produced and maintained as part of market building (Ottosson, Magnusson, & Andersson, 2020). These narratives and visions, especially in sustainable markets, are created by various actors. This is part of the enrolment of actors, which allows the 'tending to concerns', which is discussed later in this section. Tending to concerns is another way of considering the problem framing. The role of problem formation has increasingly been regarded as pivotal within environmental policy (Bardwell, 1991) where problems have the characteristics of wicked problems due to their complex nature, lack of endpoint and clear solution (Balint, 2011; Kreuter et al., 2004). The problem formation step in policy formation, as described by Rochefort and Cobb (1994), argues that the role of agenda-setting is political and embedded in both cultural norms and power structures, such that problem formation is tightly bound to the solutions which will be provided. They further argue that this process limits certain groups and arguments from accessing the policy debate. In this way, we cannot view policy and narrative formation as neutral acts, but must consider them as embedded in institutional and power structures. Birkland (2007) provides a framework of theories of agenda-setting, which foreground that decisions happen as the inner layer of other agenda structures, namely institutional and systemic agenda structures. This helps us to understand the boundaries on which regional actors must act. Regional actors formulate problems and solutions and adjust for regional needs, which can be an important starting point for understanding their role in market building. However, it is also essential to understand they do this within wider systemic constraints.

3.2 Markets and Marketisation

What do we mean by 'a market'? It is a word that has a common understanding of meaning, but which Callon described as having 'false familiarity' (Callon, 2021). The definition of the term has been subject to numerous discussions (see Rosenbaum, 2000), a debate which will not be repeated here. Instead, a summary of the theoretical views of markets and their formation, which has informed my work in identifying and analysing the market, will be reviewed. The discipline[2]of economics (Callon,

[2]The use of the word 'discipline' rather than 'field' is intentional here. As Nilsson and Helgesson (2015) found, in the wider marketing field, a broader and more nuanced view of the market is found by practitioners.

1998a) and marketing studies (Mele, Pels, & Storbacka, 2015) have devoted little attention to understanding the very concept of a market and how markets are formed. The modern sociology of markets[3] has helped us to better understand markets by bringing forward the importance of social networks and institutions in shaping markets. This has been further developed more recently, adding a performative view of market formation (Fligstein & Dauter, 2007). It is this last addition which has been a starting point for the theoretical basis of this study of biogas markets.

Within economic sociology, the sociological view of markets has emerged to mitigate blind spots which occur when viewing the economy and markets from a neoclassical perspective. Economic sociology broadly challenges pivotal assumptions found in neoclassical economics. Some of the assumptions which are relevant within the biogas market are discussed. The first assumption is the focus on scarcity and utility maximisation being the driving forces of market formation. It contributes by including other forms of economic actions, adding nuances to the concept of rationality and viewing it as a variable which has to be understood and explained (Dosi, Orsenigo, & Sylos Labini, 2010). The second assumption is the manner in which neoclassical economics defines markets as an exchange between a buyer and a seller. In this lies an oversimplification that price setting is the principal action of the shaping of the market (Callon, 1998a). Another deficiency of mainstream economics is that value is equal to utility or monetary value, and by focusing on market penetration, innovation and market success factors, the important process of how markets come to be shaped is ignored (Buchhorn, 2010). While neoclassical economics focuses on market formation as part of the reaching of a state of equilibrium, a sociological market view stresses that, although markets are in constant movement, they are not assumed to be converging on or diverging from equilibrium. Instead, the movement is conceptualised as part of the stabilisation and de-stabilisation of social processes surrounding markets (Fligstein & Dauter, 2007).

Part of the performative view of markets is considering how they are brought into being and shaped, sometimes referred to as the markets-in-the-making lens (Caliskan & Callon, 2010; Çalişkan & Callon, 2009; Callon, 2021). Instead of focusing on the presumed movement towards equilibrium, the changes occurring in a market have been described by Callon using the metaphor of markets becoming 'hot' or 'cold'. The market is in flux between states where they are stable and where they are not. The movement is a result of how the market is framed, i.e. what is included or excluded as belonging to the market (Callon, 1998a). From this, the performative view of markets has helped to create a lens in which the dualisms of the economic and the social, and their categorisations of good or bad, are replaced with a view that considers how markets come into being in the first place and the work that is needed to maintain them.

[3]Fligstein and Dauter, 2007 distinguish between the sociology of markets and economic sociology. I use the term sociology of markets to distinguish a specific branch within economic sociology. However, other authors on which this thesis relies use other terms, all of which I consider to fall under the perspective of economic sociology as defined by (Smelser & Swedberg, 2005): "the sociological perspective applied to economic phenomena" (the 'Definition of Economic Sociology' section).

Although the above definitions of a market have been used to identify markets, it is still useful to go one step further and examine the theoretical components of a market from a sociology of markets perspective. The market is described by Callon and Muniesa (2005) as 'goods, agents and exchanges', which together act as a collective device. In order for the goods to be exchanged, they are made calculable. However, the use of the word calculable is itself in question, and it is argued that the calculation needs to be re-clarified. The first task in the redefinition process is to remove the binary between qualitative and quantitative and, in doing so, also refrain from setting actions as binary opposites between calculation and judgment. To do this, the authors focus on what happens during the calculation process. This involves detachment and objects being brought into a new space with new associations, ultimately leading to the creation of a result or a new entity. For goods in a market, this requires the goods are "detached and reattached that the two agencies become quits" (Callon, 2005, p.7). Importantly, it is not this detachment and attachment process, but the forms of socio-material arrangements at work that enable (or prevent) this from happening. This is because "concrete markets require a set of investments and operations to shape calculative agencies, to qualify and singularize goods, and to organize and stabilize the encounters between goods and agencies," (Ibid. p. 8)

To understand the biogas market, the concept of marketisation has been used both to identify and delimit the unit of study, and for explanation building. Taking markets to be an ongoing process in constant flux, we see markets as more than the transfer of goods. This means that goods are considered as a process, rather than objects (Callon, 2021, p.41). This entails considering the phases which occur before goods are transferred from the conception and production (Caliskan & Callon, 2010). This process of marketisation has been defined as "the entirety of efforts aimed at describing, analysing and making intelligible the shape, constitution and dynamics of a market socio-technical arrangement (Ibid. p. 3). To understand how this definition has been used, I will first describe socio-technical agencements (STA) and then expand on the concept of devices.

Markets as socio-technical agencements are defined by Caliskan and Callon (2010) as being identified by three qualities: they organise and circulate goods, including the transfer of some form of rights; they are made up of heterogeneous objects such as technical devices, infrastructure, knowledge, discourses and narratives, and lastly, they create a space for confrontation (p. 3). This perspective has its roots in actor-network theory (ANT), which has at its core flat ontologies (Latour, 2005, 2012). Cochoy, Trompette, and Araujo (2016) notes that this is problematic for market studies where markets are not conceptualised simply as a device which facilitates exchange but that, through agency, the actors are active in the shaping of the marktet. To address the lack of accountability of agency, the term 'agencement' is used instead of arrangement. The word 'agencement', which is borrowed from French and has no suitable English translation, is a play on the words 'arrangement' and 'agency' (Hardie & MacKenzie, 2007). It contains the "constellations, equipment, instruments and infrastructure" (Berndt & Boeckler, 2023, p.126). This allows a very explicit consideration for viewing agency and asymmetry in how the actors, through negotiating in the market, result in varieties of domination (Cochoy, Trompette, & Araujo, 2016). To put it simply, "agencements are arrangements endowed with the capacity of acting

in different ways depending on their configuration" (Callon, 2006, p.311). As opposed to the use of arrangement, agencement is preferred in this context of biogas systems. Agencement foregrounds the important activity taking place between the different actors', devices, and materiality and the term allows for adequate room to account for the different public and private positions. However, the focus on the arrangement of actors can also help when understanding how methane or nutrients can have the same material components. However, depending on the configuration of the agencements, the outcome of marketisation can vary. It is then this active work that we can follow when we view the socio-technical as an agencement (Caliskan & Callon, 2010).

Another significant contribution from the sociology of markets is the foregrounding of the heterogeneous parts which make up the market. One component is conceptualised as a device. The term market device refers to the "material and the discursive assemblages that intervene in the construction of markets" (Muniesa, Millo, & Callon, 2007, p.2). Doganova (2020) stresses that a focus on devices in markets should not be taken as a unit of analysis as such, as this can allude to there being a preconfigured object to study. Instead, the research can use the concept of a device as a point of initial inquiry, a place to begin the unravelling of the actors, agency and arrangements which has brought the device forward and made it part of the market. The market devices considered in this thesis include the valuation devices for socio-economic value and the discursive devices that used to promote biogas.

3.3 Value and Valuation

In addition to having a problematic view of markets, traditional neoclassical economics has thus been argued not to have the tools necessary to adequately assign value to objects which are outside of economic exchange practices. Tools such as cost-benefit analyses and willingness to pay have been developed within fields such as ecological economics, but have been criticised as being insufficient to deal with ethical issues such as discounting future needs and the problem of assigning a monetary value to nature (Hwang, 2016; Isacs, 2021; Spash, 2017). I proffer that one important aspect of the problem with these methods centres on the problem of definitions of value and the use of these conceptions of value.

Within marketing and consumer research, numerous conceptions of the word value exist, e.g. shareholder value, use value or identity value. These stem from different ontological underpinnings of the word, such as economics, psychology, or sociology (Karababa & Kjeldgaard, 2014). Considering the definition of 'value', Vatin (2013) clarifies that the word can exist as both a transitive verb, a verb needing an object – to value something, and as a noun. First, we may consider the verb "to value", to evaluate, as Paper II explicitly deals with. However, this form of the word cannot be separated from its noun form, when we talk about the value of biogas in terms of monetary amounts, for example. Similarly, the value we found, as a noun, cannot be separated from the verb form. Vatin argues that the French language adds a clearer distinction between evaluating (évaluer) and valorising (valoriser), while the English verb, as defined, contains both of these concepts to some extent (Ibid.). The noun form is encountered more often when describing a biogas market, such as 'the value

of increased biogas is worth X amount to the local economy'. However, in this thesis, I have considered these two forms of 'value(s)' in the context of unpacking what happens during the valuation in order to better understand the link between the two.

Vatin (2013) argues that valuation comes in two processes and that a clear distinction should be maintained between these two forms in order to unpack what is included under valuation practices. The first is value assignment, or simply what is the value? The second is the reflexive form, i.e. is it worth it? In this context, we see the need for valuation and clarity in values in order to understand decision-making by public actors regarding matters such as renewable policy support. Regarding the valuation of nature, some argue that questions such as 'is it worth it?' cannot be answered without bringing in ethics and justice (Jacobs et al., 2016). This question entails various forms of judgement and will always be variable over space and time. This is the case for the valuation not only of nature but also everything which is deemed to be 'peculiar items'. These are objects that are socially construed to be beyond the reach of money, such as love, life, nature and art (Fourcade, 2011a). Specific to nature, which is a major component of the valuation of biogas systems, it is argued that any valuation of nature within the current market paradigm will always be in conflict with a belief in the intrinsic value of nature (McCauley, 2006). In addition, this valuation of nature with its perceived ability to capture both intrinsic and cultural values, can do so at the peril of wider justice issues. Monetary valuation has been argued to have the potential to exacerbate the problem of social justice, as the process itself is designed to protect the status quo, such as dominant cultural values, and does not reconcile unequal access to resource control (Matulis, 2014; Schaafsma et al., 2023).

As policy-makers and civil servants grapple with decisions relating to sustainability, they are either directly or indirectly asked to make valuations of nature and our impact on nature. The valuation of nature has been debated extensively within the practices of valuations for ecosystem services. There, it has been argued for the last two decades that the valuation of nature is the only mechanism available for avoiding complete environmental destruction (Costanza et al., 2017). Others have argued that, despite the problems, it is still the best way of tackling environmental problems caused by economic activity (Jacobs et al., 2016). This builds on the role of valuation in its broad sense of 'assigning importance'. Highlighting that value and valuation are not always concerned with monetary value, it is also argued that the challenge is to ensure that valuation practices represent the stakeholders' values, which can be social, economic and instrumental, as well as environmental and intrinsic value (Ibid.). This desire for pluralism has resulted in methods such as socio-economic analysis [4], which can be viewed as part of the valuation that accommodates matters of concern, which will be discussed in the final section of this chapter.

Two of the concepts intertwined with valuation which are important to consider as we unpack valuation practices are comparability and commensuration. Comparability, linked to the definition of singularization, is essential in creating products and their markets by making the product known, enabling them to be singled out, yet still

[4]Socio-economic valuation is not the only method to aim for pluralism. Other methods, such as multi-criteria decision analysis, have similar aims (see Lindfors (2022))

able to be compared amongst other objects (Callon, Méadel, & Rabeharisoa, 2002). Commensuration is the translation of qualities into a common metric and is not always for the end purpose of setting a monetary value (Espeland & Stevens, 1998; Styhre, 2013). Commensuration can be used to allow prioritisation, justify prices, and rank. However, this practice is equally socially constructed (Beckert, 2020) and can, through the use of tables, ratios and other devices as a technical endeavour, be represented as an essentialist fact (Espeland & Stevens, 1998). The authors argue the problem with comparability and commensuration is that it can exclude properties which are hard to measure (Ibid.). This is especially true with peculiar objects which must be valued through specific "Intermediaries and technologies" (Fourcade, 2011a, p.1173) which have been used in market-shaping. This thesis has specifically examined intermediaries and technologies, such as cost-benefit and socio-economic analyses, but also pricing and discourses, whose central purpose is to provide a device for comparison and commensuration. However, strategies and public discourses have also been used to assign value to various peculiar objects ranging from greenhouse gas emissions to energy security. These concepts can also help us unpack how objects such as biogas and biofertiliser are used to create value and shape markets through comparison and commensuration.

3.4 Matters of Concern

Previously, societal concerns were discussed as part of the problem and solution framing which was shown to be part of public strategy and the formal production of value through socio-economic reports which built support and legitimacy for the support for the biogas market. I will now expand this discussion to include the framing which occurs as part of market shaping, considering a wider space than public policy and strategies, primarily through the public framing of biogas as a product. These framings are important, as they are part of a sociocultural framing and act as a "alternative communication strategy to the dominant monetary value quantification approach" (Närvänen et al., 2022, p.212). For this reason, considering the framing of products can help us to understand the value placed upon biogas and the biogas system, and how concerns are addressed. As societal values and concerns come into play within a market, economic value can be created or destroyed, and markets are shaped.

The biogas market has been approached and analysed as a concerned market. A concerned market is a market where the economic and the social are combined, where the exchange of money is used to drive a desire for political, social or environmental concerns [5] (Barman, 2015; Geiger et al., 2014b). Products do not always enter the market as such, but can change narratives to position themselves as green and respond to matters of concern(Reijonen & Tryggestad, 2012). It is closely linked to formal valuation practices in that it creates a need for valuation and reacts to practices of valuation (Roscoe & Townley, 2016). The biogas market comprises and affects public concerns. At times, these concerns are linked to wider concepts such as energy

[5]This definition is given along with the same sentiment by Geigher et al, i.e. that in fact all markets are the results of concerns; in other words, "there are no markets without concerns" (Geiger et al., 2014a, p.14)

security or creating a fossil-free region, while at other times they address much more specific concerns such as soil health, nutrient recycling or local air quality.

Matters of concern, building on the Latour's work (Latour, 2004) can be thought of as a politically charged interpretation of a matter of fact. Separating matters of fact from matters of concern, Callon (2007) argues that we can follow value and value creation by charting how solutions, whether social or technical, are brought forward and brought into the market (Huguenin & Jeannerat, 2017). In a similar vein, Skjølsvold (2013) notes that, within energy policy aimed at tackling climate change, we are often faced with arguments that either appeal to matters of value or matter of fact. Cochoy (2014) warns against viewing concerns as an external phenomenon, a pressure 'on' a market, and notes that they can also develop from within a market as actors try to make concerns known for the benefit of their product.

As discussed in the introduction, biogas can be considered to be a sustainability object and, as such biogas, is promoted by public and private actors to overcome concerns. The sustainability of biogas is considered to be performative (Corvellec, 2016), meaning that its status as a sustainable energy source is socially constructed. Therefore, as new concerns are raised, its sustainability status can change, as was witnessed in the case of ethanol. This first-generation biofuel lost both its societal and political support as its sustainability came under question with the rise in concern for land-use change and food crops for energy use (Mohr & Raman, 2015). The biogas system as a market is also influenced by changing societal concerns, such as energy security and the rise in concern for nutrient recycling.

3.5 Hot and Cold Markets

Callon has introduced the term 'overflow' to describe what happens when externalities in a market are created. An overflow occurs when the frame or boundary of the market is breached. This overflow, which economists view as externalities, requires the market frame or border to be redrawn. Cochoy (2014) has used Callon's concepts of hot and cold markets to describe concerned markets, where a cold market is characterised by overflows which are internalised or agreed outside the market. In contrast, a hot market is one where the concerns regarding overflows begin to matter (Geiger et al., 2014a). In these hot markets, work is required to (re)negotiate the boundaries of a market and matters of concern are invoked (Callon, 2009; Geiger et al., 2014b). The enactment of concerns can heat up a cold market (Cochoy, 2014). D'Antone and Spencer (2014) use the example of the palm oil market to illustrate the influence of concerns. These concerns were introduced after the market had already become well-established and made the market hot. This forced actors in the market to react and create different versions of the market to address the different concerns, such as environmental and social justice. This concept can help us to understand both drivers for biogas market development, such as replacing fossil fuels for transport purposes or the need to recycle nutrients. It can also help us to understand how evolving tensions continue to shape the market, such as the effect of fossil gas in the biogas market which will be discussed in Chapter 6.

Two concepts will be used to describe what happens as markets heat up or cool down: pacification and singularisation. Pacification has been used to describe the cooling of products or entire markets. This pacification process is a form of framing which is necessary in order for products to participate in the market. According to Callon and Muniesa (2005), a transaction cannot take place without framing. In his example, a car which has been purchased does not come with effects such as pollution, traffic fatalities or exploited workers. This is agreed by the buyer and seller to be outside the exchange frame. However, this framing is not inherently static. Rather, it is essential, as it makes the item known, discrete and packaged. Karnøe, Kirkegaard, and Caliskan (2022) define pacification as the process which allows the qualities of a product, be they economic or non-economic, to be qualified in such a way that they are known. In the authors' case of wind energy, as in the case of palm oil, this is not a static situation and must be maintained through constant work. Whether or not the status of an object is pacified will, in turn, affect whether the market is hot or cold.

Singularization is a similar concept to pacification in that it describes the process by which products are made known but not necessarily linked to concerns. Here, the focus is on the process by which comparison is made and the object is made open to calculability. This means the product can be both distinct and compared at the same time. This process of reduction and calculation removes social complexity and allows the circulation of goods (Callon & Muniesa, 2005). The process of singularisation results in framing and with this comes a boundary which can be recognised and agreed upon as being the place where the market begins and ends (Berndt & Boeckler, 2023).

This changing of the boundaries of products and the market, driven by controversies and concerns, can be helpful in understanding how the value of biogas, as a sustainability object, is influenced by other concerns, such as fossil gas, mineral fertilisers or animal husbandry. The market must redraw the boundaries to incorporate the concerns, so that the market is cold and therefore unquestioned.

4 Method

4.1 Methods and Materials

This chapter outlines the research journey over the timeline of the project. I start by introducing the motivation behind the case selection and then introduce the three regions. This is followed by a description of the methodological approach, with a discussion of the role from a multidisciplinary perspective. This is followed by a presentation of the methods used: interviews, documents and media analysis. Finally, the analytical methods used are addressed.

Using Case Studies

The case study is an overall approach that explores multiple perspectives and uses methods that investigate phenomena which are contextual by nature. The situatedness of the phenomena is central to the study itself (Lewis & Mchnaughton Nicholls, 2014) Although case studies can vary in form, Yin points to one definition, noting that in a case study, the "boundaries between phenomena and context may not be evident" (Yin, 2018, p.15). Case studies in general and this one in particular are often built upon examining and collecting data on multiple features or aspects of the case. One critique of case studies is that they lack the possibility of generalisation. However, one answer to this which is relevant in this thesis is that generalisation is not always the aim of a case study. The value of a case study may be that application of the results or findings which takes place through identifying a conceptual or theoretical contribution can in turn lead to the transferability of knowledge (Hammersley, Gomm, & Foster, 2011).

The case study was chosen as an overarching method for comparing and contrasting visions, strategies, values and local markets of biogas market expansion in three Swedish regions: Jönkoping (pop. 368 856), Kalmar (pop. 246 667) and Gotland (pop. 61 029)[6]are shown in Figure 2.3. The decision to collect data from multiple regions initially allowed for an inductive approach whereby, after entry into the field, I could begin to investigate the differences between the regions. This activity spawned further questions about how these differences were affected by market and policy arrangements. It should also be noted that, although data was collected and reflected upon using a comparative case study approach, the research questions were not answered via this approach alone. However, it warrants discussion, as it has been a pivotal feature of my data collection.

The form of a case study approach will depend on whether the case is meant to be explorative, descriptive or explanatory (Mills, Durepos, & Wiebe, 2010). Initially, the approach was closest to an explorative design with an ambition of theory generation. Identifying regions with similarities in current biogas production, biogas strategies and regional population make-up was desirable. The regions also required ambitions and political advocacy for a biogas market that were similar, though not identical. However, choosing an outlier was also considered to be noteworthy. One region, Gotland, considered to be an outlier, was also selected for this thesis. As an island with only limited ferry access, its position entails distinct infrastructure considerations compared with mainland regions. To enable comparison, infrastructure considerations have been included in the analysis. As has been discussed previously, the presence of a fossil gas network has significant impacts on the development of a biogas market (Nevzorova & Kutcherov, 2019). Therefore, regions such as West Gotland and Skåne were excluded at an early stage in the project, and the focus was placed on regions with similar access to fossil gas infrastructure.

The counties of Jönköping and Kalmar are comparative examples of neighbouring regions with comparable size and population density. The comparison of these two regions with Gotland, which is an island with specific geographical challenges, allowed for a contrasting perspective and a deeper understanding of the challenges that are specific to the island. As Figure 4.1 shows, Jönköping and Gotland have experienced prolonged periods of stagnation, although Jönköping has increased since 2020. Kalmar has seen steady growth, although it only produces 6% of its potential and has two large-scale plants at the planning stage. When these plants are in production, the region will produce 245 GWh of biogas (Region Kalmar, 2020). Figure 4.2 shows the three regions with biogas plants that are in production or planned.

[6]Population data from 2023 SCB, 2024

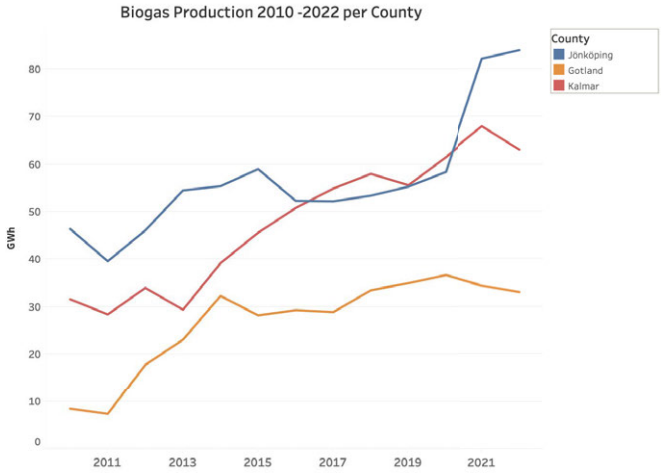

Figure 4.1: Comparison of biogas production in the three selected counties.

Data collected from the Swedish Energy Agency (2023)

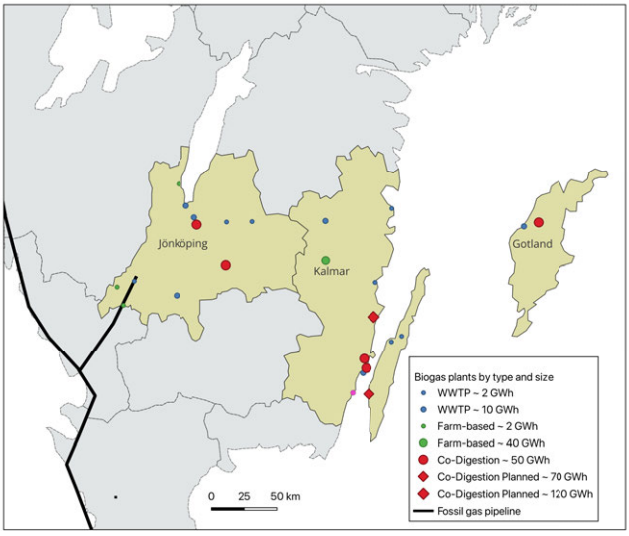

Figure 4.2: Biogas plants in the three selected counties.

Data obtained from Energigas(n.d)

Jönköping

The Jönköping region is geographically located between Sweden's three largest cities: Stockholm, Gothenburg, and Malmö. The largest city, Jönköping, is situated along

one of the country's busiest transport corridors. Biogas production in 2010 was limited to production from WWT and food waste in Jönköping and Vetlanda, producing approximately 30 GWh. In addition, small-scale projects started by local farmers were underway in Sävsjö and Reftele. In 2010, the region set a goal of becoming a plus-net energy region. This would be achieved through a combination of energy efficiency initiatives and an increase in the production of renewable energy, where solar power and bioenergy from forestry products would alone account for half of the project's approximately 8,000 GWh to be produced in 2020. Other renewable sources, such as hydro-power, would grow slightly in that period, and biogas production was projected to increase from 30 GWh to 240-360 GWh by 2020 (Länsstyrelsen i Jönköpings län, 2010). However, this did not happen. In 2022, the county produced 84 GWh across 15 different plants [7]

Despite not achieving their goals, the public actors were active in various market building activities during the period under study. In 2011, the "climate board" (klimatråd) group was formed, hosted by the county administrative board. This organisation aimed to involve all actors within the county who could and wanted to contribute to the goal of becoming a "plus energy" county. Today, this organisation has over 50 members, ranging from larger industry actors such as Ikea to local high schools, and includes public and private sector actors. In 2014, the climate board worked with the regional energy office to initiate a project focusing on biogas, rather than a general approach to all renewables. The project consisted of networking and knowledge production regarding biogas's economic and social benefits. In addition, the project formed a new biogas network, focusing on networking for information exchange to civil society and was directed at politicians and decision-makers. The project acted as a focal point for work relating to marketing activities for biogas, involvement in the procurement of public transport, and lobbying at local and national level. However, one of the significant outcomes of this work was the biogas agreement. This agreement was meant to overcome one of the challenges being encountered in the region, namely that biogas expansion required a distributed network of refuelling stations, but there was unequal uptake by the various municipalities with regard to this initiative. The biogas agreement brought together all the municipalities in an agreement to provide at least one refuelling station.

Kalmar

This area is commonly recognized as having an excessive amount of substrate, but a shortage of biogas and biofertiliser consumption needs. This presents a contrast to the neighbouring region of Jönköping, with its lower level of agricultural activity and stronger presence of the transport sector. Kalmar has been actively involved in the development of biogas since the late 1990s. The development initially focused on using WWT as input, which was typical for the Swedish biogas industry at that time. The first plant was located in the city of Kalmar and was one of the first in Sweden to adopt co-digestion, an important step in handling the large amounts of organic material from the agricultural sector. Some initiatives, such as the "Amanda" biogas train, represented bold and ambitious steps in the biogas market, but for var-

[7] This includes biogas from co-digestion and from recovered gas from landfills

ious reasons, failed to be converted into working long-term solutions. Nevertheless, these initiatives demonstrate the region's commitment to extensive and innovative solutions.

Like the other regions, the end of the first decade saw the region's first biogas strategy. National climate programmes, such as the KLIMP programme, were used to fund the construction of the co-digestion plant in the region, but they also funded new refuelling stations, in addition to other essential steps in market building. One of these was an energy office, a network that was considered to be important in the early stages of market building. These activities coincided with the "No Oil" programme. This programme, which began in 2006, was gaining momentum and aimed to eliminate the use of fossil fuels in the region. As discussed within the broader Swedish context, it was deemed to be most feasible and appropriate to promote biogas for transport use, as Swedish emissions were already so low that replacing electricity did not have as significant a climate impact. In addition, the region felt the biogas market was already significantly mature to continue its expansion. In 2014, at county administrative level, work began with neighbouring counties to promote the use of biogas through engaging broader actors and functioned as a learning period for those working operationally with biogas.

Gotland

Gotland, a sparsely populated island of just 65,000 inhabitants situated in the Baltic Sea, is known for its rich cultural heritage and is a very popular holiday destination. Primary industries include agriculture, tourism and the cement industry. The agricultural sector has significant arable agriculture and animal husbandry. The region has been active in improving its environmental impact, as it has significantly higher average carbon emissions per gross regional product (GRP) than Sweden (SCB, 2022). One of the initiatives that the region has been working actively on over the past ten years is through strategic public transport procurement, where they believe that the use of biomethane in vehicles and industry offers the potential to make a positive impact.

The island has set ambitious goals for its production and consumption of biogas. Recent studies showed that 165 GWh could be produced using manure and other organic waste streams (Larsson et al., 2023). These goals for biogas production form part of a wider framework of environmental goals which strive for the island to be climate-neutral regarding its energy supply by 2025. Gotland has been actively working on a biogas strategy for more than a decade, with its first explicit strategy being published in 2009. Since then, the goals and expectations for the upcoming decade have been laid out clearly. In 2014, this strategy was reviewed and updated. Initially, the island set a target of producing and consuming 100 GWh of biogas by 2020, of which 30 GWh was to be upgraded to vehicle fuel. These goals have yet to be achieved, as total biogas production currently varies between 30 and 35 GWh. The island also set a target for 2030 of producing 300 GWh, which will require considerable expansion of the current production and market available on the island. Today, despite the stagnation, biogas is still the primary preferred fuel for Region Gotland, with procurement rules stipulating that 70% of public transport should run on bio-

gas. The region has considered itself the primary driver for biogas consumption on the island (Gotland Region, 2020)

As of 2022, Gotland has two active biogas plants. The largest of these is owned and operated by a private company. It produces approximately 25 GWh (29 in 2015) of energy, with the main substrate originating from manure supplied by nearby farms, notably pig manure from a neighbouring farm. BroGas also uses residual products from the food industry, household waste and agricultural by-products. The second plant on the island, the municipal wastewater treatment (WWTP) plant in Visby, also generates biogas, and this output is either upgraded to vehicle fuel or used for heat generation.

Comparisons

The three regions were initially compared in terms of their policy and strategies. They shared a commonality, having all set ambitious targets for biogas production in the range of 250-300 GWh. This indicated a political commitment and belief in biogas. However, the three regions were at varying stages of market development when the project began in 2019. All three had used procurement in order to build a biogas consumption market, which led me to investigate issues outside of procurement as a strategy tool in order to elucidate the differences that led to the varying degrees of success in achieving the ambitious goals.

4.2 Methodology and Research Approach

Research Setting and Approach

This study is based upon a realist social constructivism perspective. Many of the theories I have engaged with have their roots in science and technology studies (STS), which start from the assumption that the world, both natural and social, is constructed (Hacking, 1999; Lynch, 2016; Sismondo, 2017). From an STS foundation, the sociology of markets and valuation studies have developed. What these bodies of literature have in common is the view that the phenomenon being studied is co-created through the actions of individuals, through discourses, practices and devices. Nevertheless, the theories differ in their weighting or focus on the 'the social' or 'the material'. A realist perspective focuses on the importance of the objects which exist, regardless of our observation of them (Barad, 1996). This is based on the argument that, by combining the two traditions of realist and social construction, when appropriately considered, rather than being binary opposites, they can be used in complementary ways (Elder-Vass, 2012). Working in a multidisciplinary department and, more importantly, being part of a multidisciplinary research group, I have come to see how one's theoretical lens changes the field's boundaries. In turn, this affects the research question and how one processes the information that unfolds during the data collection period. The 'field' for some of my colleagues within the research group was implicitly understood to be political arenas, while for others, it was energy technologies. By way of contrast, for my own purposes, the field could be defined as

the markets which are linked to sustainable transitions, and this positioning impacted the formation of questions and, significantly, the analysis process.

The choice of analytical orientation has been an iterative process. My position has, to some extent been to let the data direct me to the theory. Nevertheless, I have also used a particular theoretical starting point inspired by STS to begin the analysis. This section starts with a brief description of the analytical tools used. As outlined in the theory chapter, the data analysis was influenced by pre-existing theory. The identification of analytical approach is important, "For, without some analytic orientation, one would not recognise the 'field' one was studying, let alone be able to formulate a research problem therein" (Seale et al., 2003, sec:Analytical Frameworks). The multidisciplinary setting is appropriate, as it has been argued as being suitable for combining societal and scientific problems (Jahn, Bergmann, & Keil, 2012), such as sustainable energy transitions. The mission of the Biogas Solutions Research Centre (BRSC) is to create a multidisciplinary centre of expertise where "in-depth collaboration between scientific disciplines and with practitioners, new solutions and analyses of the contribution to a sustainability transition to actors along the value chain, to the biogas sector and to communities at large" (Linköping University, n.d.). This collaboration takes place in research groups, such as the regional working group and the national policy group, and is comprised of researchers, civil servants and private sector workers.

This platform can be considered a delimited neutral arena model (Felt et al., 2016). This type of cooperation means that actors meet in a neutral setting and do not directly interact with the core knowledge production in any original domains. This produces a situation where the actors act as "gatekeepers" to the knowledge in their own domain and control what is shared with the wider group. This was considered and reflected upon during the production of this thesis. Additionally, delivering the results to the broader audience, as described below, can act as what has been described as a "reality check" for the academic members (Ibid.). The mixed group of actors was influential during the collaboration and framing stage, with, in this case, the members helping to define the research area and participating in discussions regarding how the research aims could best be answered. The group was also important during the re-integration of knowledge phase (Lang et al., 2012). The research was regularly reported back to the group, which I expand upon in the participant observations section.

Participant observations

During the course of my thesis project, I participated in frequent meetings hosted by the Biogas Solutions Research Centre, as documented in Appendix A. The meetings centred around the theme of "The role of municipalities and regions in developing sustainable biogas solutions"". The discussions provided a platform for representatives from the biogas actors, specifically the municipalities and regions, including members from the three chosen regions and representatives from other Swedish regions. In addition to this, private sector actors and other researchers were also regular attendees. The observations from the meetings have been treated methodologically as a meeting ethnography, which can be sites of ethnographic inquiry (San-

dler & Thedvall, 2017). Meetings can be rich sources for inquiry, as: "In meetings, power is produced and enacted, dynamics of identity and hierarchy are negotiated, and organisation is produced, determined, and challenged." (Ibid, p. 1). Observations have been helpful, initially in what is usually described as 'sensitising the researcher' (Glaser, 1978), and primarily helped in understanding the history of the biogas market. Becoming more acquainted with and aware of the issues, questions, framings and problems which were important to biogas actors, specifically the public sector, later became vital. As noted previously, these meetings enabled me to share my work in progress with others, including the representatives from the regions under study. These presentation moments led to group discussions, which enabled my understanding and analysis to be questioned and the material from the regions to be re-formulated or restated. Although it was not possible to know beforehand the exact make-up and content or the audience for these meetings, the process can be considered to be worthwhile, as described by Lewis and Mchnaughton Nicholls (2014), who argue that group discussions can act as sites for data collection and, importantly, for validation.

The data collected during these meetings is considered to constitute naturally occurring, or naturalistic, data, argued as being preferable (Potter & Hepburn, 2008), and has been treated in this thesis as one way of balancing the researcher-provoked data (Silverman, 2020). To maintain the integrity of the meetings and allow for open discussions, I chose not to formally quote or cite any particular person in the meetings, as this might have introduced a degree of censorship in the discussions. The meetings allowed observation, note-taking, and informal discussions with participants. Thus, the meeting notes were used as a part of the data collection process and were not used in the coding. The notes were included in the note-taking and sense-making of other data sources, such as policy documents and interviews. At times, I acted as co-ordinator during the meetings and could therefore influence the topics being discussed. On other occasions, I participated in the meetings and could ask questions and share opinions. However, for much of the meetings, I assumed the role of participating observer, enabling naturalistic data to be collected. Although this could be labelled as participant observations, this was done with the warning: "There is no such thing as non-participant observation" (Smith, 2002, p.87). I have therefore reflected on the effect that my presence might have had on the discussions. The exception to this approach with regard to meeting notes occurred during Paper IV. In this instance, the meetings I attended were open to the public, both face-to-face and online. As these meetings were open to the public, I felt that there were no issues relating to coding of the data or using it as part of a deeper analysis. Details of these meetings can be found in Paper IV.

Methodological Triangulation

Methodological triangulation was chosen to produce data that is as rich and detailed as possible. Although some fields use triangulation as a way of creating objectivity, this work was based on the premise that an objective reality is neither possible nor the goal. Instead, triangulation was deemed necessary, as no single source could provide the depth and richness of data required (Wadhwani & Decker, 2008). In addition to the methods which are outlined in the preceding section, quantitative data,

e.g. concerning the production and consumption of biogas, was used to contextualise the primary data sources. At times, this also enabled new sub-questions to be developed, e.g. noting the stagnation in the biogas market in a specific region or analysing consumption patterns.

4.3 Methods – Data Collection

This section presents the methods that were used and the data that was collected in this research project. Table 4.1 outlines the methods that were used in each paper, along with the theoretical focus and analytical tools that were used. In addition, the aim and objectives of the wider thesis question are presented. This is followed by an in-depth discussion, focusing on the primary methods used for data collection — namely, interviews and document analysis.

Interviews

A pivotal source of data was the use of interviews. This method was chosen as the research questions were aimed at understanding the opinions, processes, values and accounts of events surrounding the development of the biogas, which, according to Rowley (2012), makes interviewing an appropriate method. It was discovered early in the research process that, within the regions and municipalities, particular individuals had important information regarding the history of the biogas market and the rationality for biogas support. Twenty-four interviews were conducted as shown in table 4.2 and, although not all were used in all papers, they were analysed when approaching the overall research questions [8]. A detailed list of each interview is found in Appendix B table 8.2. The participants were selected through purposeful sampling to remain in line with the aim of providing "information-rich cases" (Baxter & Eyles, 1997a, p.513). The search for participants began within the biogas research network, whose members share an interest in renewable energy and biogas advancement. From there, the specific regions were selected for the study. Once the regions had been selected, appropriate respondents were suggested during research group meetings, leading to a snowball effect in participant recruitment (Parker, Scott, & Geddes, 2019).

The interviews were conducted based on a semi-structured interview guide. Semi-structured interviews should involve an interactive exchange between the interviewer and the interviewee, but not an open conversation. This enables the interviewer to actively raise specific questions and points, while at the same time retaining enough boundaries to address the research question (Noaks & Wincup, 2004). The interview guidelines centred around the historical role of the public and private sectors in biogas market development, the recognition of value within biogas systems, and challenges and barriers to current and future biogas market development. The interview guides were adjusted to reflect whether the respondents were from the private or public sector and if they were primarily involved with biogas, biofertiliser or both.

[8] All interviews were conducted by myself except for one interview which was a part of Paper IV and was conducted by my co-author

Paper	Study Area	Methods	Analytical Frame-work	Results
I	Kalmar Jönköping Gotland	Longitudinal comparative case study Interviews, policy documents	Thematic Analysis – Codebook	National mission was insufficient to align the needs of all market actors. Vision was created to match a wide range of actors, resulting in increased support
II	Kalmar Jönköping	Interviews/ Valuation reports	Thematic Analysis	Valuation process occurs in a series of steps: motivating, scenario building, qualification or quantification, and finally a monetizing or narrative production.
III	National /regional	Media sources	Narrative Analysis Frame analysis	Political and economic framings show the bridging narrative changes over time and space. The relationship between fossil gas and biomethane is built largely upon material synergy, but the market still requires boundary setting and market framing.
IV	National	Interviews and media sources	Thematic Analysis Frame analysis	Growing attention on circularity and benefits such as carbon storage, soil improvement, and food security becoming increasingly important, and the paper concludes that the dominance of biogas could change.

Table 4.1: Methods employed throughout the project

Description	Geographical Scope	Number
Public Actors	Kalmar	5
Public Actors	Jönköping	3
Public Actors	Gotland	2
Biogas Production	Multiple	4
Biofertiliser Companies	Multiple	7
Biomethane Project	National	1
Biogas distributor	National	1
Energy Office	Gothenburg	1

Table 4.2: Summary of interviews conducted

Interviews have come under critique as a method, an issue which was considered as part of the research design (Baxter & Eyles, 1997a). Hammersley (2003) argues that the critique is not merely concerning how to fine-tune the interview approach,e but questions whether the interview can ever help us understand a phenomenon. The critique at the core of this is whether accumulated data can be said to be a reflection of a reality, internal or external. Some see the interview from a realist perspective, where the interview material reveals reality (Seale et al., 2003). Continuing on from a realist social construction perspective, I have used the interview's output 'as topic', which acknowledges the reality-producing or co-construction of reality that occurs in highly social interactions such as the interview (Rapley, 2004). From this perspective of the interview, the researcher is an active participant in the co-production of the data and thus requires reflexivity throughout the research process. When done in this way, the position of the researcher can be a strength of qualitative research rather than a source of potential bias (Baxter & Eyles, 1997b).

One way to approach the critique of interviews as a method, as argued by Martin and Coenen (2015) and considered in this project, is to draw on inspiration from the interactional analysis. When the interviews are transcribed, it is suggested that the interactions within the interview should be recorded and analysed. Although transcripts were produced using standard orthographic methods, the interviews were closely examined with extensive notes taken, which attempted to capture both text and utterances. One of the findings during the analysis of interviews was the respondents' answer to the question: "What is the value of biogas?". This revealed the absence of a common interpretation of the term 'value', and the interaction between the respondents and myself to create a shared understanding became a focal point. The same awareness of the critique concerning interviews can apply to multiple forms of data collection, such as social interaction, text, and visuals (Hammersley, 2013, p.87), which were also considered in my data collection process.

All interviews were conducted using online conferencing applications, so some discussion of interviewing in this manner should be addressed. Appendix B indicates when video or video and voice were used. Prior to the Covid-19 pandemic, online interviews were gaining attention and popularity among qualitative researchers. However, discussions revealed that it was not uncommon for it to be framed at best as

a methodological compromise and at worst should be avoided where possible (see Keen, Lomeli-Rodriguez, and Joffe (2022) for an overview). For this thesis, I have considered some of the posited downsides of video interviewing, specifically questions of access, non-verbal cues, respondent fatigue and in-depth personal responses (Nehls, Smith, & Schneider, 2015).

The issue of access to online interviewing tools was also deemed important to consider, as it had an impact on the selection of participants. It delimited the research to some extent and should be acknowledged as a constraining factor for the results. After March 2020, visits to potential participants such as farmers and biogas production operators became difficult due to the COVID-19 pandemic. Based on my initial scoping, this group appeared to be less interested in using video conferencing, and it therefore became clear that I should focus the research on the public actors. However, with regard to accessibility, civil servants were comfortable using video conferencing, which the participants themselves noted, although this was also evident in their interactions. For example, there was no need to explain how to use the software. The potential problem of lack of social presence or non-verbal cues was deemed not to be a barrier. This was partly due to the ability of video conferencing to enable a high degree of transmission of social cues as both giver and receiver (Ibid.). However, two interviews were conducted without video due to technical issues, which should be taken into consideration. Social cues and their effects on in-depth discussions have been considered as part of the research method. The questions were designed to elicit the official happenings and positions of the actors, as opposed to seeking to elicit the respondents' emotions or personal understandings of the situation in question. Thus, it was deemed not to be an important factor. However, as mentioned previously, when the interviews began and the ambiguity concerning the concept of 'value' became apparent, I began to focus more on how the respondents negotiated the questions, paying attention to when they found the question straightforward or something which required prompting in order to find a common interpretation.

Document Analysis

The analysis of official documents, interview transcripts and meeting field notes was a significant source of the data analysed in this thesis. The following section briefly discusses document analysis as a tool as it applies broadly to the thesis. The following analysis section presents discussions of the specific form and use of textual analysis.

Document analysis can be an important source for data collection, particularly in highly bureaucratic arenas such as government policy-making, as "the particularities of documents, the circularity they are part of and comprise, constitute a key entry point for understanding the unique features of these institutions" (Asdal & Reinertsen, 2021, p.26). Documents are social products (Hammersley & Atkinson, 2007) and 'do something'. Their purpose is to connect and perform an action and, as such, they can be important sources of data in understanding a phenomenon (Asdal & Reinertsen, 2021). Appendix C shows the complete list of all primary public sector documents used in the comparative case study, while a classification of these documents is presented in table 4.3. Relevant documents were found using web-based searches, including webpages, public documents and press releases. This was combined with

consulting with respondents from the three regions. The meetings also provided opportunities to inquire about relevant policy and strategy documents.

Type	Geographical Scope	#
Strategy and Policy	Kalmar	18
Strategy and Policy	Jönköping	13
Strategy and Policy	Gotland	19
White Papers/ Reports	National	11
Remittance	Regions/national actors	16

Table 4.3: Summary of documents included in the study.

Media Analysis

An analysis of media sources was used for Papers III and IV and as such warrant a short discussion on how media sources, as opposed to more general texts, have peculiarities about them that I have considered in this thesis. Media sources have been used to better understand the 'public sphere' within which environmental problems are not only discussed, but more importantly defined (Jönsson, 2011). A media analysis has been found to be particularly helpful when working with contested issues (Lidskog & Olausson, 2013; McLennan, Becken, & Moyle, 2017). This was relevant for considering issues such as the tensions within the market, such as the role of fossil gas in a biogas market or how developing concerns affect nascent markets such as biofertiliser. However, some reflection on the sources of news media should be mentioned. While print media was once seen as one of the most important spaces for political debate and influence, this is no longer the case in 2023. Both papers that used news media focused on print media, which is a limitation of the study. A further study that includes social media would be an appropriate next step.

4.4 Analysis - Analytical Framework

The analysis of the data involved the use of thematic and narrative analysis, as well as discourse and framing analysis. The following section first discusses the commonality of the analytical tools. This is then followed by a discussion of each of the analysis tools used. Analysing textual data can be carried out using different tools and techniques, and reporting on the analysis within neat and distinct boundaries is not always straightforward or even valuable. Nevertheless, some general steps were performed in the project, one of which was the coding of qualitative data. The documents, media sources, and interview transcripts were first imported into a qualitative data analysis software program (CAQDAS) to enable me to experiment with the data, such as by organising it by descriptive coding and then by categorizing it into categories. Visual displays of the coding and note-writing based on the participant observation notes were performed. This initial step was executed with little input from theory, which can be helpful as an inductive approach even when not attempting to perform a rigorous grounded theory study (Yin, 2018, p.169). For the first

two papers, where regions were compared, the coding method was used with an iterative approach for explanation building. When one explanation was found, the other case(s) were examined to see whether this account deviated from it or was consistent with it (Ibid.).

Coding

Various analytical methods were used for the four papers. Thematic analysis was used for Papers I, II, IV, while narrative and frame analysis were used for Paper III. Although there were some differences been the exact analysis methods used, qualitative coding was central to the data analysis for all data types. The overall process for coding was taken from guidelines proposed by Saldaña (2015). The analysis can generally be said to have been divided into first- and second-level coding. The first level of coding is aimed at finding patterns and reducing the data, while the second level of coding aims to develop either the higher-level categories of aggregated codes or focus on the naming of the connections between the codes. Throughout the thesis, the differences in coding form depended to some extent on the research question and aim. For example, for Papers I and IV, I used a priori codes based on an existing framework. Thematic analysis as an analytical tool is often critiqued for being poorly defined, but at its core, the primary purpose of thematic analysis is, according to Braun and Clarke (2006), to find the patterns within the data and thus enable large sets of data to be reduced or managed using a smaller set of themes. This feature of thematic analysis is not unique and is shared by many text analysis tools, such as content analysis.

There are numerous approaches to the general and broad method of pattern-based qualitative research. The distinctions between labels such as thematic, qualitative content analysis and discourse analysis are often blurred, as the traditions are heterogeneous in their practices and applications and often blend into each other depending on their use (Braun & Clarke, 2021). From a theoretical stance, this primarily occurred by focusing on macro-level discourses such as the framing of sustainability, resources and the notion of 'value. It has been argued that this pluralistic approach, the combination of themes and discursive analysis is one of the strengths of thematic analysis. The balance between the use of discursive, thematic and frame analysis can change depending on the situation (Terry, 2016), which was found to be helpful in this thesis. Analytical pluralism is argued to be helpful when the situation under investigation is considered to be complex, and the knowledge or insight gained from using different analytical methods is complementary (Frost et al. (2011) cited in Clarke et al., 2015).

Papers I and II began with a thematic approach, noting that thematic analysis should be understood as a holder for a range of different approaches but can be inductive, deductive, semantically focused or based upon latent meanings (Yin, 2018, p.18) and is so broad that it can be considered as a generic approach (Ryan & Bernard, 2003). In Article I, thematic coding was used with theoretical sensitivity, which was required as the codes and themes were derived from an existing framework for describing mission-oriented policymaking. Thematic analysis can be helpful when themes are not explicitly present in the texts, but require a degree of interpretation by the researcher (Morse, 2012). Although it began with thematic analysis, Article II was

concerned with the practices, or what the text was 'doing', i.e. how value was constructed, and can be said to be closer to a structural approach. Papers III and IV paid closer attention to the language and discursive strategies surrounding the biogas market formation, creation and maintenance. The focus on discourse within public policy and planning has been described as the 'argumentative turn' in policy analysis, which is purported to be at the base of the policy and planning creation process. Discourse contains and reveals the assumptions, legitimising, authority, interests and values. In this way, language not only describes these features, but constructs them (Hajer, 1993). Like thematic analysis, discourse analysis can be a wide, all-encompassing method. Regardless of the variation, one apparent aspect is acknowledging that language plays a significant role in creating, forming and maintaining political policy (Feindt & Oels, 2005). Summarising the justifications for putting discourse in a central position when analysing energy transitions, "words do matter in politics"(Späth, 2012, p.1258).

4.5 Research Reflexivity and Delimitations

There are a few delimitations of this study and areas of the method selection that I have reflected upon during the process of the project and are worth noting. The first is the timing of the interviews, which represents a significant contribution to the data. The interviews began quite early in the research project, and, as such, my knowledge of the subject domain was possibly not as strong as would be recommended for semi-structured interviews. For semi-structured interviews, it is suggested that, although the researcher is not expected to be able to foresee all possible or potential answers, they should have adequate knowledge to understand the limits or outer boundaries of the answers which can be expected. This has undoubtedly led to me not exploring specific avenues regarding the biogas market value chain such as substrate provision and in general resulted in the project being led more by the respondents.

In connection with the potential issues arising due to COVID-19 and the use of online interviewing which has been discussed, has meant that farmers were not accessible. The agricultural sector is a crucial and central group of actors within the biogas system. To mitigate any weakness in the project this might have caused, Paper IV focused on trade journals from this sector. These journals provide a voice for the sector in the hope of achieving some degree of representation for their concerns. The lack of representation of these voices also meant that the focus of the thesis project was centred around the consumption side of the market.

As a researcher, it is essential to take a position on the ethical considerations of the study, along with the methodology and delimitations. This research project has been designed according to the guidelines outlined by the (Swedish Research Council, 2017). The participants were informed about the project in writing and had given their consent to be recorded. They were also given the opportunity to obtain a copy of the transcribed interviews before the analysis began and retract any text, in part or whole, to which they were not comfortable consenting. The interviews were conducted in the context of the respondent's professional roles, and their identities have

been anonymised in the results. The methods used in this project do not raise any ethical concerns.

5 Summary of Articles

5.1 Article I

From global climate goals to local practice – mission-oriented policy enactment in three Swedish regions.

Published in Science and Public Policy, 2021 This article was co-written with Thomas Magnusson and Hans Andersson

The concept of framing grand challenges as missions to be tackled by governments has become popular and has been used as a rallying call for change, often led from the supranational level. Missions aim to engage a wide range of actors to tackle one of society's grand challenges or wicked problems, such as human-induced climate change. The public sector has traditionally had an active role in mission-oriented policy responses, although there are discussions over the exact form and extent of the engagement. Three Swedish regions have been analysed to discover whether and, if so, how national missions were interpreted and translated into local policy. This article builds on a framework proposed by Wanzenböck et al. (2020), which captures the dynamics between problem and solution framing of wicked problems to understand how policymaking responds. According to these authors, to achieve the goals of addressing a grand challenge, there should be an alignment between the problem view and the solution view, but the process of alignment can vary. This framework was applied in a novel way to compare developments in the regions with consideration for the temporal dimension, enabling an understanding of how the framing changes over time.

Methodologically, the paper is a longitudinal comparative case study based on document analysis and interview material with representatives from the three regions. The coding process was primarily deductive, as we applied coding based on the initial categories of the framework: contestation, complexity and uncertainty, with a sensitivity to the effect of convergence and divergence of the problem-solution framing. However, this grouping into codes deductively occurred only in the last step, after descriptive coding was performed for documents and interview transcripts.

The paper found that biogas was often used as a call to solve a wide range of problems and that a translation of the high-level missions occurs, which matches local problems and concerns. The national goals for greenhouse gas reduction were important for all regions and throughout the period of study. However, despite the importance of this national mission, it was not sufficient to align the needs of all market actors. The paper found that when looking at the local level, the same expected process of problem-solution framing did not go from divergence to convergence, as theorised by Wanzenbock et al. (2020). Instead, it was a 'messier' process, where new problem-solution framings took place at the local level, sometimes organically from a bottom-up perspective, while on other occasions, new framings occurred as a response to activities at the national level. However, when alignment occurred, strategy converged around the biogas market development.

The paper contributes empirically with insights into the local market making of biogas in Sweden and, with the upswing in interest in the development of biogas throughout Europe, there may be relevant findings for policymakers from both inside and outside Sweden. Theoretically, the paper develops the framework of Wanzenböck et al. (2020), showing the importance of considering a temporal aspect to the analysis, which is especially relevant in topics such as current environmental policy, which operates in an ever-changing system. Lastly, it contributes to the literature on problem-solution framing to demonstrate that alignment can come in a variety of forms.

5.2 Article II

From Benefits to Value(s): Biogas Systems Valuation Practices from a Swedish Regional Perspective.

Published in Journal of Sustainable Development; Vol. 16, No. 5; 2023

The article addressed the difficulties encountered with the increasing use of cost-benefit analyses and socio-economic valuations. These tools are increasingly becoming central tools used for policymaking, which results in a specific means of categorising the impact of human activity on our environment. This method of dealing with economic externalities has been questioned and argued to be problematic from ethical and pragmatic perspectives. Concurrently, the move towards quantification has been shown to affect policymaking and has been problematised as a tool which, although it creates a common language between actors, adds a new form of distance through the erasure of that which cannot be quantified (Porter, 1995). Specific to cost-benefit

analysis, one point of critique has been the built-in normative assumptions regarding value and our ability to value non-market objects. These problems are made concrete when quantification is used as valuation within the biogas system, which is a very complex multi-functional system.

This article aimed to understand the valuation process by asking three questions: What normative assumptions are bound by the process of identifying benefits and translating them into value? Secondly, the paper asked how the practice of socioeconomic valuations deals with the complexities of the biogas system and how public actors manage the knowledge produced in the valuation process. Valuography was employed as the primary theoretical lens. Valuography, following social studies of science and technology (STS) and economic sociology traditions, maintains that valuation is a socio-technical endeavour and is performative as it constructs a reality (Helgesson & Kjellberg, 2013; Molnar, 2022). The study used a multi-method research strategy, interviewing actors from the different administrative levels in two Swedish regions acting as an exploratory phase to understand the biogas market in each region and to understand the sense-making of the "value" of biogas from the public actors. From this stage, documents that pertained to formal socio-economic valuation on the regional level were identified. A thematic analysis was performed, which looked at the practices and the performativity of the reports, while keeping a sensitivity from valuography of how the values are determined.

The paper showed that the valuation process occurs in a series of steps: motivating, scenario building, qualification or quantification, and finally, a monetised value or a narrative is produced. This process allows a translation of the benefits of biogas to be understood as value. The paper found that there is a preference for the quantification of benefits. However, despite the reports' use of a final socio-economic value for biogas production, unpacking these tidy end numbers revealed a messy and uncertain basis. The effect of quantification and its importance can be understood when we foreground the role of both abstraction and political work, which occurs in the processes (Mennicken & Power, 2015). Nevertheless, as not all the benefits could be quantified, such as the value of regional development or the value of reaching political goals, qualitative value-making was also employed.

The findings of this article contribute by adding to the empirical literature regarding biogas systems, an example of a complex multi-functional system which is intertwined with multiple social, political and environmental systems. This paper found that the degree of complexity has resulted in an inability to reach a fully quantitative and monetary value. This may be relevant for policymakers, as they attempt to use socio-economic valuations in decision-making to consider the importance of a pluralistic view. Theoretically, it contributes to the field of valuography by bringing forward an example of how one can analyse environmental concerns, using the theory to make visible what is too often invisible.

5.3 Article III

The marketisation of the methane market - an investigation into the framing of biomethane and fossil gas in Sweden.

Submitted June 2023

The war in Ukraine brought our relationship with fossil gas to the forefront of our minds for both citizens and politicians. Fossil gas [9] and biomethane often exists in Sweden, as elsewhere, in the same market. However, the tensions between the two objects have been understudied. Tensions are found when one fuel, which is argued should fall under a 'keep-in-the-ground' policy, is mixed with biomethane, a fuel promoted at the local, Swedish and European levels for being green and sustainable. At the same time, we also see a contrast with fossil gas, which has been targeted as part of the phase-out of fossil fuels while being positioned as a cleaner choice for energy. Biogas systems, on the other hand, has attracted both increasing political support due to its ability to replace mineral fertilisers and fossil fuels and support for its exemplification of circularity. This paper considered how biomethane and fossil gas markets are framed as connected, whether this connection is an enabler or a hindrance for biomethane and whether this has changed over time. As biogas is a locally anchored product, the question also asked whether there were differences in the framing at regional and national levels.

To understand the public framings, the methodological choice was a media analysis covering the period of 2015-2023 and consisting of regional and national newspapers and public relations material from one of the national gas actors. The material was initially coded based on the framings of fossil gas in the literature: environmental, economic growth and bridging fuel. The text was then analysed for valence, that is, whether the frame was positive or negative. Marketisation theory drove the second coding phase by considering frames for product singularisation.

The findings support the existence of the original frames and, when considering biomethane and fossil gas together, two additional frames could be found: political and infrastructure. The bridging frame, previously discussed in the literature for fossil gas, was found to be more nuanced and complex when considering the directionality of transitions, the temporality, and the actors involved when considering the narrative for a common methane market. The paper demonstrated that the political and economic framings indicate that the bridging narrative changes over time and space. It was also found that the framings of the market create visions for the future, which are strategically built upon a degree of vagueness.

Additionally, the paper demonstrated that the marketisation of biomethane occurs within a larger methane market, which must be created and maintained by institutions, businesses, politicians and lawmakers. The singularisation of the products was an important part of the framing needed to stabilise the market. Without the work of boundary setting and market framing, the two products may, despite materiality, not have been placed together. Efforts have been made to frame them as part of a single

[9] In this article, I decided to use the term 'fossil gas' rather than 'natural gas'.

methane market at times and, to a lesser extent, some actors have done the opposite in order to singularise biomethane. The effect of the bridging narrative on the market shaping of each product has not been entirely positive for either side.

This paper adds to the existing literature on marketisation with its novel analytical approach, which demonstrates the usefulness of combining concepts of framing with the concept of framing, which is part of marketisation. By applying the concepts of marketisation and media work, it offers valuable insight into the creation and maintenance of markets. It can also contribute to a better understanding of the role of market framing, narratives, and active work concerning the biomethane market. This can assist actors, specifically within the public sector, in determining how their policies should support growth within the market. This research is especially relevant given the pressing need to reform the methane market and align it with societal objectives.

5.4 Article IV

A Market Perspective on Biofertiliser. *This article was co-written with Linus Ekman Burgman Submitted December 2023*

A market for biofertiliser is developing with the increase in biogas production, yet the product remains an overlooked component of biogas systems. Managing biofertiliser presents numerous challenges. However, this valuable product has the potential to address various societal and environmental concerns. Ensuring that biofertiliser can be marketised helps to ensure that targets for biogas production are met while contributing to a solution to other problems, such as soil quality and dependency on mineral fertilisers. For this reason, there is an increasing desire to ensure the economic viability of biofertilisers. This paper examines the biofertiliser markets and their connections to biogas markets in Sweden. Theoretically, this paper employs the framework proposed by (Ottosson, Magnusson, & Andersson, 2020) to uncover the exchange practices, proving the system and the narrative building that has occurred by actors seeking to influence the biofertiliser market. This framework has been complemented by the literature on *concerned markets*, that is, markets that are driven by societal concerns. This has enabled a closer understanding of how markets are driven and how they must react to external and internal concerns. This paper asked the following questions: How has the position of the biofertiliser market, situated within a broader biogas market, been shaped due to its dependencies and connections by its position? Secondly, how do the concerns of the actors from both the biofertiliser and biogas markets interact and affect the shaping of the biofertiliser market?

The paper uses a multi-method approach, using interviews from a cross-section of biofertiliser and biogas actors representing a variety of business models. To understand the narratives which existed in a wider context, a media analysis was performed. The media analysis was comprised of a search of four newspapers from within the waste and agricultural sectors from 2013-2023. The data was coded to examine where and how exchange practices, proving the system and narrative building came into play and how concerns shaped these three categories of practices.

This paper demonstrated that the market for nutrients from waste is nascent, with various technologies and business models being used, each with its own specific connectedness to the biogas market. However, the connections were strong enough that the concerns from each market seeped into the other. Despite the current dominance of the concerns of the biogas market, the growing attention to circularity and benefits such as carbon storage, soil improvement and food security are becoming increasingly important, and the paper identifies that the dominance of biogas could change.

Considering policy as a market device, biofertilisers have not received the same attention from the public sector as biogas. Biofertiliser is managed as part of the biogas market and, despite the growing concerns, has not received adequate policy attention in terms of nutrient recycling or food security. This has also been seen in direct investment, where the private sector was found to be the driver of market innovation. Through innovation and changes in materiality, the market is undergoing a phase of change. Previous limits to distribution have been addressed through new processes, which allow the product to be sold as pellets or other concentrated forms. This results in the exchange practices changing to resemble that of a more standardised or commodity-like product. This change in materiality was also found to affect the narratives of the product and remove the strong connection to local circularity. However, it was also found that, even with the pellets or concentrate form, biofertiliser cannot occupy the same space in the mineral fertiliser market. This means that the biofertiliser market cannot rely on the same strategies used by market actors and public actors when building the biogas market, and new approaches and policy tools must be found that capitalise on the specific concerns regarding the use of mineral fertilisers.

This paper contributes empirically to the market-shaping literature, demonstrating the usefulness of the approach when considering adjacent and developing markets. The findings may be relevant for policymakers wishing to expand the biogas or biofertiliser market. It achieves this by first demonstrating the connections between exchange processes, proving the system and building a narrative. Secondly, it contributes to actors who require a better understanding of how the values and concerns of one market are affected by the adjacent markets of biogas and biofertilisers.

6 Discussion

The four papers in this thesis have used different entry points for understanding biogas markets. This has enabled an investigation into regional perspectives, along with a national-level study in order to understand the conditions that the regions have operated under and to put the regional markets into the context of the national situation. This chapter presents a description of four identified forces of market shaping: socio-material agencements, policy-making, value representations, and concerns and contestations.

6.1 Social-Material Agencements

The empirical cases have shown that a number of socio-material features of the biogas market are instrumental in shaping the market. I use the concept of agencements to describe the biogas markets, which are combinations of features, to highlight the complex make-up or arrangement of, for example, actors, technologies or regulations. These actors and devices have agency within the market due to the specific arrangement within which they are situated. I will discuss two socio-material properties as they interact with these agencements: the effect of the materiality of the biogas system input and output and the equivalence making with fossil counterparts.

The materiality of the substrate used as input into the process and the outputs, the biogas and the digestate, were central to the shaping of the market. This materiality was found to allow particular agencements, notably where local actors, both private and public, had vested interests in expanding the market. Even though the economic constraints in relation to the transportation of inputs and outputs of biogas produc-

tion are important, it was found that economic impacts were not the only effect of the materiality. By positioning the product as a local resource and local solution through the political work in vision and strategy building, this spatial constraint had a significant influence on the market shaping. This *local-ness* was then leveraged as part of the value-making. Examination of the socio-economic valuation reports allowed a view of how value is made, qualitatively and quantitatively, for the socio-material properties which are connected to a delimited geographical area. For example, limiting local eutrophication, local air quality and the ability to contribute to renewable fossil-free energy for a region have the effect of anchoring biogas firmly within localised regions. The value connected to the local-ness was also evident, where value was placed on the energy which was produced in Sweden, distinguishing Swedish biogas, for example, from Danish. The rationality for this distinction was not only placing value upon energy security, but also contributing to local emission reduction goals.

A second aspect of materiality that has had an important impact on market shaping is the material equivalence to established fossil-based competitors, namely fossil gas and mineral fertilisers. In this thesis, this was shown to be instrumental in creating positive and negative narratives surrounding the value of biogas, but it can also be seen in the actors involved in biogas market development. The relationship between biogas, specifically biomethane and fossil gas, was difficult to avoid throughout the research project. The existence of fossil gas infrastructure was a talking point with regional actors both in interviews and during the wider biogas research centre meetings. The presence of fossil gas actors within the biogas community was also notable and seemingly uncontroversial. Due to this material equivalence, fossil gas and biogas markets can be considered adjacent markets[10]. While it was socially beneficial for fossil gas actors to attach themselves to biogas actors, the biogas actors needed the market reach and infrastructure of the fossil gas to expand.

From a material and technical perspective, each product can and does exist independently. However, there also exist a blending of products, which creates a blending of markets. As described in the background, this blending is literal in the product 'vehicle gas', which is sold as a varied and often undefined mixture of the two products. The entry of traditional fossil actors such as Shell, Gasum and Energy Gas Sweden into the biogas market, which are active in advocacy and narrative building for biomethane, showed that this material equivalence has an impact on the actors who are involved in the market. The media analysis performed showed that this blending also occurred socially, and the products are often discussed with diffuse boundaries. It was found that this joining of markets was at times negative and at other times positive for each product. This resulted in a need to differentiate the products, and this process is described in detail in the last section of this chapter.

Biofertiliser markets have similarities to biogas markets in that it is positioned as an alternative to a less sustainable established incumbent. However, mineral fertilisers and biofertilisers are not equivalent in the same way as biomethane is equivalent

[10]I use the term 'adjacent markets' with inspiration from Kjellberg and Olson (2017) who describe markets which have an effect on one another due to the plasticity of markets where the borders are changed, e.g. through social practice.

to fossil gas. This materiality is important, when considering the agencements of markets. When a strong, established incumbent is present, it applies additional pressure for the product to be disentangled from the comparison and to bring forward new qualities that can allow it to compete. The relationship between the market and competition is important as it illustrates that markets, through agencements, are the arrangement of actors and as such they are "an expression of competition itself" (Callon, 2016, p.16). Both biogas and biofertiliser rely on material similarities to their fossil competitors. This means that, in order for substitution to be possible, the products must first be compared to established products. After this, they must differentiate themselves to leverage their qualities, such as being fossil-free or sustainable, and thus become the preferred option. In this process, the social becomes central. Political work has been important for biogas to distinguish itself from fossil gas. This can include actions such as clauses in procurement policies stating that fossil gas cannot be used in biogas buses.

As the literature suggested and the respondents through the thesis indicated, policy instruments have not been sufficient for this distinction between biofertilisers and for mineral fertilisers to create significant change in the biofertiliser market. However, there have been policy interventions which have worked as market failure mechanisms to enable biogas to compete, e.g. the carbon and energy tax exemptions described in Chapter 2. Nevertheless, the political work done by regional actors to bring forward sustainable and other positive narratives, such as 'local-ness', has also helped to differentiate the products. Biogas has been given an advantage through the visions created by the regions when presented as a solution or through formal valuation. However, this work was not seen in the biofertiliser market. We can say that the agencement for biofertiliser is quite different from that for biogas. Due to the material constraints of biofertiliser, it often is found to operate within a tight-knit web of local actors, primarily connected through the agriculture sector and relying on personal contacts and established trust. Although it was found that there is growing attention and concern for issues such as mineral scarcity, geopolitical issues and soil health, it was not seen to be sufficiently established to enable the biofertiliser market to compete with its mineral equivalent. As a result, it has to primarily rely on material properties or a significantly lower price for comparisons.

Changing Agencements

Agencements are never fixed. As regulations, technologies and actors enter or leave the market, the agencements are re-configured (Callon, 2009; Cochoy, Trompette, & Araujo, 2016). For both biogas and biofertilisers, the market is changing, and new agencements can be observed. For biofertilisers, new innovations, which have come from actors outside of the traditional biogas value chain, have meant that the product can be sold in both salt and pelleted forms, with the problematic water content removed. This change in materiality enables an easier replacement of mineral fertilisers, as this form more closely mimics the material form of mineral fertilisers. It also largely removes the geographical constraint of how far the product can be transported economically, which allows for the re-ordering of social networks. With unprocessed digestate, the market formed itself often around a trade of manure in exchange for digestate, locking in biogas producers. This new configuration enables

digestate producers to sell outside their local agricultural network. Biofertiliser actors linked to pelleted and concentrated products no longer see their market as their local agriculture network, but may consider how their product can be shipped to other regions in Sweden or elsewhere in Europe. While the untreated digestate is a heavy and voluminous material and of no value for the biogas producers, it is framed as waste. Farmers would often want compensation for alleviating the biogas plants of this residual matter. However, this arrangement is changing. Although still in the early innovation phase, new technologies would mean the waste can be a resource in a new value chain of processed biofertiliser. In addition to transport distance, the weight also impacts the bottom line for farmers who use the product and who must offset the impact of soil compaction which occurs when spreading biofertiliser. Although this is a positive innovation for the biofertiliser market, it will also change the visions and valuation of the biofertiliser as part of a local biogas system. Beyond materiality, geopolitical factors such as the war in Ukraine have affected the price of fertilisers. As was shown in Paper IV, this also changed the agencements and the shape of the market. The higher price further incentivises actors involved in innovating the product. The dramatic increase in energy prices has also led to biofertilisers actors being able to compete in times of radical increases in mineral fertiliser prices.

Another change in the agencements for biogas has also begun to take shape since the introduction of liquefied gas (LNG/LBG). Compressed biogas is highly dependent on gas pipeline infrastructure, while LBG can use more decentralised infrastructure and can be transported longer distances economically by road, unlike its compressed form. While fossil gas pipelines form part of wider national infrastructure systems, the LBG infrastructure is more agile. This infrastructure is being built in a piecemeal fashion, largely by the private sector with support from programmes such as 'Climate Leap'. The fossil and biogas markets remain connected, as a similar blending of LBG and LNG occurs to that of the compressed form. As the investment for LBG infrastructure is less expensive than pipelines, biogas actors could invest in liquefication stations and avoid reliance on the infrastructure provided for fossil gas. Although large actors who sell both fossil gas and biomethane nationally have been active in building liquefication and LBG refuelling infrastructure in the areas under study, it was the biogas actors who were also active in these investments. Nevertheless, the framing that biogas requires the fossil gas industry to grow was clearly indicated, with varieties of fossil gas being a bridge to a renewable future that is still very relevant. The change in materiality was found not to disentangle fossil gas from biogas, and the bridging narrative remains. Instead of replacing the narrative that biogas will eventually replace fossil gas, it was found that the bridging narrative takes a variety of forms, which included a new narrative of a bridge from Russian fossil fuels, rather than a bridge to a fossil-free future.

6.2 Strategy and Policy as Market Shaping

The second force of market shaping is through policymaking in the form of the missions and visions that have been used for market shaping. Due to the local-ness described previously, the activities of regional actors have been important. One policy action used by the regional actors was problem and solution framing, which enabled

biogas to be positioned as a solution to problems, promoting consensus and legitimacy building.

Missions, Visions and Market Building

The relationship between larger missions and wider societal problems has increasingly become part of local and regional sustainability policies, often connected with innovation or transformation strategies (Diercks, Larsen, & Steward, 2019). Within the frame of using local development to promote sustainability and vice versa, as a system that seemingly both increases regional economic activity and improves sustainability, biogas fits neatly with such local sustainable development efforts. As was observed in the regional strategies and through the narrative building which was aimed at market building, one commonality across time and space was that biogas is firmly positioned as a sustainability object. As such, it is linked to political, societal and commercial goals, including reducing fossil fuels and greenhouse gases. This positioning allows biogas to become the solution to a number of problems or societal concerns, from energy security and eutrophication to climate change.

The presence of fossil fuels may appear to be a straightforward problem which can be solved by technology and innovation. This line of thinking lies at the heart of ecomodernism (Hajer, 1995), which posits that there is no inherent conflict between economic growth and the impact on nature[11]. However, when the problem is expanded to include root causes, such as the problem of unsustainable societies, it shares all the characteristics of a wicked problem. One of the key characteristics of a wicked problem is that it is 'ill-defined' (Rittel & Webber, 1973). For this reason, Schwab and Combariza Diaz (2023) argue that the energy transition must be approached as a wicked problem, so that it can adequately account for the messiness which comes with a just energy transition, where a fix in one geographic area could result in other problems elsewhere.

Based upon the perspective that problem formation forms part of the policy agenda setting (Rochefort & Cobb, 1994), problem-solution framing was analysed in this thesis. For all three regions, but particularly in Gotland and Kalmar, the problem formation was a rallying call for the engagement of actors beyond those interested in simply promoting biogas. The problem was at times framed using a very general label of "unsustainable". If we unpack this, we can see that, despite two decades of the frequent use of the word 'sustainable', its meaning still needs to be clarified and is often disputed (Farley & Smith, 2020). Secondly, the root causes of the lack of sustainability are still in question, leading to practices gaining and losing sustainability labels as framing changes (Garud & Gehman, 2012). One way to avoid this problem of working towards undefinable goals such as sustainability was by focusing on the discrete problem of fossil-fuel use in transport. The regions were able to focus their actions, specifically in terms of technological solutions such as alternative

[11] Although there exists some discussion between ecomodernists regarding the degree which technology can prevent and fix ecological discussions, a common view is that capitalism and consumption are not in conflict with environmental protection (Mol, Sonnenfeld, & Spaargaren, 2020)

fuels, where they were connected to a straightforward problem with limited possible solutions. The connection to a fossil-free Sweden mission was a principal component of the sustainability and energy policies from 2008 onwards in all three regions. However, in terms of promoting biogas and concrete market-building activities at the regional level, despite the importance of the fossil-free mission at the national level, it was not sufficient to motivate and mobilise the building of a biogas market in any of the three regions.

For Kalmar County, the county that has come closest to achieving the aims, had an aggressive strategy for obtaining fossil-free status. The respondents noted that their regional strategy was designed to be a forerunner, even for the government, in terms of achieving fossil-free status. The 'No Oil' programme became a collective vision for various programmes and initiatives to justify and legitimise investment and support for biogas. Nevertheless, despite the success, the problem and solution boundary were expanded to cover the problem of eutrophication. The problem of eutrophication for Kalmar meant that biogas was not only one solution to the problem but, for the farmers, it was framed as the optimal solution. For the county of Jönköping, a region that uses more fossil fuel for transport per capita than the national average due to its position along one of Sweden's busiest transport corridors, it has meant that a fossil-free vision would be challenging. This entailed a need for a different problem formation for the region. They worked around creating a vision of a net-plus energy region, which was closely linked to the national goals for both renewable energy production and energy security. By contrast, for Gotland, the national fossil-free goals were comparatively disconnected from regional activities concerning biogas on Gotland. Instead, a more prominent narrative was a vision of using local resources for local sustainability and improving the island's energy security. At the same time, Gotland experienced issues at national level that interfered with its ability to control the transition. This is similar to findings by Chlebna and Mattes (2020), who found that regional transitions are susceptible to influence, both positive and negative, from developments at not only local, but also national and international level, which can make regional transitions 'fragile'. This was found to be the case when policy regarding ferry traffic and the laying of a cable to export energy from the island left them in periods of uncertainty, a situation which was reported to cause problems relating to long-term investment.

It has been argued that the problem-solution framing for climate issues is important to the overall outcome. The specific framing of the problem will for example inevitably exclude some solutions (Bardwell, 1991) and, as such, has an impact on market building or lack thereof. When environmental issues are framed as climate issues, energy transitions are framed as the solution and environmental problems can thus be portrayed as 'tame problems with technical solutions' (Dewulf, 2013). Framing the problem was crucial, as exemplified by Kalmar's approach of broadening the discussion from fossil fuels to incorporate issues of eutrophication. For market shaping, this problem of fossil fuels in transportation meant that all three regions placed considerable focus on building the consumption side of the biogas market for transportation. In terms of procurement policies, this widened the scope of the problem and built widespread support for the growing biogas industry. In turn, this meant that procurement policies which favoured biogas were not questioned, and there was

sufficient legitimation for supporting the building of the market. This aligns with the academic literature on wicked problems, which suggests that cross-sector collaboration is necessary to address wicked problems and the importance of building legitimacy (Wesseling & Meijerhof, 2023).

The perspective of mission-oriented challenges in understanding how the regions had approached building a biogas market in response to grand challenges helps to understand the roles and limitations of these roles through the actions and visions which guide public actor engagement. Proponents of mission thinking argue that, for these grand challenges, public investment is crucial and must extend beyond helping to fix market failures in a piecemeal fashion (Mazzucato, 2016). All regions displayed some degree of traditional market-fixing policy instruments, such as public procurement (Grandia & Meehan, 2017). For Kalmar and Gotland, the public sector's economic investment and risk were primarily limited to procurement and lobbying for biogas in order to increase demand in the market. On Gotland, it was decided in 2009 that the region and municipality would not directly invest financially in building the required infrastructure, such as biogas plants or refuelling stations. Instead, it would act as a facilitator for the planning and as a coordinator for the various actors that needed to be enrolled in order for the market to gain traction. The exception was Jönköping, where the municipality owned the largest WWT plant and a co-digestion plant for food, agricultural and industrial waste. This plant was sold to a private company in 2018. From this point onward, instead of direct investment, the strategic focus was placed on how the region could utilise its regional assets, such as strong entrepreneurial networks, in order to create or sustain the market for consumption.

The visions and strategies that replaced direct investment show that market building occurred by allowing for procurement policies which favoured biogas, thus building the consumption side of the biogas market. These types of strategies, policies and tactics of public actors are a vital part of marketisation (Berndt & Boeckler, 2023). Starting with the mission for a fossil-free future, this evolved into creating networks, building narratives, and defining common goals, but was tailored around each of the regions' own concerns. This tailoring to specific local contexts helped to legitimise biogas as a means to achieve the goal of becoming fossil-free, while at the same time building upon other concerns. For Gotland, it built upon the value of using their own resources and contributing to increased energy security. For Kalmar, it was allowing increased animal husbandry in Kalmar, while for Jönköping it was branding a plus-energy county. This narrative building could be one way of avoiding relying solely upon traditional market fixing actions where single actions such as subsidies and one-off economic investment are seen as a way of correcting market failures when working towards a common societal goal.

6.3 Value Production

The third force of market shaping to be identified was through formal value production. The benefits of regional biogas production and consumption were translated into value which can impact the shaping of the market. The process of formal valuation was found to be an additional activity where regions were active in the market-

shaping process. This was through the formal valuation and representation of value. The valuation process was approached in this thesis as a performative action that does not simply represent the value of biogas; it plays a role in the creation of value. Valuation functions as a part of the market shaping by formalising and legitimising the benefits of biogas, which lie outside the traditional market with standard price-setting practices. To focus on the verb form of the word 'value', value production can come from various sources, such as discourses and calculative tools. One specific form of value production studied in this thesis was socio-economic reports. From the regional perspective, differences were found in the use of this approach for promoting biogas. While all regions felt the process of socio-economic valuation could be of use, they noted that competence and lack of resources were barriers to the implementation of formal valuation. Value production was examined in detail for the two regions that performed formal socio-economic valuations.

One central feature of biogas as a sociotechnical system is its position within different systems, such as waste, agriculture, energy, and transport systems. Socio-economic value can be approached from a particular system, solely from the perspective of energy security or from an environmental or regional development perspective. Such attempts to evaluate a biogas system would, at best, be incomplete but could also be quite misleading in terms of the benefits or value that the biogas system adds to society. To add to the complexity, biogas is a circular system, a feature that is an increasingly important part of the biogas narrative identified in Papers III and IV. However, circular systems are also difficult to analyse as regards value, as methods such as life cycle analysis are not adequately developed for estimating value in circular systems (Iacovidou et al., 2017). As products become more complex, their valuation cannot be met through technical or functional evaluation alone, and must rely on political and social factors (Beckert, 2009). For the examples given in this thesis, political and social factors were the initial process of evaluation. However, for Jönköping and Kalmar, the complexity of biogas systems has resulted in a situation where biogas actors feel that the cost of biogas does not represent the true value for society. They therefore reasoned that better technical or functional valuation would increase the perceived value of biogas.

Despite the theoretical challenges and the ethical problems (Gowdy & Erickson, 2005), regional stakeholders have generally indicated that formal valuation is important and unproblematic in terms of knowledge production. Despite political backing, especially in Kalmar, public actors felt it was imperative to prove the value of the biogas system for the region. Consequently, they took measures to improve credibility. Value judgements were made for public actors to ascertain and justify the degree of support that a biogas market should be given. In this way, the biogas system is not unlike any other policymaking process, where the costs and benefits are weighed against each other, and policy can be implemented based on the result (Dobraja, Barisa, & Rosa, 2016; Mishan & Quah, 2020). However, a biogas system requires a monetary value for nature and ecosystems, both now and in the future. In Paper II, it was shown that this complexity was only marginally represented in the reports themselves, specifically in the regional biogas valuation reports, which aimed for the quantification of benefits. National reports appeared to function more generally as knowledge-making and input to policy decisions, which allowed for more space to

be given to narrative and discursive translation of benefits, or the valuation of societal value.

Valuation of biogas requires boundary setting, which was often considered to be important in order to demonstrate how and by whom value is created (Dussauge, Helgesson, & Lee, 2015). Boundaries are based on the system boundaries of biogas. We can begin to consider the boundaries of the objects themselves. Following (Latour, 2012), the primary products in a biogas system, energy and fertiliser can be viewed as hybrid objects [12]. In other words, these are objects that belong to both nature and society. Understanding biogas and biofertiliser as both naturally and socially constructed phenomena highlights our inability to disentangle the material, such as fossil origins, from the social contexts. The value of a fossil-free fuel source only reflects the value that society deems at a specific moment in time. Papers III and IV provide examples of exogenous factors, such as geopolitics, which can change not only the market value of products quickly, but also the value which society places upon objects. However, the socio-economic valuation did not allow for this connection between the social and the natural to be sufficiently transparent. Calculations of avoided emissions through replacing manure or mineral fertiliser made assumptions about the societal aspect, such as the spreading and storage techniques that farmers employ when switching to biofertiliser. Reducing objects such as carbon emissions, avoided emissions and increased employment to numerical calculations can hide the complexity and social dependencies involved. Instead, these reductive numbers are at risk of being naturalised into a fact. These matters of fact (Latour, 2004) are generally perceived as objective and, for objects which pertain to definitions of sustainability, the political and social are often hidden (Skjølsvold, 2013). This situation can lead to problems for shaping due to what Latour describes as the production of "prematurely naturalised objectified facts' (Latour, 2004, p.227). This point is discussed in the final section of this chapter.

Within the process of valuation, other important boundaries can be observed. One of the boundaries identified was the definition of a socio-economic value, which becomes an overarching concept and acts as a boundary-setter throughout the valuation process. These definitions are entwined in economics and provide the guiding concept for the valuation process and how the recipients of the information should interpret the results. This includes definitions regarding externalities, which are deeply embedded in neoclassical economics. This knowledge, with its basis in economic reasoning, is then understood with a perceived authority (Blok, 2011). The socio-economic definition as found in the reports also assumes taken-for-granted assumptions about how to price future pollution, i.e. it contains normative assumptions, that techniques such as future discounting are socially and morally acceptable. These assumptions become further engrained in the shaping of the market. This can have effects outside of the socio-economic report itself. As was found in this thesis, the space for introducing other ways of pricing externalities, such as a stronger focus on the polluter pays and limiting or banning fossil fuels, did not form part of the pol-

[12] Latour and Crawford (1993) notes that there are in fact only hybrid objects in the world. In this case, the distinction is used to foreground that with biogas and biofertiliser; their hybrid nature impacts how we can use and describe them, especially in terms of their position in markets.

icy discussions or the bridging narratives for fossil gas. The narrative was generally found to focus more on bringing about a growing awareness of the benefits or value of biogas in order to allow the market to eventually choose biogas.

Within this paradigm of favouring quantifiable knowledge (Asdal, 2008; Mennicken & Salais, 2022; Porter, 1995), specific processes and tools are elevated in importance and status within valuation. The regional actors recognised the significance of demonstrating the advantages of backing biogas through quantification. To achieve this, they used scenario building, life cycle analysis, and economic valuation. These tools went beyond basic reporting. In the regions, the process of valuation acted as a form of translation to quantify the benefits of biogas. This provided compelling evidence to public officials that supporting biogas was a beneficial option from a societal perspective. The ability to measure and therefore demonstrate the benefits was considered by the actors to be pivotal in securing continued or increased political support. This preference for the quantifiable value was similarly found in the biofertiliser market. Although the social connections within the biofertiliser market were strong, and discursive strategies for communicating the value were used, it was also found that Excel spreadsheets which could quantify the benefits into monetary amounts were crucial in convincing farmers to change their fertilisation method. This hybrid creation of value was also found in the reports. When quantifiable values could not be provided, the reports used qualitative reasoning to translate benefits into value.

These valuation devices are not enough to create value. The value creation comes when these devices have political and institutional support (Fourcade, 2011b). As the output leaves the original site of valuation, such as the report, they circulate into new spaces. These value-making exercises circulate into a general discourse and become part of a wider discussion. When weighing up the benefits of an expanded methane market or the value of replacing mineral fertilisers, local actors can draw upon these defined values to strengthen their positions for supporting the market. For biofertilisers, this was seen as part of market-shaping narratives, which brought forward the societal benefits of replacing mineral fertilisers, such as improved soil health. This forms part of what Muniesa calls a 'valuation network', which is in constant motion for determining price and differs from a valorisation view of price setting, where there is no clear distinction between evaluating and value making (Vatin, 2013). It is in this space that the political and social construction occurs. However, complexities, assumptions, social relations, and knowledge-making are hidden in the readily digested number presented to decision-makers.

6.4 Matters of Concerns

Continuing to build on the premise that markets are entities which embody societal values (D'Antone & Spencer, 2014; Fourcade & Healy, 2007), this section considers how the biogas market creates tensions, and also attends to tensions and concerns. These concerns and tensions become a force for market shaping. It has been argued that markets and politics are inseparable from each other. The analysis was based on the theory that the connection between the markets and the political often occurs through concerns, e.g. as argued by Callon: "markets trigger the emergence of mat-

ters of concern to which they are not always able to provide satisfactory answers. These matters of concern then evolve into many (potentially) political issues whose solutions may, in turn, impact on the organization of economic activities." (Callon, 2007, p.139) The biogas and biofertiliser markets fluctuate between periods of hot and cold. During cold periods, the markets and their products are well-known and uncontested, while during hot periods, the product framing or boundaries move and are contested. Two types of tensions that contribute to such situations have been observed. One is related to the particular socio-technical agencement of biogas that fossil gas and biomethane share a common space in the market, and the tensions of this shared space create concerns which, once incorporated into the market, make the market hot. This is a market where the borders of what belongs in the market and what constitutes an externality or unwanted effect become contested. The latter type of tension is linked to a discussion of the sustainability and circularity of products and the framing of the product which is adjusted in order to attend to concerns.

The shared market of fossil gas and biomethane has obvious potential for concerns considering the positioning of biogas as a sustainable energy source. On the one hand, it has been posited that biogas was able to expand due to the existing infrastructure, knowledge and skills which was developed for fossil gas (Ulmanen, 2013). On the other, the presence of fossil gas was considered to have a negative impact on the selection of biomethane due to the perceived links to the fossil gas market(Mutter & Rohracher, 2022). With this perplexing situation, we can see that it is an area that can lead to tensions. The case of fossil gas can in part be understood against the background of the long history of gas being associated with various geo-political issues (Högselius, Åberg, & Kaijser, 2013). With the rationality that a diverse energy mix is required for economic and political reasons, there has been a defined role for fossil gas, and there has been an explicit policy recommendation in support of fossil gas in the EU since 2006 (Bahgat, 2006). Gas development support programmes have not been without opposition, as seen with the proposed LNG storage facility in Western Sweden, which was halted after significant public opposition (De Rosa, 2022). Despite concerns regarding over-reliance on Russia, for much of the 2010s, the EU encouraged an expansion of LNG as a transport fuel through the Trans-European Transport Network (TEN-T) programme, which aims to bring about the integration of transport policies throughout the Union, which includes, among other infrastructure requirements, specific requirements regarding fuel availability (Commission, n.d.). As such, the EU requires the construction of LNG stations along Swedish highways which form part of the TEN-T corridor in Europe10. From a technical perspective, these stations can sell LBG where access is available, but what is actually offered is left largely to market forces.

Here, we see a direct tension between policies aimed at emission reductions, the vision of fossil-free, and policies that impose obligations regarding the provision of LNG infrastructure. This shared socio-technical arrangement enabled the presence of LBG to reframe the market for methane to include biomethane, which led to the fossil gas market becoming cool. Concerns and controversies regarding fossil gas were tempered with the hope of replacing LNG with LBG. Faith in this bridging narrative can explain why respondents were rarely concerned about the increase in biogas leading to the acceptance of a fossil fuel. The fossil gas and biomethane markets find

themselves in a situation where they both compete against and rely on each other. While the markets share much of the same technical infrastructure, considering the fuels as a sociotechnical system instead of a technical system, we can highlight the social constructions, such as environmental concerns and geopolitics, which have the potential to either join or separate these two objects.

These tensions are alleviated through pacification of a product to help cool the market. This means redrawing the boundaries of the market, so as to take into consideration the origin of the product. Originally, the source of the methane became a defining feature, referring initially to whether the methane had fossil or renewable waste as its origin. However, this has changed recently, and the products have begun to be pacified by further distinguishing or, in Callon's language, singularised based on geopolitical concerns. This singularisation was a significant process, as it positions products within a market. It is dependent on being able to define the product with, for example, certifications, measurements and forms of standardisation (Callon, Méadel, & Rabeharisoa, 2002). As opposed to the market frame only including whether or not the gas was renewable, through concerns, the geographical origin became part of the framing of the methane market. For the methane market in Sweden, actors began to redraw the boundaries to focus on the methane which was not of Russian origin. For biomethane, this redrawing of contested borders meant that they were highlighting that their product was not only renewable, it was guaranteed not to come from Russia. This pacification of the product, by redrawing boundaries and making clear the qualities and expectations of the product, was the result of concerns.

A similar situation was found regarding biofertiliser (Paper IV), where different points of pacification and singularisation of the product were found. This differentiation was carried out for both digestate and sludge from waste and water treatment (WWT) plants and from the mineral fertilisers. The digestate from WWT plants has different limitations regarding where and how it can be used but, even when legally permissible, some farmers were hesitant to use the sludge or digestate. This created a situation whereby the respondents from across the biogas and biofertiliser chain felt the need to consistently distinguish the biofertiliser from biogas plants, so that it would not be confused with the fertiliser that was produced through the processing of WWT. Secondly, the product was found to be singularised in order to acknowledge the origin of the nutrients, i.e. the origins of the product were brought into the framing of the product. At times, it is beneficial for biofertiliser to be shown to be comparable to mineral fertiliser in terms of cost or precise amount of nitrogen, phosphorous and potassium (NPK). However, as concerns began to matter in the mineral market, it became important to further singularise the product from NPK-based products based on the origins of the product. This allowed biofertilisers to be detached from the wider markets of fertilisers, which became hot when concerns grew regarding the use of fossil fuels or, more recently, products from Belarus and Russia.

For the fertiliser, the object has been both an economic and a non-economic good at different times and depending on the region. This can be understood when considering the difference between a good and a product. Goods can circulate, because they have value and this can be independent of any monetary exchange (Çalişkan & Callon, 2009; Dewey, 1915). An economic good is created at the point of economic

exchange and, as in the case of biofertiliser, can occur without anything significant happening to the materiality of the product. However, the societal context in which the object exist in the social networks is altered so that the biofertiliser becomes an economic good. It is at this stage it is often found to go from being referred to as the digestate, to biofertiliser. Part of this change takes place through the creation of value, which is shown to be created through the enactment of concerns both inside and outside the market. For example, the price of mineral fertilisers changed the economic value of biofertiliser. This was found to extend beyond supply and demand. However, due to the narratives surrounding avoiding Russian fertilisers, the value of local biofertiliser was made more concrete. However, this new value could not always be further translated into value for the end consumer.

This observation shows the importance of considering the adjacent market of mineral fertilisers and how concerns in one market impact the other market, as is apparent within the methane market. This observation reinforces the view of valuation networks as ever-changing and the pivotal work required to, for example, singularise the product and 'make' the product 'sustainable or to pacify new concerns which have impacted the market. Creating value in the product's origins, rather than merely in the product and its use, is reminiscent of first-generation biofuels[13], where the opposite was found. The fuel itself was considered and supported for its sustainability and status as renewable. However, the origins of the biofuel began to be questioned as the food versus fuel debate became a part of the public discourse (Mohr & Raman, 2015).

As with first-generation biofuels, biogas depends on its status as sustainable in order for the public sector to continue to support the market. Therefore, it is important to unpack the properties or qualities which are assigned to biogas and biofertiliser which 'give' it "sustainability. Beyond 'local-ness' and renewable, the narrative has developed to focus on the circularity of the biogas system. Biogas, which is purported to be an idealised example of a circular economy, is often positioned as a win-win or green-growth example worthy of policy support. These green-growth policies have been found to be the dominant policy approach (Tilsted et al., 2021). This narrative is not unexpected, as regions were often tasked with working with goals for economic growth, while at the same time also working towards energy transformation and climate goals. Here, the local boundaries of biogas were argued by the respondents to make biogas an optimal choice. However, this importance of local-ness could be in tension with environmental concerns. For example, the ability of biogas to limit eutrophication through nutrient recycling was an important justification for increasing the use of biogas in all three regions. However, this reasoning did not extend to rationalising the use of biogas produced in Denmark which, from a climate/GHG emissions perspective, would offer equal benefits to that produced in Sweden. However, this was not considered to be a benefit, i.e. the consumption of biogas which was produced elsewhere when the value of local development or local eutrophication could not be accounted for.

[13]In this context, the definition of first-generation biofuels refers to "Biofuels produced from food or animal feed crops are referred to as first-generation biofuels." (Jeswani, Chilvers, & Azapagic, 2020, p.2)

The biogas system can be susceptible to similar critiques to that of recycling. One critique of recycling is that, although the activity itself has limited impact, recycling allows for additional inertia with regard to any greater societal change (Lippert, 2011). The biogas system contains similar waste flows which, instead of assuming they mitigate environmental problems, could lead us to question whether the system prevents more radical and transformational changes. The material showed that, although social and psychological factors were considered by the public actors, this was in terms of behaviour such as sorting organic waste or supporting private biogas cars. There was little focus on the need for a larger societal transformation. This can be linked to the critique of circular economy narratives that they are embedded within an ecomodernist perspective (Hobson, 2016). This lack of transformative change was also apparent in the motivations and visions for biogas in Kalmar, where a desire to increase animal husbandry was seen as justifying the expansion of biogas. Biogas systems are commonly associated with providing a more sustainable method for managing manure, similar to recycling the move to a biogas system results in a waste becoming a resource. In Denmark, where intense animal husbandry is an important component of the Danish economy, NGOs have questioned this link between expanded animal husbandry and sustainability, claiming that manure is not a renewable resource, as it is dependent on important inputs (Jorgensen & Andersen, 2012).

To conclude this discussion, it is important to note that, although I have discussed four forces of market shaping, these categories were adopted for the sake of sorting the material and to aid the reader. In reality, the four forces were found to be interconnected and interdependent. Missions and visions are formed around the perceived value of biogas, and the value of biogas is dependent on the concerns that are sufficiently brought forward to have standardised procedures for calculating. In turn, quantification solidifies the importance of benefits which can be quantified. Local actors were able to bring forward local and regional conditions and societal value(s), such as entrepreneurship, pride in local farming or island resourcefulness, to demonstrate that biogas systems added value to the region. The missions which match the problem and solutions are connected to the value production, as the two processes are linked and work together to strengthen and validate the other. Similarly, the value-making and visions are enabled and constrained by the socio-material properties of the biogas system, which do not act in a deterministic way, but become a part of the socio-material agencements which depend on the social, political and discursive elements as much as the material.

7 Conclusion

In this thesis, I have considered the interplay between political and market actions, examining how they mutually shape and develop the biogas markets. I have explored how the biogas markets are affected by the interaction of political and market framings. In particular, this thesis has examined how regional public actors and the private sector have created value and addressed concerns through the biogas market. As a locally specific configuration, the biogas and biofertiliser market depends upon the actions of regional actors. By offering new insights into the practices involved in market shaping, the aim is to enhance our understanding of these crucial and often hidden processes in publicly supported renewable markets.

The first question asked how actors in different regions have used visions and valuations as a part of policy formation regarding biogas market development. This question stemmed from the awareness that regional actors have been important in the development of the biogas market. I therefore sought to understand how visions and strategies were used and linked to the notions of value for biogas. This thesis has shown that the political dimension was a vital component in shaping the biogas market and also described how the regional actors used visions which were intertwined with problem-solution framing. It was shown that work was needed by actors, such as the translation of missions into locally contextualised visions. This local vision was connected to biogas systems functioning as a solution to many problems. The extent to which these visions could be used to strengthen the biogas market varied between the regions.

Political and market framing also intersected when unravelling how political actors create and use values. The translation of benefits into values meant that the benefits

of biogas to the local region were not simply a technical solution to a problem, but that the production and consumption of biogas provided benefits that should be valued in their own right. On the one hand, the complexity of biogas and its position at the intersection between waste, agriculture and energy system means both that it is important for decision-makers to reduce the benefits into a readily palatable number, and that it is a system which is particularly challenging to manage using soley quantitative methods. The translation of benefits into value relied heavily on quantifying the impact of human activity on nature. The effect of quantifying biogas properties and its importance can be understood when we foreground the role of abstraction and political work, which was found to occur in the process of value-making. As some methods for quantification are more established than others, there is a risk when relying on quantification that we value what we can quantify. Greenhouse gases have established routines for quantification, while other benefits (and costs) such as biodiversity and nitrogen leakage are less well-established. This result should also be considered in terms of both the role of quantification in providing legitimacy and the importance of legitimacy for products within a concerned market. When we rely upon socioeconomic valuations, it brings forward an array of philosophical, ethical and pragmatic problems. Despite challenges, reports provide a final socioeconomic value for biogas production, albeit without revealing the underlying complexity. The visions and values were found to work in a feedback loop to each other. The visions showed the benefits of biogas, such as strengthening the local economy, while the socio-economic value places a qualitative value on this, which could then be further used to strengthen the vision.

The second question asked how the socio-material properties of the biogas system have affected the dynamics of biogas development. The importance of the materiality was addressed in all four papers, and it can be concluded that it is pivotal to shaping the market. Two aspects of materiality were traced: firstly, the local-ness of both biogas and biofertiliser and, secondly, the material equivalence to fossil gas. Both examples demonstrate the importance of considering the socio-material, and not just the materiality, as shaping in a deterministic way. When considering the development of biogas markets, it became clear that biogas markets have operated in a geographically confined space. These boundaries emerge due to the socio-material characteristics inherent in both biogas system production and consumption. The socio-material properties of a biogas system were found to favour particular agencements, e.g. local waste management or local agriculture. The geographical constraints are economic in nature, but they also are influenced by environmental impact. These arrangements, bound by the socio-material properties, were leveraged by the regional actors who used this and were able to frame it as a benefit or value and created locally bound visions, such as of their 'own waste' and their 'own energy'. More than just acting as a variable in a formula for sustainability, the local-ness of biogas was shown to be used to create visions. These conditions, such as the desire to increase animal husbandry or build on regional entrepreneurship, are tightly linked to the respondents' perceived "value" of biogas in the empirics, which demonstrated the link between the socio-material, market shaping, and value.

The second aspect of materiality which has shaped the market is the equivalence to fossil gas. The tensions that this has caused are addressed further on, but it is

also important to consider that the equivalence had other impacts which were found to be understood as enablers for the biogas market. The benefits of biogas ranged from the ability to utilise the infrastructure built for fossil gas, to the engagement of large commercial actors who would invest in biogas production and consumption. This was found to be tightly linked to the bridging narrative that fossil gas would eventually be replaced with biogas. This thesis also found that the links with fossil gas had a regional connection due to local conditions, such as the presence of local fossil gas infrastructure or major LNG users such as Gotland with its ferry service.

The final question asked what tensions exist within the biogas market. This question was addressed using the concept of concerned markets. In Papers III and IV, I looked more closely at the concerns that come into play in market shaping. In this perspective, I conclude that concerns have acted as drivers for the market. Firstly, biogas as a sustainability market is itself a concerned market, where social values are important to the market and product framing. Additionally, the methane market, having both environmental concerns and being highly entwined with politics, is a hot market where concerns continually redraw the boundaries. Importantly, it was found that whether biomethane belongs to a methane market or a biomethane market is not predetermined. Efforts have been made to frame them as part of a single methane market at times and, to a lesser extent, some actors have done the opposite to singularising biomethane. This has primarily been built on a bridging frame that fossil gas is a bridge to a better future. At times, this was a fossil-free future but, more recently, it was a future free from dependence on Russian energy. It was also found in this thesis that this feature of the markets can be problematic for both biomethane and fossil gas.

Tensions were also found by tracing the concerns which were part of the biofertiliser market-shaping. The biofertiliser market is nascent, primarily built upon the need to manage waste from biogas production. However, actors are increasingly attempting to position the market as one which addresses other concerns, such as soil quality and nutrient recycling. The biofertiliser market demonstrates how markets contend with concerns by redrawing borders to either include new concerns, or attend to concerns. In both cases, the redrawing of boundaries concerns overseeing externalities, including externalities such as improved soil heath or redrawing boundaries to exclude products such as WWT digestate. For biofertiliser, issues such as the links to the digestate from WWT or the presence of plastics in the product meant the market had to define itself in a way which addressed these concerns.

In summary, this project has revealed the importance of local contexts in the biogas markets. It showed how regions could adapt national missions to translate the policy objectives into problems and solutions, enabling them to utilise their local conditions, which was essential for supporting a growing biogas market. However, this is changing. The local narrative, which has been at the centre of the biogas story, may no longer be relevant. Despite innovations in pellets, biofertiliser is currently most economical when used close to biogas production. A local nutrient narrative could replace local energy. A new narrative about the importance of local nutrients would be beneficial in raising awareness of the importance of nutrient recycling, which has received considerably less attention than GHG emissions. Adding a strengthened nu-

trient narrative could help to alleviate some of the problems and concerns regarding the methane market. At times, the narrative of fossil gas as a bridge led to doubts about biogas as a bridge to a fossil-free future. There is a risk that, instead of biogas greening fossil gas, fossil gas could have a 'browning' effect on the biogas market. This situation is somewhat alleviated through the types of valuation which were studied in this thesis. The motivation for formal valuation was seen to be focused more on 'making visible' the benefits, and thus the value of biogas, than on the purpose of bringing in a formalised decision-making tool, as is common with cost-benefit analyses. The nature of these practices, which rely on existing techniques for translating societal benefits into value, prioritise effects such as GHG emissions and could therefore be seen as further entrenching the importance of the benefits of emission reduction and, in its current form, these tools do not appear to be equipped to capture the societal value of nutrients.

Lastly, it was found that the biogas market has been built for the energy market, but it is increasingly becoming important to consider the role of biofertiliser in this market. What was previously considered to be a by-product and a problem for producers could be made into an asset, both in terms of traditional market exchange and as it provides societal value. Building on the starting concept of this work, that markets do not simply appear or that objects are inherently valuable or sustainable, this work has shown how this viewpoint holds true in the case of biogas and biofertiliser. The transformation from a waste by-product to an asset could be an important empirical and theoretical view to foreground that work is needed in order for an object to be seen as valuable or sustainable.

Further research could continue to unpack the consequences of creating a 'sustainability object' from biogas systems in the unfolding new configuration where localness will not have the same weighting. One methodological starting point could be to consider markets more from a practice-oriented perspective in order to understand in more detail how the practices of the actors shape a market in change. As discussed, biogas systems will begin to occupy a space which is less bound to the local and, with this change, it would be reasonable to ask how this reconfigures the market. Another avenue could be to further pursue the inquiry into the biofertiliser market in order to understand how they can be economically viable without biogas. Biogas is only one market within the wider bioeconomy, where the search for "green carbon" for production of items such as plastics is likely to intensify. In order to avoid the pitfalls of path dependencies, it could be important to understand how we evaluate the different options we have open to us for circulating waste.

Returning to the quote which started this thesis, there is a need to develop fuller knowledge and wiser actions in order to tackle the current ecological crisis. In this thesis, I have presented a new view of the Swedish biogas market from a holistic perspective, which I hope can aid decision-makers and biogas actors in their approach to the complexities that they face and offer another path for moving from knowledge to wisdom.

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8 Appendix

Appendix A

Date	Event	Notes
2019-08-27	Regional BRC working group	
2019 -08- 29	National Policy working group	
2019-11-05	Regional BRC Meeting	
2019-11-05	National Policy working group	
2019-12-18	BRC Conference	
2020-01-21	Regional BRC Meeting	
2020-01-21	National Policy working group	
2020-03-31	Regional BRC Meeting	Online
2020-04-01	National Policy working group	Online
2020-06-12	BRC Conference	Online
2020-08-25	Regional BRC Meeting	Co-ordinator for meeting
2020-08-26	National Policy working group	Online
2020-11-03	Regional BRC Meeting	Online
2020-11-04	National Policy working group	Online
2021-08-31	Regional BRC Meeting	
2021-09-01	National Policy working group	
2021-12-9/10	BRC Conference	
2022-04-7/8	BRSC Kick-off	New research centre begins
2022-06-9/10	BRSC Conference	
2022-08/29	Regional BRSC group	

Table 8.1: Appendix A - Biogas meetings attended

Appendix B

Actor	Geo-Region	Media
Public Transport Authority	Kalmar	Both
Energy Office	Kalmar	Audio
Kalmar Region	Kalmar	Both
Municipal Authority	Kalmar	Both
County Authority	Kalmar	Both
County Authority	Jönköping	Both
Energy Office	Jönköping	Both
Jönköping Municipality Politician	Jönköping	Audio
Gotland Region	Gotland	Both
Gotland Region	Gotland	Both
Biogas Producer_2	Östergotland	Both
Biogas Producer _1	Östergotland	Both
OrangeGas	National	Both
DriveLBG	National	Both
Energy Office	Göteborg	Both
HZI	Jönköping	Both
Biogas Producer	Götland	Both
Biofertliser Broker 1	National	Both
Biofertliser Broker 2	National	Both
Biofertliser Broker 3	National	Both
Biofertliser Seller 1	National	Both
Biofertliser Seller /equipment 2	National	Both
Biofertliser seller/ equipment 3	National	Both
Substrate / Waste management	South Sweden	Both

Table 8.2: Appendix B - Interviews conducted

Appendix C

Table 8.3: Appendix C - Documents included in analysis

Year	Document	English title	Actor
2009	Biogasnat pa Gotland	Biogas network on Gotland	Gotland Biogas Association
2009	Regionalt tillväxtprogram för Gotland 2008-2011	Regional growth programme for Gotland 2008-2011	Gotland Municipality
2009	Region Gotland - Vision 2025	Region Gotland - Vision 2025	Gotland Municipality
2009	Biogasstrategi Gotland	Biogas Strategy Gotland	Gotland Municipal board
2010	Rapport fran Gotlands Energidialog	Report from Gotlands Energy dialogue	Swedish Energy Agency
2011	Energi dialog 2011 Gotland	Energy dialogue 2011 Gotland	Gotland County Council
2011	Energiläget 2010	Energy Overview 2010	Region Gotland
2012	Gotlands Färdplan 2050	Gotland's Roadmap 2050	Gotland County Council
2012	Klimat- och energimål för Gotland 2012-2020	Climate and energy goals for Gotland 2012-2020	Gotland County Council
2013	Region Gotland fokusområdem	Region Gotland Focus Area	Region Gotland
2014	Energiplan för Region Gotland Energi 2020	Energy Plan for Region Gotland Energy 2020	Region Gotland
2014	Gotland Biogasstrategi 2014-2019	Gotland Biogas Strategy in 2014-2019	Region Gotland
2015	Biogasbilisten: Biogas är mer än ett bilbränsle	Biogas motorist: "Biogas is more than a car fuel	Region Gotland
2017	Energiläget: En avstämning av Gotlands klimat- och energimål	The energy situation :A reconciliation of Gotland's climate and energy goals	Gotland County Council
2019	Gotland Plan for arbetet med infrastruktur for elfordon och fornybara drivmedel	Gotland Plan for the work with infrastructure for electric vehicles and renewable fuels	Gotland County Council
2019	Energipilot Gotland Färdplan för att möjliggöra att Gotland blir pilot för ett hållbart energisystem	Energy pilot Gotland Roadmap to enable Gotland to become a pilot for a sustainable energy system	Swedish Energy Agency
2019	Tillsammans mot 2030 - Energi- och klimatstrategi	Together towards 2030 - Energy and climate strategy	Gotland County Council
2020	Vart Gotland 2040 - Regional utvecklingsstrategi for Gotland	Our Gotland 2040 - Regional development strategy for Gotland	Region Gotland

Continued on next page

Year	Document	English title	Actor
2009	Energi and Klimatprogram information	Energy and Climate Programme information	Jönköping Municipality
2010	Klimat- och energistrategi Med nya klimatmål för Jönköpings län	Climate and energy strategy With new climate goals for Jönköping County	County Administration, Jönköping
2012	Färdplan 2050 – underlagsrapport för Jönköpings län	Roadmap 2050 – background report for Jönköping County	County Administration, Jönköping
2015	Biogas från stallgödsel i Jönköpings län En förstudie	Biogas from manure in Jönköping County A feasibility study	County Administration, Jönköping
2016	Samhällsnyttan med biogas – en studie i Jönköpings län	The societal benefits of biogas – a study in Jönköping County	Energy Office North Småland
2017	Samverkan för biogas i Jönköpings län	Collaboration for biogas in Jönköping County	Political board for municipal forum
2017	Värdet av biogas En samhällsekonomisk analys av biogasens nyttor	The value of biogas A socio-economic analysis of the benefits of biogas	Energy Office North Småland
2018	Utvärdering av ERUF projektet Kraftsamling biogas II	Evaluation of the ERDF project "Pooling resources biogas II"	Energy Office North Småland
2018	Överenskommelse kring biogas i Jönköpings län	Agreement for biogas in Jönköping County	Region Jönköping
2019	Klimat- och energistrategi för Jönköpings län	Climate and energy strategy for Jönköping County	County Administration, Jönköping
2019	Infrastruktur for elfordon och fornybara drivmedel	Infrastructure for electric vehicles and renewable fuels	County Administration, Jönköping
2020	Stod till energikartlaggning	Aid for energy audits	County Administration, Jönköping
2008	Regional klimat- och energistrategi för Kalmar län	Regional climate and energy strategy for Kalmar County	Kalmar County Administration
2009	Biogas i Kalmar Län	Biogas in Kalmar County	Region Kalmar
2010	Fossilbränslefri region nya mål och utmaningar	Fossil fuel-free region new goals and challenges	Region Kalmar
2012	Räpport färdplan 2050	Report roadmap 2050	Kalmar County Administration
2014	2014 Biogas i Mörbylånga kommun - fungerar det?	2014 Biogas in Mörbylånga municipality - does it work?	Mörbylånga Municipality

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Year	Document	English title	Actor
2014	Regional strategi och handlingsplan for biogas till fordon i Blekinge, Kalmar och Kronobergs lan	Regional strategy and action plan for biogas for vehicles in Blekinge, Kalmar and Kronoberg counties	Kalmar County Administration
2015	Regional strategi och handlingsplan för biogas till fordon i Blekinge, Kalmar och Kronobergs län - Halvvägsutvärdering	Regional strategy and action plan for biogas for vehicles in Blekinge, Kalmar and Kronoberg counties - Halfway evaluation	Energy Office South East
2015	Morbylanga Lokaliseringsutredning slutrapport	Mörbylånga Localization Investigation final report	Mörbylånga Municipality
2016	Fossilbränslefria Kalmar kommun 2030 Klimat - och energiprogram	Fossil-fuel free Kalmar municipality 2030 Climate and energy program	Kalmar Municipality
2016	2016 Rapport Biogas Morbylanga LOVAprojekt	2016 Report Biogas Mörbylånga LOVA projekt	Mörbylånga Municipality
2019	Fossilbränslefri region - mål, strategier och handlingsprogram	Fossil fuel-free region - goals, strategies and action programmes	Region Kalmar
2019	Klimat- och energistrategi Kalmar lan	Climate and energy strategy Kalmar County	Kalmar County Administration
2019	Fossilbranslefri-kommun-2030	Fossil industry-free-municipality-2030	Kalmar Municipality
2019	KLT Kalmar Skydd av miljon – working report	KLT Kalmar Protection of the environment – working report	Region Kalmar
2019	Kommun Kalmar handlingsplan-for-fossilbranslefri-kommun-2030	Municipality Kalmar action plan for-fossil free municipality -2030	Kalmar Municipality
2019	Klimat- och energistrategi för Kalmar län	Climate and energy strategy for Kalmar County	Kalmar County Administration
2020	Biogasresan i Kalmar lan, slutlig	The biogas journey in Kalmar County, final	Region Kalmar

Articles

The articles associated with this thesis have been removed for copyright reasons. For more details about these see:

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Biogas offers a sustainable alternative to fossil fuels, promoting circularity and local economic growth. Regional actors have promoted it in Sweden for some time. More recently, decision-makers within Sweden and the EU have joined this enthusiasm for biogas. Despite this, in Sweden, the production is only a fraction of what is possible. The primary aim of the thesis is to investigate the interplay of political, societal, and market framings and their influence on biogas markets. The study focuses on biogas markets in Sweden, particularly emphasising the role of regions.

The study found that a biogas system's *local-ness* and similarity to fossil gas in terms of materiality play a significant role in shaping the market. This allows public actors to create local solutions to local needs, which also affects how public actors and society value biogas. Furthermore, the study has identified that the socio-material properties of biogas have both positive and negative effects regarding its connection with fossil gas, which has a crucial role in shaping the biogas market.

The biogas market is evolving, shifting from waste to by-product to asset. The role of biofertiliser is also changing. Market boundaries are still being defined, and stakeholders can use this knowledge to influence market development. This study contributes to the renewable energy literature by emphasising the need for regions to adjust their value and strategy creation approach to reflect new socio-material realities.

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