Governing the emerging sociotechnical imaginary of a climate-positive Sweden

An exploration of the political discussion on negative emissions technologies as a climate change solution

Kirstine Lund Christiansen

Master Thesis Series in Environmental Studies and Sustainability Science,
No 2020:032

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science (30hp/credits)

LUCSUS
Lund University Centre for Sustainability Studies

LUND UNIVERSITY

Governing the emerging sociotechnical imaginary of a climate-positive Sweden

An exploration of the political discussion on negative emissions technologies as a climate change solution

Kirstine Lund Christiansen

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science

Submitted May 12, 2020

Supervisor: Wim Carton, LUCSUS, Lund University

This page left intentionally blank

Abstract

In recent years, negative emissions technologies (NETs) have gained attention as a strategy to tackle climate change. While the academic debate on NETs has been heated, international and national governance frameworks for regulating and incentivising the technologies largely remain unseen. In this thesis, I add to a growing debate concerning the governance of NETs with an empirical investigation of the development of national-level governance in Sweden. Sweden is an intriguing case, because of its target to become climate-positive after 2045, i.e. remove more carbon from the atmosphere than emitted. Through eleven elite interviews with key actors from the Swedish establishment, I explore what role NETs play in shaping a sociotechnical imaginary of a climate-positive Sweden, what governance regimes may evolve, and how this may impact Sweden's response to climate change. I find that both material and ideational factors support the role of NETs in the Swedish establishment's vision of climate-positivity. The authority of the IPCC plays an important legitimising function for developing NETs, and especially bioenergy with carbon capture and storage (BECCS) plays into a Swedish identity of being an international frontrunner regarding climate change. Simultaneously, a governance regime and incentive structures for NETs can largely develop within the current socioeconomic system in Sweden. However, the funding of NETs may challenge the established 'polluter pays'-principle by shifting the distribution of rights and responsibilities in society. Hence, the public will have the responsibility to pay private companies to provide negative emissions if they want a clean atmosphere. While choosing to incur those costs collectively is a valid political position, its feasibility relies on public support, which requires an open discussion about NETs. Finally, the issue of funding also points to a more fundamental and international problem: if NETs are to be used to compensate for excessive emissions in the past, the international community must find ways to assign responsibility for those past emissions. Assigning that responsibility may reignite previous discussions of historical responsibility, which may severely jeopardise the effectiveness of NETs as a solution to climate change.

Keywords: bioenergy with carbon capture and storage; climate governance; carbon dioxide removal; climate recovery; elite interviews; polluter pays principle.

Word count: 11,997.

Acknowledgements

Thank you, Wim. From I first stepped into your office and started rambling about negative emissions technologies, I have felt supported and encouraged to explore this topic in my own way. I have thoroughly enjoyed our conservations and greatly appreciate the feedback throughout.

Thank you, Adam, Alice and Eglè, for the talks and discussions during this thesis process. It has been a pleasure to share the journey with you.

Thank you to all my interviewees. I am truly grateful that you took the time and shared your thoughts and ideas with me. I have been really inspired and encouraged by the reflections and considerations, I heard from all of you. I hope this thesis can be an input in the important work you are engaged in.

Thank you, Dana, Keeli, Miriam and Vera. These last two years would not have been the same without you.

Thank you to my friends and family for letting me talk about negative emissions technologies and other climate-related topics at every occasion, I could find. A special thanks to Gitte and Nicklas for reading through my thesis and giving me feedback. Also, a special thanks to Peter for being so supportive throughout my studies, not the least in these last four months of thesis work.

Thank you to the researchers that have taken the time to talk to me about this topic and the many lecturers and scholars who have inspired me in the process. Thank you to my colleagues for 3.5 years of talks and discussions, which have inspired and ignited my passion for science and research.

Wrapping up this thesis, I also wrap up six years of university studies. It has been six years of absorbing knowledge from some of the brightest researchers, discussing theories and concepts with fellow students and exploring subjects at my own choosing. Those six years have now culminated in four months of complete immersion in, what I consider, the most fascinating topic in the world. I know that I am truly blessed for having had the opportunity to do so.

Table of Contents

Abbreviations

CCS	Carbon capture and storage
CO_2	Carbon dioxide
CPE	Cultural political economy
BECCS	Bioenergy with carbon capture and storage
GHG	Greenhouse gas
IAM	Integrated assessment model
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, land-use change and forestry
NET	Negative emissions technology
RCP	Representative Concentration Pathway
SCF	Swedish Climate Framework
SR1.5	IPCC's Special Report on Global Warming at 1.5°C
SRM	Solar radiation management
STS	Science and technology studies
UNFCCC	United Nations Framework Convention on Climate Change
VER	Verified emission reduction

1 Introduction

In recent years, negative emissions technologies (NETs) have gained prominence as a solution to limit climate change and reduce atmospheric greenhouse gas (GHG) levels. In October 2018, the IPCC's *Special Report on Global Warming at 1.5°C* (SR1.5) showed that most scenarios in which we keep global warming below 2°C and virtually all 1.5°C scenarios depend on large-scale deployment of NETs (Rogelj et al., 2018). By allowing removal of carbon dioxide (CO_2) from the atmosphere for long-term storage in the bio- or geosphere, NETs provide a technological hope that we can avoid dangerous climate change (Beck & Mahony, 2018).

NETs as a climate solution has, however, been at the centre of a heated academic debate, where researchers have criticised their inclusion in integrated assessment models (IAMs), expressing concerns about the feasibility of deploying NETs on the large scales assumed in the models (Anderson & Peters, 2016; Beck & Mahony, 2018; Minx et al., 2018). IAMs combine models of the climate and socioeconomic systems to produce potential future scenarios, which allow scientists to explore the effects policies and societal development have on the climate (Low & Schäfer, 2020). An often-cited critique is that the IAMs assume that large areas of arable land, often twice the size of India, will be available to produce biomass for the most prominent NET, bioenergy with carbon capture and storage (BECCS) (Popp et al., 2017; Smith et al., 2016). The availability of an area of that magnitude has been deemed unrealistic, given that we also need to halt the biodiversity crisis and ensure food security for a growing population (Anderson, 2015; Schneider, 2019; Williamson, 2016).

Despite insecurities concerning the feasibility of deploying NETs, researchers have argued that the very inclusion of NETs in IAMs has altered the political reality of climate change mitigation. By seemingly showing that 1.5°C is still feasible without radical mitigation efforts, the modelling has effectively made the technologies politically inevitable (Beck & Mahony, 2018; Carton, 2019). Perhaps, as a result, the international public debate around NETs has increasingly moved from polarisation to what Haikola and colleagues (2019) have called reluctant acceptance.

Given this potential inevitability of deploying NETs, a critical area of engagement for sustainability scientists is to ensure that their use becomes as socially acceptable and environmentally sustainable as possible (van Vuuren et al., 2017). Responding to this need, more researchers now consider ideal and potential governance regimes of NETs (e.g. Buck, 2019; Honegger & Reiner, 2018; Horton et al., 2016; Reynolds, 2018b). The debate on governance has primarily been theoretical, since there are no international agreements for governing NETs (Horton et al., 2016; Talberg et al., 2018) and few coun-

tries are developing national governance frameworks (Fridahl & Bellamy, 2018; Moe & Røttereng, 2018).

Through an in-depth case study of the emerging discussion in the Swedish establishment, I aim to add to this growing strand of research by exploring how national-level governance of NETs will develop. Sweden is an intriguing case due to the country's 2017-goal of becoming climate-positive after 2045[1], which has prompted the development of NETs policies and pilot projects (Ministry of Environment and Energy, 2018a).

Through the concept of sociotechnical imaginaries from science and technology studies (STS), I explore the role NETs play in the Swedish vision of climate-positivity. Furthermore, through cultural political economy (CPE), I ask what potential governance regimes, we may see emerge in Sweden around NETs. By examining perceived opportunities and challenges in Sweden, I open for a discussion of whether NETs can be part of a viable solution to climate change, or if opponents are right in dismissing the techniques.

1.1 Research questions

I pursue three lines of enquiry represented by three research questions:

Research question 1: How does the Swedish establishment envision NETs to play a role in creating a climate-positive Sweden and what factors shape this role?

Research question 2: What governance regimes does the establishment consider regarding NETs and how will costs and benefits of deployment be spread across society?

Research question 3: What implications may the development of NETs have for Sweden's efforts to limit climate change?

In research questions 1 and 2, I explore different aspects present in the Swedish discussion to understand the vision of climate-positivity, which NETs feed into, and the expected political regulation of the technologies, including distributional effects. As the political discussions around NETs are still in their infancy, I focus on providing an in-depth and nuanced exploration of the case based on eleven elite interviews I conducted with representatives from the Swedish establishment[2]. The final line of

[1] The term climate-positive is somewhat bewildering. It refers to reaching net-negative emissions, i.e. that more GHGs are removed from the atmosphere than emitted. The term is popular in marketing, but both Sweden and the C40 Cities Climate Leadership Group use the phrase politically (Anzilotti, 2018). In this thesis, I use climate-positive synonymously with net-negative emissions.

[2] I use the term establishment to denote those individuals and groups who will likely affect the Swedish discussion on NETs and the development of governance regimes. It thus includes politicians, but also civil servants, researchers and representa-

enquiry focuses on the expectation that NETs will help us limit climate change by exploring to what extent and under which conditions we can expect this to be the case.

To answer my research questions, I proceed as follows; in section 2, I define and situate the concept of NETs in the broader academic debate and introduce the Swedish case. In the subsequent three sections, I outline my research philosophy, important theoretical concepts, and my methodology. In section 6 and 7, I present and discuss my results relating to the three research questions posed above, before I conclude in section 8.

2 Background

2.1 Conceptualising NETs

Negative emissions denote "intentional human efforts to remove CO_2 from the atmosphere" (Minx et al., 2018, p. 3) and can be achieved through several different techniques known as NETs[3], as seen in table 1. These vary greatly in costs, benefits, risks, maturity, potential, etc. (Minx et al., 2018).

Table 1. Types of negative emissions technologies. Adapted from Minx et al. (2018).

<table>
<tr><th>Technique</th><th>Storage medium</th><th>Capture via</th><th>Earth system</th></tr>
<tr><td>Afforestation and reforestation</td><td>Above-ground biomass</td><td rowspan="4">Photosynthesis</td><td rowspan="5">Terrestrial</td></tr>
<tr><td>Soil carbon sequestration</td><td rowspan="2">Soil</td></tr>
<tr><td>Biochar</td></tr>
<tr><td>Bioenergy with carbon capture and storage</td><td rowspan="2">Geological reservoirs</td></tr>
<tr><td>Direct air carbon capture and storage</td><td rowspan="2">Chemistry</td></tr>
<tr><td>Enhanced weathering and ocean alkalinisation</td><td>Minerals</td><td rowspan="2">Ocean</td></tr>
<tr><td>Ocean fertilisation</td><td>Marine sediments</td><td>Photosynthesis</td></tr>
</table>

tives of businesses and civil society organisations who may all affect the public debate and development of policies (see also section 5.1 and 5.2).

[3] Within the literature, NETs are also referred to as CO_2 removal or GHG removal (Gough & Mander, 2019). I use the term NETs throughout the thesis.

Academia has debated the conceptualisation of NETs vis-à-vis more traditional climate change strategies. The concept initially entered mainstream climate change debates with the Royal Society's 2009-report on geoengineering, which defined NETs as one of two types of geoengineering, the other being solar radiation management (SRM) (Shepherd, 2009). However, researchers have since argued that NETs and SRM are fundamentally different and should not be treated under the same label (e.g. Heyward, 2013; Lomax et al., 2015; Minx et al., 2018). Since several techniques, included as NETs, have also been considered traditional mitigation measures, e.g. afforestation and soil carbon sequestration, NETs may in some respects be closer to mitigation (Reynolds, 2018b).

In this thesis, I combine insights from Heyward (2013) and Meadowcroft (2013) to conceptualise NETs as a climate change strategy (see figure 1). According to Heyward, NETs constitute one of five distinct strategies to address climate change: mitigation, NETs, SRM, adaptation, or rectification. NETs resemble mitigation, since both techniques aim to avoid a given level of atmospheric GHG concentration (Heyward, 2013). Still, unlike mitigation, which focuses on eliminating current and future emissions, NETs draw GHGs, which have already been emitted, out of the atmosphere, storing them in enhanced or artificial carbon sinks (Heyward, 2013).

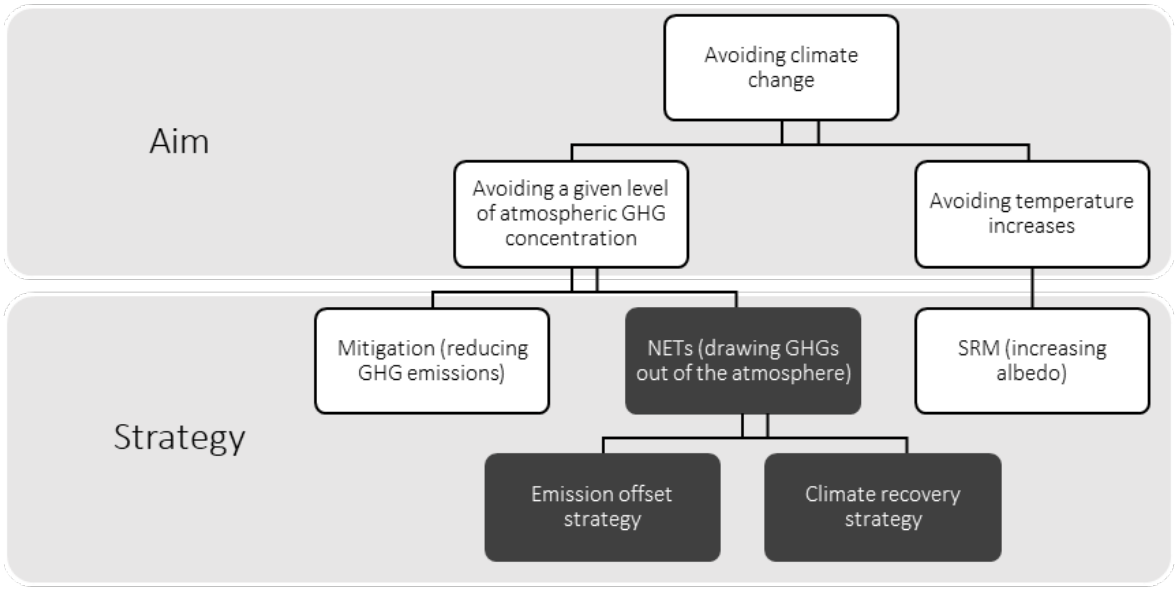

Figure 1. Strategies to avoid climate change. The figure shows three of Heyward's five climate change strategies, namely mitigation, NETs, and SRM. For simplicity, I omit adaptation and rectification, as these strategies aim to deal with the effects of climate change rather than avoiding climate change. NETs are highlighted in black and further divided into an emission offset and a climate recovery strategy in line with Meadowcroft. Adapted from Heyward (2013) and Meadowcroft (2013).

I nuance this conceptualisation through Meadowcroft, who holds that NETs can be employed through two distinct strategies: an emission offset or a climate recovery strategy. Through an offset strategy, negative emissions compensate for continued present-day emissions to reach a balance of

net-zero or slightly positive emissions (Meadowcroft, 2013). Through a climate recovery strategy, negative emissions compensate for excessive historical emissions to reach net-negative emissions and atmospheric GHG level, thus only decreases through this latter strategy (Meadowcroft, 2013).

2.2 The history of NETs

NETs gained prominence in IAMs around 2007, when the IPCC included the Representative Concentration Pathway 2.6 (RCP2.6) in their assessments (Beck & Mahony, 2018). By allowing large-scale removal of GHGs from the atmosphere, the inclusion seemingly doubled the remaining carbon budget (Fuss et al., 2014; Geden, 2016). Some researchers, however, found the inclusion controversial, as they considered RCP2.6 the result of an international political community eager to see a pathway to 2°C, which was politically acceptable, i.e. did not require extensive societal transformations (Anderson & Peters, 2016; Beck & Mahony, 2017).

To reach 2°C, RCP2.6 relied heavily on BECCS, a technology deemed technically possible, but largely unproven at the time (Beck & Mahony, 2018). The principle behind BECCS is that, as biomass grows, it draws CO_2 from the atmosphere through photosynthesis. When the biomass is then converted to energy or bioproducts, instead of re-emitting the CO_2 to the atmosphere, it is removed and transported for underground storage (see figure 2). By providing both energy and negative emissions, BECCS is particularly useful in IAMs, which generally seek to optimise costs and benefits (Low & Schäfer, 2020). In fact, so useful that the median estimate across IAMs suggests that 46% of our primary energy use in 2050 should come from BECCS (Lehtveer, 2018).

The inclusion of RCP2.6 into the IAMs happened at a time, when climate science, especially as performed by the IPCC, was seen to shift towards focusing more on assessing potential policies than causes and consequences of climate change (Beck & Mahony, 2017; Workman et al., 2020). This shift has been criticised for masking the political nature of the assumptions in IAMs, which influence the scenarios they produce (Jasanoff, 2015b). For example, the IPCC is only mandated to assess the technical and bio-physical feasibility of resource allocation for NETs and not social or political feasibility (Beck & Mahony, 2017). Thus, some scenarios assume vast amounts of land and other resources being allocated to NETs (e.g. Dooley et al., 2018; Popp et al., 2017; Realmonte et al., 2019; Smith et al., 2016), causing considerable criticism for compromising other aims such as food and biodiversity security (Schneider, 2019).

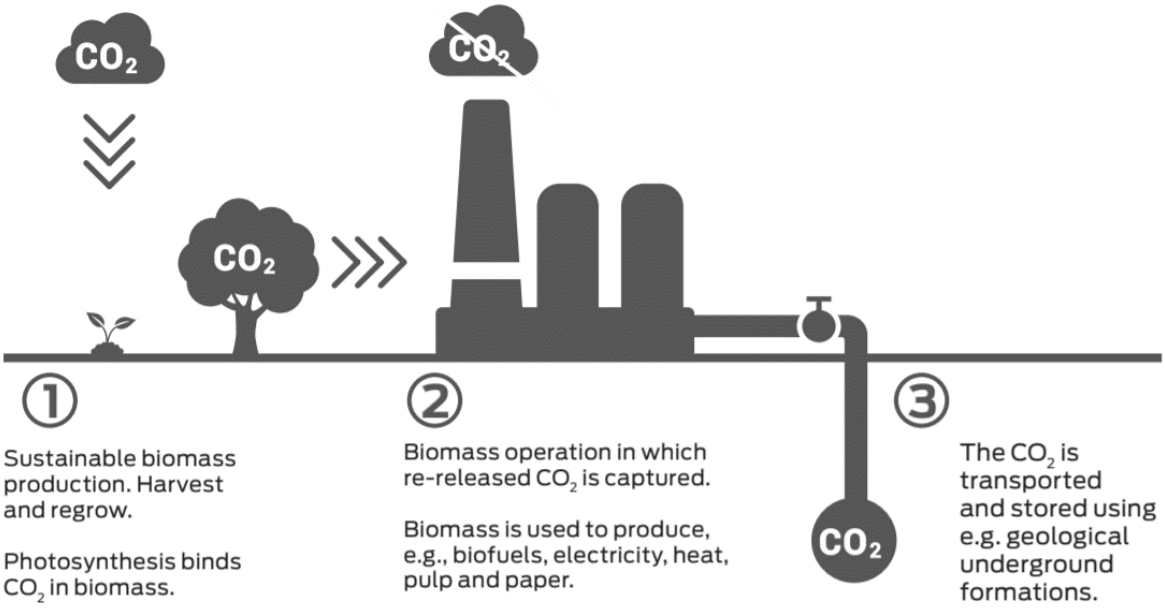

Figure 2. Principle of bioenergy with carbon capture and storage (Fridahl, 2018).

Others have argued that the production of scenarios hide the many assumptions the modelling community makes about the climate system, where uncertainties exist (Fuss et al., 2014; Jones et al., 2016; Minx et al., 2018; Workman et al., 2020). One example is uncertainties about how the climate system will respond to negative emissions. Contrary to the general understanding at the time, Zickfeld and colleagues (2016) proved it unlikely that one ton of removed CO_2 will have a proportional effect on temperatures compared to one ton emitted. Rather, it is more likely that removed CO_2 will have a smaller impact than emitted CO_2, primarily because the large historical carbon uptake in the oceans will continue to affect temperatures despite NETs (Zickfeld et al., 2016). Such insights have led some to argue that depending on NETs constitutes hubris if we believe we can manage the carbon cycle without fully understanding it (Minx et al., 2018).

Finally, some researchers have argued that IAMs are not only based on debatable techno-scientific assumptions, but also on inherently political assumptions, which cannot be assessed scientifically (e.g. Carton, 2019; McLaren et al., 2019; Workman et al., 2020). An example is that the discount rates used in IAMs are generally positive, which means that a cost incurred in the future, *ceteris paribus*, will appear preferable to that cost being incurred today (Bednar et al., 2019). This assumption tends to delay action and inherently means that we value the welfare of our generation higher than future ones (Bednar et al., 2019; Carton, 2019; McLaren et al., 2019; Workman et al., 2020).

Assumptions are necessary to build models and scenarios (Beck & Mahony, 2018) and it has therefore been argued that the assumptions mentioned are legitimate, as long as they are communicated

clearly to policymakers (Geden, 2016). The IPCC and other climate science communities have, however, been criticised for not communicating clearly. Hence, scenarios become seen as inevitable, while other potential pathways could be produced with different assumptions (e.g. Anderson & Peters, 2016; Geden, 2016; Haikola et al., 2018; Larkin et al., 2018; Low & Schäfer, 2020; Workman et al., 2020).

Collectively, these issues may lead to a moral hazard risk. The moral hazard argument entails that if NETs are believed to be available in the future, necessary according to climate science, and cheaper than other solutions, then we will be less supportive of traditional mitigation measures in the present (Minx et al., 2018). Thus, we may not initiate the radical changes required to avoid dangerous climate change (Anderson & Peters, 2016; Buck, 2012; Campbell-Arvai et al., 2017; Geden, 2016; Markusson et al., 2018). Though this argument enjoys traction among opponents of NETs, it has been criticised for lacking empirical grounding (Bellamy, 2018; Colvin et al., 2020).

Despite the discussions within academia, no international agreements governing NETs exist (Horton et al., 2016; Talberg et al., 2018), few countries have developed national policies (Moe & Røttereng, 2018) and the private sector has few incentives for developing NETs (Fridahl & Bellamy, 2018).

2.3 NETs in Sweden

In 2017, a broad parliamentary coalition adopted the Swedish Climate Framework (SCF), which sets the goal that Sweden should reach net-zero emissions in 2045 and after that pursue net-negative emissions (Ministry of Environment and Energy, 2018a). The SCF specifies that while Sweden's emissions should fall by 85% compared to 1990-levels, the remaining 15% can be reached through supplementary measures (Ministry of Environment and Energy, 2018a), i.e. through an emission offset strategy with negative emissions. The remaining 15% are expected largely to be non-fossil emissions from the agricultural sector (Ministry of Environment, 2020a). The SCF does not specify any targets for the amount of net-negative emissions, which should be delivered after 2045 (Ministry of Environment, 2020a).

In 2018, the Swedish Government appointed a Commission to investigate the possibilities of reaching the remaining 15% (Ministry of Environment and Energy, 2018b). The Commission was tasked to investigate three types of measures leading to negative emissions: 1) land use, land-use change and forestry (LULUCF) sector activities, 2) BECCS, and 3) verified emission reductions (VER) in other countries (Ministry of Environment, 2020a). Especially BECCS has been proclaimed as a promising solution, with researchers pointing to large potentials for deployment in Sweden (Hansing & Fridahl,

2018; Karlsson et al., 2017). The results of the Commission, published in January 2020, supported this assessment (Ministry of Environment, 2020a).

In 2019, while still awaiting the results of the Commission, the Swedish government took initial steps to support the development of NETs by investing 100 million SEK in industrial test projects (Ministry of Environment, 2019). This support effectively constituted the first economic incentive for companies to develop NETs, and led to the launch of the first Swedish test facility for BECCS in December 2019 by Stockholm Exergi (Stockholm Exergi, n.d.).

3 Research philosophy of sustainability science

A crucial aim of my thesis is to bridge the distinction between problem-solving and critical research. First developed by Cox (1981), this distinction has been central in sustainability science (Jerneck et al., 2011; Mahmoud et al., 2018). According to Cox (1981), theory and research tend to be problem-solving or critical. Either you approach the world as you find it and research aims to solve problems within current scientific paradigms and socioeconomic structures or research questions current paradigms and structures aiming to ensure fundamental changes at the expense of solving concrete problems (Cox, 1981).

Following the criticisms of NETs outlined in section 2.2, it could be straightforward to employ a critical research approach to investigate the Swedish discussion. However, according to Colvin and colleagues (2020), assessing NETs from a purely critical perspective may polarise the debate, which could result in a stalemate situation, where we do not develop alternatives to NETs, but simultaneously do not deploy NETs due to lack of societal acceptance. In that case, it may become impossible to avoid dangerous climate change (Colvin et al., 2020).

Hence, I aim to balance the two traditions. Concretely, I ask how NETs governance will likely develop, without questioning the inclusion of NETs in the SCF. But next, I explore the potential distributional impacts of NETs and how NETs may impact Sweden's ability to respond to climate change. Ultimately, I aim for the reader to ask themselves: is this development desirable, and if not, how do we improve the situation (Flyvbjerg, 2004)?

As such, my research follows the credo of sustainability science, aiming for research to be problem- and purpose-driven to inform better societal decisions (Clark & Dickson, 2003). With this, I also recognise that as a researcher, I carry values and ideas myself (Spangenberg, 2011). Most importantly, I acknowledge that I, personally, hold conflictual sentiments towards NETs, agreeing that the concept

and the way it has been debated (or rather, has not been debated) entails a risk of moral hazard. Simultaneously, since climate change is only growing more challenging, I believe NETs, if used wisely, may allow us to amend mistakes of the past and avoid the worst impacts of climate change. It is with this personal conflict and desire to contribute to NETs being a solution and not a hazard that I conduct my study.

Besides employing a research strategy indicative of sustainability science, I also aim to contribute to key discussions in sustainability science about concepts of power and temporality. As reviewed in section 2.1 and 2.2, NETs entail complex interplays between past, present, and future. In short, present scientific results provide visions of future solutions, which will allow us to offset emissions of the past. As such, studies of the politics surrounding NETs can inform ongoing debate within sustainability science about the role of temporal scales (Cash et al., 2006; Wiek et al., 2011).

Furthermore, power plays a central role in the study, especially through the critical examination of the power inherent in scientific results and visions about the future. Importantly, I understand power in a Foucauldian sense, i.e. power is both a productive and restrictive force that limits what appears politically possible, but also simultaneously allows for changes in status quo (Flyvbjerg, 2004).

4 Theoretical entry points

Theoretically, I build on STS and CPE. The two perspectives complement each other by emphasising both the role of ideas and materiality in shaping social reality (Jasanoff, 2015b; Newell, 2015). Ideationally, both theories share the concept of imaginaries, while scientific innovations and economic structures, respectively, provide the material side. As NETs generally remain a vision for the future rather than empirical reality, the concept of imaginaries provides a lens to examine factors shaping the phenomenon (Gough & Mander, 2019), while perspectives of both science and economy allow for a well-rounded exploration of the case.

4.1 Science and technology studies

A central assumption in STS is that science and politics cannot be fully separated, but constantly influence each other (Jasanoff, 2015b; Turnhout, 2018). Political decisions, programmes and funding thus influence how science is conducted (Turnhout, 2018). Simultaneously, science produces certain understandings of the world, which influence political decisions (Lövbrand, 2009; Turnhout, 2018). However, since scientific assessments tend to appear neutral, basing political decisions on scientific

authority tend to depoliticise politics and make decisions appear objective (Lövbrand, 2009; Turnhout et al., 2015; Workman et al., 2020).

In this thesis, the STS concept of sociotechnical imaginaries is central. Originally developed by Jasanoff and Kim (2009), sociotechnical imaginaries refer to "collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects" (Jasanoff & Kim, 2009, p. 120). That is, visions about a desired future society shape governance of science today, e.g. regarding regulation and funding of new technologies (Burri, 2015; Jasanoff & Kim, 2009). Simultaneously, science also plays a crucial role in shaping the futures and the politics we can imagine (Lövbrand, 2009). Sociotechnical imaginaries thus have performative power, i.e. they make some actions, and therefore some futures, more or less possible (Jasanoff & Kim, 2009). Again, I understand this power in the Foucauldian sense of being both restrictive and productive; ideas and visions of the future allow societies to progress. While techno-scientific discovery may be similar across different contexts, the particular sociotechnical imaginary that forms in each context is highly dependent on existing identities and narratives in that society (Jasanoff & Kim, 2009).

NETs may thus represent potential scientific opportunities to limit climate change, which enable specific visions about a preferred future society, where we keep temperature increases below 2°C (Gough & Mander, 2019). As the vision about NETs becomes collectively shared, it, in turn, influences political and scientific decisions, e.g. by leading to more investment into developing technologies such as BECCS.

According to Jasanoff and Kim (2009), sociotechnical imaginaries are neither political programmes nor discourses. Rather, they are somewhere in between; a discursive vision that leads to decisions and action (Jasanoff & Kim, 2009). While a full-fleshed political framework for governing NETs has still not been developed in Sweden, important political steps are already taken to promote the development as reviewed in section 2.3.

4.2 Cultural political economy

To further nuance the concept of sociotechnical imaginaries, I use insights from the theoretical tradition of CPE. While theories of political economy explain processes in society by referring to material interests and economic structures, theorists of CPE hold that material aspects are necessary, but not sufficient to understand societal development (Jessop, 2010). To fully understand how practices such as NETs gain influence, we must ask both which economic structures and material interests underpin this development, but also which identities, values and norms facilitate and inhibit such development

(Jessop, 2010; Markusson et al., 2018). Thoughts of CPE thus align with STS's attention to ideas and technological materiality but adds the further nuance of economic materiality (Tyfield, 2012).

Theorists of political economy often understand climate change as a collective action problem, where free-riding and over-exploitation degrades a common-pool resource, namely the atmosphere (Newell, 2015). A common solution to cease over-exploitation is to incorporate the ecological service provided by a clean atmosphere into the market mechanism (Mauerhofer et al., 2013). This reasoning has inspired carbon markets, carbon taxes etc. (Newell, 2015).

While such solutions have material aspects, they also hinge on different ideas, norms, and values in society. An example is the 'polluter pays'-principle often used to address the collective action problem (Bernstein, 2002). The principle normatively privileges market solutions over stricter regulatory ones, but also includes the normative idea that companies are responsible for cleaning up their pollution (Bernstein, 2002) and that the public has the right to a clean environment (Mauerhofer et al., 2013).

Tying together aspects of materiality and ideas through Jessop's concept of imaginaries, Levy and Spicer (2013) identify different systems of ideas about the climate, which advocate different responses and correspond to different interests and identities in society. Among them is an imaginary of techno-markets or ecological modernisation, which has historically been prevalent in shaping our understanding of and actions towards climate change (Levy & Spicer, 2013); a conclusion shared by other researchers as well (e.g. Hajer, 1995; Jänicke, 2008; Jessop, 2010; Mol & Spaargaren, 2000). The techno-market imaginary assumes that our climate is vulnerable, but that we can manage it "through appropriate economic incentives and technological innovation, without fundamentally compromising lifestyles or economic growth" (Levy & Spicer, 2013, p. 666). Within this imaginary exists differences in how much emphasis one puts on the role of the state, ranging from complete confidence in the market as the best mechanism to solve problems to a belief that the state must actively support the development of green industries (Levy & Spicer, 2013).

5 Methodology

5.1 Case study

My study is an in-depth case study of the emerging political discussion on NETs in Sweden. The case study approach allows me to explore values, interests, and mechanisms of power at play in the development of a governance regime in a concrete empirical setting (Flyvbjerg, 2006). Furthermore, an

in-depth case study can increase the Swedish society's understanding of the values and assumptions, which underpin the emerging political agenda on NETs, thus adding to society's practical rationality and ability to make informed decisions (Flyvbjerg, 2006). The results found in this study is considered context-dependent, but since the governance of NETs is a new empirical phenomenon, an exploratory study can add considerable knowledge (Flyvbjerg, 2006). The results may thus still be informative for understanding a wider range of phenomena (Lund, 2014). Conceptually, the results may illuminate the role of sociotechnical imaginaries in climate change governance, and empirically, the case may reveal challenges policymakers will face when developing policies on NETs.

Empirically, I explore the discussion in the Swedish establishment. I understand establishment as those actors who influence societal decision-making in Sweden. It is thus not only politicians, but also civil servants, industry representatives, researchers, and civil society organisations. While actors outside of Sweden also influence national policy, for simplicity, I delineate the study to encompass actors within Sweden only.

I chose Sweden as case both for practical, research and strategic purposes. Practically, it is an exclusive club of countries, which have started serious discussions on how to deploy NETs (Moe & Røttereng, 2018). Among those who have, Sweden was the most accessible to me, both geographically and linguistically. For research purposes, Sweden is furthermore intriguing, as the discussion on establishing a governance framework is gaining momentum, with the Commission presenting its results in January 2020 and a deadline for public referrals in late May (Ministry of Environment, 2020b). Therefore, I can study initial discussions and ideas, which shape the governance structures. From a strategic perspective, my study may have a, albeit small, chance of transcending academia and play a role in shaping the governance of NETs in Sweden, as I will share my results with my interviewees at a time, where the governance structure has yet to be determined.

5.2 Qualitative interviews

The main data for my study is eleven semi-structured interviews. I sampled the interviewees purposefully according to their proximity to the policy process or their public engagement with the NETs agenda. As such, I expect them to possess important information about the current discussions on NETs and how NETs governance may develop. The eleven interviewees included four politicians, three civil servants, two energy industry representatives, one civil society organisation representative and one researcher. I considered the spread of the professional backgrounds positive, as my objective was to piece together different perspectives to gain a broad and balanced understanding of current discussions (Aberbach & Rockman, 2002; Lomax et al., 2015).

The interviewees were all professionals working actively with the NETs agenda, most of them in high-level positions. As such, I consider the interviewees elites, i.e. they are understood to be of particular relevance and as having certain types of unique knowledge (Aberbach & Rockman, 2002). I, therefore, modified the interview guide for each interview, dependent on the experience I assumed the interviewee to have (see appendix). I also revised the interview guide according to the knowledge I gained throughout the study (Kvale, 2007).

While I sampled the interviewees according to the knowledge, I assumed they possessed, I also, to a certain extent, consider them representative for a wider circle of stakeholders with similar positions (Bogner et al., 2009). I, however, do this cautiously as I do not verify whether they are representative. Due to the interviewees' schedules and geographic residence, I conducted some interviews in person and others via Skype or phone. Some interviewees asked for the questions beforehand to prepare, which I then sent.

5.3 Thematic analysis

In line with the purpose-bound research philosophy, my focus in the study was to provide productive and useful results (Fereday & Muir-Cochrane, 2006; Nowell et al., 2017), rather than a full account of all aspects brought forward in the interviews. Productive and useful results are here understood to be those who illuminate aspects of an emerging sociotechnical imaginary and potential governance regimes of NETs. Therefore, reflections mentioned by several interviewees were not necessarily considered more important than observations raised by only one or a few interviewees (Fereday & Muir-Cochrane, 2006).

Practically, I undertook a thematic analysis to uncover the most important aspects of NETs in Sweden (Nowell et al., 2017). Due to the interpretive process of constructing themes through repeated readings of the data, the thematic analysis bridges inductive and deductive research practices (Fereday & Muir-Cochrane, 2006). Since I explore a phenomenon with little previous empirical research, I consider this iterative process between theory and data conducive.

I identified the themes through several rounds of reading and coding the interviews. The initial coding was open but based on my prior knowledge and analytical interests (Nowell et al., 2017). Between each coding, tentative themes were established. I selected the final five themes (see section 6) as they collectively incorporated the primary reflections raised across the interviews and individually provided novel perspectives to answer the research questions.

All interviewees consented to being referred to by titles. Still, since several interviewees requested anonymity beyond that, in the analysis, I only reference the interviewees according to randomly assigned ID numbers. As there is limited previous research on the political discussion of NETs in Sweden, my primary purpose is to explore some of the overarching ideas and challenges and not, e.g. compare the views of different groups in society. I, therefore, deemed it more important to gain access to key actors and in return, assure them confidentiality, than reporting the exact origin of any specific quote or opinion.

5.4 Limitations of the study

In this study, I aim to give a focused yet comprehensive account of the discussions around NETs in the establishment in Sweden. However, due to resource limitations, it was impossible to cover all aspects of the debate. I chose to focus on ensuring broad representation from the political parties, where I include four out of eight political parties with representatives from both right- and left-wing parties.

From the private sector, I focus on one type of industry, namely the energy sector. I, therefore, lack representatives from, e.g. the agricultural, forestry and industrial sectors, which are also essential voices in the debate (see section 6.3). It furthermore became apparent throughout the interviews that besides missing certain types of stakeholders, I miss certain opinions as well, especially the more radical ones. Interviewees pointed to actors and organisations who hold considerably more positive and negative views about NETs than the views voiced in my interviews. These omissions limit the comprehensiveness of my results.

Another limitation of my study is the lack of comparative element. Sociotechnical imaginaries are usually identified through comparative studies either temporally, to identify development within a society, or spatially, to identify different imaginaries in different contexts (Jasanoff, 2015a). While the interviewees do compare the Swedish experience with NETs to other countries, periods, etc., these comparisons are anecdotal, and my research neither seeks to validate nor refute them.

Without variation across time or space, my study has limited explanatory power, and I cannot confidently generalise to a broader class of cases, which is often considered the case study method's raison d'être (e.g. Gerring, 2004). The Swedish context will undoubtedly differ substantially from other countries, limiting the generalisability of the study. The merit of my research thus remains to be the in-depth exploration of the single case (Flyvbjerg, 2006).

6 Results

In the following sections, I present the five main themes identified in my analysis: the role science plays in understanding NETs; opportunities of developing NETs in Sweden; challenges involved; issues regarding the governance of NETs; and finally questions about setting targets and assigning responsibility for delivering negative emissions. As I, in the interviews, asked about negative emissions in general, the results concern NETs as a broad category rather than specific technologies, unless otherwise specified.

6.1 The role of science

Because sociotechnical imaginaries arise from certain understandings of current and potential future states of science and technology (Jasanoff & Kim, 2009), I explore the interviewees' perception of the science surrounding NETs and the state of the techniques in this section of the analysis.

One crucial aspect emerging from the analysis is that many interviewees expressed that the science clearly states that negative emissions and NETs are necessary to meet the goals of the Paris Agreement, often referring to the IPCC as saying that this is the case (interview 1, 3, 5, 6, 9, 10). As one interviewee said, mentioning the results of the SR1.5 report: "if we are to meet our targets on 2°C or 1.5°C, it is obvious that we need negative emissions" (interview 5). This expressed necessity concerning negative emissions is indicative across the interviews as no interviewees argued that national or international targets can or should be reached without negative emissions. According to several interviewees, negative emissions are not just necessary to meet net-negative emissions, but also to achieve net-zero, as it is impossible to reduce all emissions in Sweden (interview 3, 6, 7, 9, 10). Aligning with the conclusion of the Commission (Ministry of Environment, 2020a), agriculture is considered the sector, which must be allowed most residual emissions after 2045.

The interviewees, who comment on the state of technology, in general, expressed optimism that NETs will be technically feasible within a reasonable timeframe; while LULUCF sector measures can be implemented immediately, BECCS is at least expected to be relevant for the 2045 goal (interview 1, 3, 4, 10). A few interviewees expressed some concerns about uncertainties regarding the costs (interview 4, 5, 10): "We do not know for sure how big the potential is, and it is also going to be expensive, we do not know how expensive" (interview 5). A couple of interviewees also mentioned that there will be uncertainties about the permanence of storage in the LULUCF sector, if fires, insect outbreaks, storms, or similar compromise storage. However, these risks were considered non-avoidable in the LULUCF sector (interview 4, 7).

A few interviewees mentioned uncertainties regarding the true potential of different solutions (interview 1, 2, 4, 5). Still, only one interviewee expressed concerns about whether the technologies proposed could indeed provide the envisioned climate-benefits (interview 2). Especially BECCS and issues of sustainable biomass sourcing were highlighted,

> I think on the technological part of it there is a lot of optimism … on how to get access to the biomass and how climate-friendly it is in the first place, and I guess the question whether BECCS will be available in the scale imagined in international climate politics or Swedish climate politics is an open question (interview 2).

Regarding this concern, I asked all interviewees how they considered the international-level critique of the inclusion of NETs in the IPCC's models. While many argued that the critique does not apply to Sweden (see section 6.2), some also dismissed the critique warning against questioning the IPCC. The reasoning behind was either strategic, because it would give climate deniers ammunition to challenge climate science in general (interview 1) or because the science from the IPCC is considered the best available (interview 9, 10).

Overall, the state of science and especially the authority of the IPCC thus appear to play an essential role in establishing confidence in NETs as a policy solution, but also for building the understanding that NETs are inevitable for reaching the climate targets.

6.2 Benefits and opportunities for NETs in Sweden

Since the establishment of a sociotechnical imaginary of climate-positivity will be dependent on the perceived opportunities and challenges of NETs, I asked all interviewees to reflect on these. In this section, I explore opportunities, while I elaborate on challenges in section 6.3. Several interviewees expressed that the opportunity to raise the ambitions for climate change action is the primary and perhaps sole purpose of developing NETs (interview 4, 5, 6, 7, 8). As one interviewee put it: "I think at the end of the day it is about saving the planet of course" (interview 8).

However, most interviewees also highlighted secondary benefits. Some mentioned that developing NETs will allow Sweden to maintain frontrunner-status in international climate politics (interview 1, 2, 6). Similarly, some saw developing NETs as potential business opportunities, both for individual companies if they can sell negative emissions as offsets (interview 3), but also for Sweden as a whole if know-how can be exported (interview 1). Others mentioned that Sweden, through NETs, can assume international responsibility by reaching net-zero, and then net-negative emissions, as fast as possible (interview 5) or develop know-how about technologies such as BECCS, which can then bene-

fit other countries as well (interview 6). Considering the different techniques available, some interviewees favoured BECCS as an especially cost-efficient option (interview 3, 11). Others advocated for measures in the LULUCF sector to create synergies with soil improvement, biodiversity enhancement or similar (interview 2, 4, 6, 7).

One aspect present in most interviews was the sentiment that Sweden has conducive opportunities for developing especially BECCS. With abundant biomass available from the large forestry sector and multiple large point-sources, where biogenic CO_2 can be captured, most interviewees considered the Swedish conditions ideal for BECCS (interview 1, 3, 4, 6, 7, 10, 11). One interviewee articulated the sentiment present in many interviews,

> In Sweden, there is a huge technical potential for BECCS, because we have huge emissions of biogenic CO_2 from large sources. So … compared to other countries, Sweden has very good potential to capture this CO_2 without conflict with biodiversity and so on (interview 7).

The ideal Swedish conditions also led some interviewees to dismiss the international-level critique of relying on BECCS for providing negative emissions as being irrelevant for Sweden. They argued that biomass is already used extensively in Sweden and producing negative emissions with BECCS will, therefore, not require more biomass and land (interview 3, 4, 6, 7, 10). Several interviewees agreed that IAMs rely too much on BECCS and that this can result in global-level land-use problems, but that the critique does not apply to Sweden (interview 3, 4, 5, 6, 7, 10).

> I think the criticism is, to a certain extent, correct, but it is not valid everywhere. … we do not need to produce more biomass to start with BECCS. What we need to do is maybe take more of this harvest residue from forestry (interview 4).

Only one interviewee questioned whether Sweden overestimates the potential for ensuring sustainable biomass for the envisioned BECCS-production (interview 2).

While NETs thus appear to be considered a solution to primarily increase climate ambitions, several co-benefits are considered. The opportunities for development are considered excellent, even indicating a sense of Swedish exceptionalism regarding BECCS.

6.3 Challenges for NETs in Sweden

When asked about the difficulties for developing NETs in Sweden, many mentioned the issue of securing funding, which I elaborate on in section 6.4.1 and 6.4.2. Others suggested issues of ensuring

proper verification (interview 1, 4, 6) and standardising accounting rules (interview 4, 6, 9, 10). Two slightly different, but also interconnected challenges were, however, raised throughout the interviews in somewhat different ways. The first concerns the risk that NETs become a reason to neglect traditional climate change mitigation. The second concerns the risk that the discussion around NETs becomes polarised. Below, I explore the two in turn.

All interviewees held that NETs are purely supplementary measures to mitigation and should not be considered alternatives to rapid emission reductions. “Negative emissions cannot be seen as an excuse to not do anything with the fossil fuels. You have to do both at the same time” (interview 1). However, several interviewees expressed concerns that other stakeholders may be less supportive of mitigation measures because NETs are considered a possibility (interview 2, 5, 8). One interviewee expressed optimism regarding NETs, in general, but also raised concern,

> I think negative emissions can be used as something that says to people that, well, since we will have negative emissions in the future, we do not have to do so much now. Let us just wait for all of these sci-fi solutions and let us not trouble the economy and the society we live in now so much (interview 8).

Contrary, some interviewees expressed confidence that the moral hazard issue will be minor in Sweden because there are already several emission reduction targets for different sectors and the entire economy, e.g. that 85% of emissions must be cut by 2045 (interview 6, 7).

Though some interviewees thus fear that NETs are used to deflect from mitigation, other interviewees fear that the discussion will be tainted with misunderstandings (interview 3, 4, 6, 7) or polarised with sceptics blocking NETs project (interview 1, 9, 10), making it difficult to reach the Swedish climate targets. One interviewee explained that while they consider the exact use of NETs a fair political discussion, they fear polarisation of the general debate,

> There is a risk that it will become polarised when it comes to one side looking at [negative emissions] as an alibi [not to cut emissions] and the other side defending itself … I hope that we can find a way to not polarise that debate, since the IPCC talks about that we need to have negative emissions (interview 9).

In their considerations of the two above challenges, the interviewees also touch upon the different stakeholders they perceive to be important in the Swedish debate. Here especially environmental NGOs and the forestry and industrial sectors are considered to be essential for how the discussion on

NETs develops as these groups either hold strong opinions or play influential roles in society (interview 1, 2, 3, 4, 5, 6, 10, 11).

6.4 Governing NETs

From the interviews, roughly three main governance issues arose, namely the incentive structure for NETs, who should pay for NETs and what should be considered NETs.

6.4.1 Incentivising NETs

The first issue concerns the system that should be created for the private sector to develop NETs. I mainly consider incentives to promote BECCS as these are new and few.

Several interviewees argued that developing NETs will require incentivising private actors through rewards (interview 1, 3, 5, 9, 10). According to one interviewee, increasing the current carbon tax should furthermore complement the reward-system (interview 5). Several interviewees also mentioned that while the system can be initiated nationally, it should ideally be scaled up or connected to the EU level, perhaps through the EU's Emissions Trading Scheme (interview 1, 5, 6, 11). However, no one presented concrete suggestions on this.

Two incentive structures stand out as the most debated: a reverse carbon tax and a reverse auction system. A reverse carbon tax entails subsidising negative emissions by paying a predetermined price to anyone who delivers negative emissions (Ministry of Environment, 2020a). A reverse auction system means that the government requests a certain amount of negative emissions and then pay the provider, who offers the lowest price in an open bidding process (Ministry of Environment, 2020a).

One interviewee argued for the logic of the reverse carbon tax due to Sweden's traditional carbon tax,

> If you put one ton of CO_2 in the air and you have to pay a certain amount, if you take the same amount out of the air, you should be paid equally, because if society values something for a certain amount, well, then it should work the other way around as well (interview 1).

Another interviewee also argued that a reverse carbon tax would probably create more incentive for companies to produce negative emissions than a reverse auction, as the companies' profit would probably be higher with the reverse carbon tax (interview 3).

However, the reverse auction option, which the Commission also recommended (Ministry of Environment, 2020a), seemed more popular among most interviewees as it ensures greater governmental control over the process, including the amount of money spent on negative emissions (interview 4, 5, 6, 10). According to one interviewee, this is especially preferable as there are still uncertainties about how much BECCS will cost (interview 4). A reverse auction system would also most likely be more cost-efficient as the price would be driven down as far as possible (interview 1, 3, 11).

A few interviewees furthermore advocated for the creation of an emissions trading scheme, where private companies can buy and sell negative emissions (interview 1), as this can increase the incentive for businesses to develop NETs (interview 3) and decrease the price of deployment in general (interview 11). Some interviewees were more cautious about this option, arguing that the state should retain control over such a market (interview 4, 8, 10).

6.4.2 Paying for NETs

Several interviewees deemed the issue of who should pay for negative emissions considerably challenging (interview 2, 3, 6, 8, 9, 10). A couple of interviewees explicitly argued that there should be some sort of 'polluter pays'-principle involved in securing funding for NETs, arguing that fossil-fuelled industries should pay the lion's share of the bill (interview 2, 8).

Another interviewee, however, argued that a 'polluter pays'-system cannot fund NETs, because residual emissions after 2045 will mainly stem from the agricultural sector. According to the interviewee, putting an additional economic burden on the Swedish farmers would undermine their competitiveness on the open market (interview 10). Another interviewee similarly reasoned that the politicians are unlikely to require the agricultural sector to pay to offset their emissions: "[the government] do not want to put any more pressure on the agricultural sector. … so, the suggestion is that they auction and basically are responsible for buying negative emissions to counter the agricultural sector" (interview 3). Another interviewee also argued that if the government presses industries to reduce emissions without helping to fund negative emissions, then production will move to other countries, where it will be more carbon-intensive (interview 9).

Generally, most interviewees agreed that considerable amounts of tax money must fund NETs projects (interview 1, 3, 4, 9, 10, 11). One interviewee recalled that the Commission defined negative emissions as a common good, which should, therefore, be paid collectively by everyone in Sweden (interview 6). Another interviewee also considered government funding an opportunity to ensure that NETs are spread widely in society and does not become a competitive factor between compa-

nies (interview 8). Only one interviewee expressed considerable aversion against funding BECCS and other CCS projects through taxes, arguing that the industries in question already receive substantial subsidies despite using fossil fuels and do not pay enough for emissions under the EU's Emissions Trading Scheme (interview 2).

As most interviewees concluded that taxes must constitute a considerable portion of investments in and production of negative emissions, a couple also raised the issue that generating negative emissions must compete with other policy areas for public funding (interview 9, 10). As one interviewee put it: "there is always this issue of what the tax payment should be used for. … how much should we spend on health and how much should we spend on school and how much should we spend on capturing CO_2?" (interview 10).

For developing NETs, securing funding on national budgets may however not be straightforward. One interviewee grappled with the issue, arguing that on the one hand, it should be possible, since the climate issue is so pressing, but on the other hand that allocating funds for projects, where results are uncertain might prove difficult (interview 9). Several interviewees also mentioned that while they believed that people working with climate issues in Sweden know that NETs projects are necessary and will require considerable funding, they doubt that the public and politicians, in general, are aware of the funding NETs will require (interview 2, 6, 7, 8, 9).

6.4.3 Defining NETs

Finally, one consideration that came up in the interviews concerned what should be considered NETs and thus incentivised. Here, the interviewees revealed diverging opinions concerning which types of NETs are preferable. One interviewee favoured LULUCF sector activities, arguing that the largest opportunities for negative emissions until 2030 would be in that sector (interview 2). Contrary, two interviewees promoted BECCS, arguing against relying too heavily on the LULUCF sector due to the risk of storage permanency mentioned in section 6.1 (interview 4, 7). Another line of division appeared between those who argued against counting VERs in other countries as negative emissions in Sweden (interview 2, 8) contra those who saw this option as a flexible safeguard, in case domestic efforts do not provide the necessary negative emissions (interview 4, 9, 10).

Whether CCS should be allowed to eliminate fossil emissions in industries such as cement, steel and fossil energy production also revealed diverging opinions. Some interviewees argued that the state should be careful and potentially quite restrictive regarding CCS technologies used in fossil-fuelled industries to avoid the moral hazard issue (interview 5, 8). Others saw fewer problems in allowing

CCS in fossil industries if the support systems are different and clearly distinguish between production that is net-negative and net-zero (interview 3) and certain conditions are met, e.g. that stored carbon is not used for enhanced oil recovery (interview 10), and that other opportunities are not available for emission reductions (interview 6). In that case, deploying CCS technologies broadly in society could even increase the learning curve and reduce the price for using CCS in general (interview 10).

6.5 Setting targets and assigning responsibility

The last issue that I focus on, which arose in the interviews, is the question of setting targets and assigning responsibility for delivering negative emissions. As mentioned in section 2.3, the SCF specifies that emissions must be reduced with 85% in 2045, while negative emissions can offset the remaining 15%. However, the SCF does not specify any targets for how much net-negative emissions should be produced after 2045 (Ministry of Environment and Energy, 2018a). Sweden thus only have goals for how much NETs can be used in an offset strategy and not how much they should be used in a climate recovery strategy.

Most interviewees emphasised that it is important to differentiate between negative emissions used to offset other emissions and negative emissions used to reduce the GHG level in the atmosphere (interview 2, 3, 5, 6, 8, 9). A few interviewees emphasised that the primary purpose of negative emissions should be to reduce the GHG level in the atmosphere (interview 5, 6), but several explained that the main political focus now concerns how NETs can offset emissions until 2045, thus reaching net-zero (interview 2, 3, 4, 6, 7). Most of these interviewees said that they did not suspect that it will be difficult to progress from net-zero to net-negative emissions after 2045 (interview 3, 4, 7, 10).

Related to the issue of setting targets, two interviewees raised the problem of assigning responsibility for producing negative emissions both nationally and internationally (interview 6, 10). One interviewee argued that they see a risk that negative emissions may allow some actors to do less, while others take the lion's share of producing negative emissions (interview 10), i.e. what is called the free-rider problem (Reynolds, 2018a). This issue could both arise internationally, but also within Sweden, e.g. if targets are set at municipal-level. If, e.g. one municipality has conducive conditions for producing negative emissions, actors in this municipality may be less interested in pursuing traditional mitigation, as they already seemingly reach net-zero or even net-negative emission. Contrary, other municipalities may have less conducive conditions for NETs and may, therefore, struggle to reach their targets. The interviewee mentioned that this might also be a problem internationally,

since some countries, unlike Sweden, will have less means to achieve negative emissions (interview 10).

This consideration aligns with the thoughts of another interviewee, who brought up what they call the global responsibility issue,

> To reach 1.5°C, the amount of CO_2 that needs to be taken away from our atmosphere is grand … and so far we have been speaking in international contexts on dividing up the responsibility for mitigation, and at one point we are going to have to start speaking about … how are we going to divide up the responsibility for negative emissions and what portion of that responsibility will Europe take or Sweden take? (interview 6).

Unable to answer the question, the interviewee indicated that it will probably be a great challenge to solve this issue through international negotiations in the future (interview 6).

7 Discussion

In the following three sections, I discuss the results of my analysis, considering my three research questions.

7.1 The sociotechnical imaginary of a climate-positive Sweden

Returning to the theoretical entry points of STS and CPE, both material factors (e.g. scientific innovations and socioeconomic structures) and ideational factors (e.g. visions about the future and national identities) shape sociotechnical imaginaries. With the vision of climate-positivity after 2045, I consider my first research question and what kind of factors are present in the Swedish establishments' discussions of NETs.

From the thematic analysis, science appears to play an essential legitimising function for promoting the development of NETs. The consensus seems to be that NETs will allow Sweden to become climate-positive and the IPCC is understood to encourage the development of the technologies.

While most IPCC-scenarios rely on large-scale deployment of NETs to reach the targets of the Paris Agreement, the IPCC, and the scientific community in general, emphasise that these are potential but not prescribed pathways (Rogelj et al., 2018). There furthermore remain pathways to 2°C or 1.5°C, which minimise (van Vuuren et al., 2018) or exclude NETs altogether (Grubler et al., 2018). Such pathways may prove more politically challenging than those with NETs (Lehtveer, 2018) and the win-

dow of embarking on them may be closing quickly (Asayama & Hulme, 2019). But the reality of these alternative scenarios emphasises that relying on NETs rather than extensive decarbonisation of the entire economy is a political choice and not a scientific commandment.

The apparent consensus among the interviewees concerning the necessity of NETs, thus supports that climate science and scenarios have performative power as certain elements of climate politics are depoliticised. It varies between interviewees, but at least some, express that there are aspects of the IPCC-scenarios, which are beyond political judgments. This notion reflects a general idea of clear separation between science and politics, which is impossible to uphold when modelling the future (Beck & Mahony, 2017, 2018). While it may be difficult to strike a reasonable balance between trust in the scientific community and healthy scepticism, it is nevertheless important to find. Refraining from questioning the IPCC and other scientific entities do not make the political influence on science disappear, it only hides it. If deploying NETs appear unavoidable, it may preclude other potential ways for Sweden to minimise their impact on the climate system.

On the economic level, developing NETs may fit well into current socioeconomic structures. Though Sweden has limited experience with the reverse auction system, it is a well-known policy instrument used in other countries to support, e.g. the proliferation of green technologies (Ministry of Environment, 2020a). The emphasis on BECCS may also serve to support and further legitimise the current Swedish forestry model and an energy system, where biomass is an important component.

NETs thus appear to align with the techno-market imaginary's understanding of the climate and society. Few interviewees questioned whether the climate would benefit from NETs, indicating confidence that the climate is manageable. Furthermore, this management through NETs is understood to be achievable through scientific innovation and certain economic structures, e.g. reverse auctions. The collective action problem can thus be solved without fundamentally changing the present socioeconomic system, and NETs can even provide new business cases. This fitness with current socioeconomic structures in the Swedish society, thus makes NETs more appealing and more likely to be a preferred climate solution.

On the ideational level, NETs furthermore appear to support a certain national identity of Sweden being a frontrunner regarding climate change. Sweden has generally been considered a climate frontrunner internationally, e.g. by being early adopters of a carbon tax, over-complying with reduction targets under the Kyoto Protocol, and having early-mover strategies regarding eco-innovations (Sarasini, 2009; Zannakis, 2015). This international reputation has translated into a national identity shared across the political landscape (Sarasini, 2009). According to Zannakis (2015), both altruistic

values of assuming global responsibility and prospects of economic gains if climate solutions are exported motivate this identity; sentiments which are also expressed in the interviews. Relating to this, the conducive Swedish conditions for developing BECCS, also appear to, at least in some interviews, lead to a notion of Swedish exceptionalism; Sweden is considered a special case regarding BECCS and therefore beyond the international-level critique of the problems that adhere to BECCS. Interestingly, this exceptionalism may partly contradict the prospects of creating business opportunities out of NETs, as a solution tailored to Swedish conditions cannot easily be promoted internationally.

While there thus seems to be material and ideational factors to support that NETs play an important role in a sociotechnical imaginary of a climate-positive Sweden, there also appears important areas of struggle. One area of disagreement identified in the interviews is the level of state control imagined in deploying NETs. Though no interviewees expressed clear disagreement, there appear conflicting perspectives on whether negative emissions should be sold on free markets between different companies or if the state should have greater control of the process. This discussion, Levy and Spicer (2013) argue, is expected within imaginaries of techno-markets and does not challenge the overall assumption that the climate can be managed within current economic structures.

Disagreement about the extent of state regulation also appears between opponents and proponents of using CCS technology in the fossil fuel industry and whether VERs in other countries should count as negative emissions in Sweden. Whether fossil fuel-CCS and VERs are included or excluded in the climate-positive vision is relevant because sociotechnical imaginaries influence how we regulate emerging technologies and practices (Burri, 2015). It will, therefore, likely determine, e.g. the level of public funding and support such practices can receive.

All these discussions remain within an imaginary of techno-markets and therefore do not fundamentally challenge the role NETs may play in the sociotechnical imaginary of a climate-positive Sweden. The issue of who should pay for negative emissions, raised across several interviews, may, however, challenge important values in the Swedish society, especially concerning the 'polluter pays'-principle. Such an ideational clash may have important implications for the acceptance of NETs. In the next section, I, therefore, consider the governance regime, which will likely form around NETs and what distributional implications this will have in Sweden.

7.2 Governance regimes of NETs

In this section, I take as starting point that the governance regime around NETs will be characterised by a reverse auction system, as this seemed to be the preferred solution among most interviewees. I

thus return to my second research question of how such a system will spread the costs and benefits of deploying NETs across society.

Both the reverse auction and the reverse carbon tax system would entail that private actors receive payment for producing negative emissions, begging the question: who should pay for it? Historically, a central principle in dealing with expenses of environmental protection has been the 'polluter pays'-principle (Bernstein, 2002), which is also employed in Sweden, e.g. guiding the country's carbon tax (Government Offices of Sweden, 2020; Swedish Environmental Protection Agency, 2019). However, deploying substantial amounts of NETs will likely require a fundamental departure from this principle with implications for rights and responsibilities in society.

GHG emissions constitute pollution, which under traditional economic theory is considered a negative externality, i.e. an effect of one actor's actions, which negatively affects others' welfare, without being accounted for within the market mechanism (Rosen & Gayer, 2014). Negative externalities can be penalised under the 'polluter pays'-principle to account for the adversity inflicted (Mauerhofer et al., 2013).

However, negative emissions constitute the opposite of pollution, wherefore the Commission defines it as a common good (Ministry of Environment, 2020a). A common good is characterised by benefits being widely spread across society, while costs are incurred by a few or a single entity (Rosen & Gayer, 2014). According to traditional economic theory, provision of a common good should, therefore, be rewarded under a 'provider gets'-principle, where the actor supplying the good receives payment from those who use or benefit from it; practically this is often funded through taxes (Mauerhofer et al., 2013).

While paying private companies to provide negative emissions through taxes, may seem straightforward as indicated by several interviewees, moving from a 'polluter pays'- to a 'provider gets'-principle implies a fundamental shift in rights and responsibilities in favour of the service provider compared to the public. Under the 'polluter pays'-principle the public is assumed to have the right to enjoy a clean environment and polluters have the responsibility to pay if they violate this right (Mauerhofer et al., 2013). But under the 'provider gets'-principle, this relationship shifts, so the service provider has the right to be paid for their services, while beneficiaries or the public in general, must pay if they want to receive the service (Mauerhofer et al., 2013). A system must, therefore, be constructed, to incentivise private actors to provide the service of a clean environment (in the case of NETs, a lower atmospheric GHG level). Still, private actors are not necessarily required to provide this service (Mauerhofer et al., 2013). As such, NETs may reinforce certain power relations by offering

new business models, markets, and opportunities for the same businesses, who have historically profited from fossil fuel-intensive production (Schneider, 2019).

The 'provider gets'-principle is furthermore often enacted if a previous 'polluter pays'-based system has not managed to sufficiently protect the ecological service in question (Mauerhofer et al., 2013). This point highlights a paradox: the reason why we must incentivise the development of NETs through a 'provider gets'-scheme is because the current governance system, meant to prevent pollution of the atmosphere and largely based on the 'polluter pays'-principle, has not worked. It further indicates a shift in the implicit baseline from which we judge climate policies. We only consider negative emissions a common good if we accept that the status quo is a polluted atmosphere. If our baseline is a clean atmosphere, then the provision of negative emissions would merely be considered the responsibility of polluting actors to clean up for their emissions. This shift in rights, responsibilities, and perceptions thus warrants a wider and more elaborate discussion of the distributional effects and ethical underpinnings of different governance regimes of NETs, including an honest discussion of who bears the responsibility for emissions.

Several interviewees also seem to hold onto the 'polluter pays'-principle, at least as an ethical point of departure, arguing that the emitters should pay for the deployment of negative emissions. Identification of those emitters, however, is problematic because NETs decouple emissions and emission reductions in both space and time (Carton, 2019; Workman et al., 2020). Negative emissions provided by one actor may compensate for an emission held by another actor in society (i.e. decoupling in space) or for an emission in the past (i.e. decoupling in time). In the first case, a 'polluter pays'-principle could be used if the actor emitting a ton of CO_2 was required to pay for the negative emission. But in the second case, responsibility for the emission lies in the past, which complicates the allocation of responsibility. Thus, the public most likely incurs the cost.

The latter point becomes particularly important, since, if we follow the scenarios of the scientific communities, considerable negative emissions must offset historical emissions (Rogelj et al., 2018). There will, therefore, not be a clear present-day polluter to incur the costs. According to calculations by Bednar and colleagues (2019), if we follow the trajectories complying with the Paris Agreement, we must rapidly scale up production of NETs, but simultaneously reduce the production of fossil fuels and other GHG intensive processes. Thus, revenues from these industries will simply not cover the costs of producing NETs. Since it is furthermore difficult to create business cases around capturing CO_2 and storing it underground, besides through offsetting schemes (Buck, 2019; Haikola et al., 2018), it will be difficult to generate profit from NETs projects. There is, therefore, no way around

large-scale public funding; in fact, Bednar and colleagues (2019) estimate that developed countries may spend up to 15% of their yearly GDP in 2100 funding NETs.

While these points do not dismiss the potential need for NETs to reach our climate goals, they clearly illustrate why a broad societal discussion is necessary concerning the governance and deployment of NETs. The prospect of NETs deployment requiring public funding of the magnitude suggested can only take place if there is broad public consensus of the necessity. Reaching such consensus will require open discussions about who will be the winners and losers of different policies and who has which rights and responsibilities (van Vuuren et al., 2017; Workman et al., 2020).

7.3 Limiting climate change through NETs

While deploying NETs thus will require public discussions in Sweden, the above section also indicates fundamental challenges around NETs as a climate strategy. In this section, I, therefore, turn to my final research question and consider what implications the development of NETs may have for climate change action in Sweden. To explore this, I return to Meadowcrofts' (2013) distinction between using NETs in an emission offset or a climate recovery strategy.

By introducing NETs into IAMs, the possibility of employing a climate recovery strategy became available, which in turn made the concepts of carbon budget overshoot and carbon debt a reality. That is, we can emit more GHGs today than our carbon budget allows us, because we can compensate through NETs in the future (Asayama & Hulme, 2019; Carton, 2019). While, as mentioned in section 7.1, some scenarios only assume minor use of NETs, with the current progression of emissions in mind, an overshoot scenario appears increasingly unavoidable (Asayama & Hulme, 2019).

Considerable negative emissions must, therefore, be produced to employ a climate recovery strategy. This point reiterates the national-level issue outlined in the previous section but scales it up to an international issue: considerable international public funding must be allocated to use NETs to offset historical emissions. However, if NETs are supposed to offset excessive historical emissions, the question of how to divide that global responsibility remains; a question which was also posed by one interviewee.

It is unlikely that countries will by themselves start producing considerable net-negative emissions for just the same reason that it is doubtful that any company starts producing by themselves: there is no incentive to do so (Reynolds, 2018a). The UNFCCC does allow countries to report negative emissions produced through BECCS to balance out other emissions from that country and sell any excessive national emission reductions to other countries (Fridahl & Bellamy, 2018). However, these op-

tions still entail a present-day buyer of negative emissions, who has a reason to buy the negative emissions, i.e. to offset their present-day emissions. The current structure thus only allows for an emission offset strategy and not a climate recovery one.

The issue is that if NETs are to offset excessive historical emissions, then nobody will have a reason to pay for them unless they have already owned up to a historical responsibility of releasing those excessive emissions in the past (Horton et al., 2016; Meadowcroft, 2013; Reynolds, 2018a). Because the present-day benefit which can be gained, namely avoiding climate change, is broadly enjoyed and the costs of producing negative emissions will be incurred by countries individually, there is no reason for one country to start generating considerable net-negative emissions unless they are compensated by the collective or an international agreement assigns them the responsibility to do so (Reynolds, 2018a). However, unlike national, common goods, there is no international tax system through which we can collectively pay for net-negative emissions, thus reaching an international agreement seems necessary. But how will we solve the issue of assigning responsibility, to achieve such an international agreement?

While it goes beyond this study to review the complex and contested history of the principle of common but differentiated responsibility, it is clear that the question of assigning responsibility for developing negative emissions has the potential to reignite and further complicate past discussions of historical responsibility. The concept of common but differentiated responsibility has been around throughout the time of international climate negotiations (Brunnée & Streck, 2013). However, it remains a contested concept, as developed countries have resisted that it entails a historic responsibility to remedy past emissions; rather, they have argued that it involves an obligation to mitigate climate change according to current capabilities and emissions levels (Brunnée & Streck, 2013).

The concept of historical responsibility was officially acknowledged at COP16 in 2010 (Friman & Hjerpe, 2015), thus providing some hope that assigning responsibility may be possible. However, a shift has also taken place from a top-down approach of assigning responsibility towards a bottom-up process, where countries have greater control of the level of responsibility they take upon themselves (Rajamani, 2016). This shift was effectively institutionalised with the establishment of the 'nationally determined contributions'-process of the Paris Agreement with which we may have seen a tendency for nations to avoid committing to tough mitigation measures (Falkner, 2016). If we in future negotiations must address questions about who bears the responsibility for providing expensive negative emissions, it may thus be even more difficult to reach binding and ambitious agreements to solve climate change.

8 Conclusion

NETs as a strategy to deal with climate change has been heavily debated within the scientific community. On the one hand, IAMs increasingly depend on future large-scale deployment of NETs to produce scenarios, where we stay below a 2°C temperature increase. On the other hand, parts of the scientific community have questioned the feasibility of deploying NETs to the extent assumed in IAMs and have argued that the suggestive promise of NETs undermines commitment to substantial emission reductions. Despite this discussion, a reluctant acceptance of NETs as part of the strategies to combat climate change seems to be the new political reality, and a theoretical debate about the ideal and potential governance of NETs has started to emerge.

In this thesis, I have contributed to this debate by undertaking an exploratory and in-depth case study of the emerging discussion around NETs in Sweden. From my analysis and discussion, I find that the authority of science and the IPCC plays an important legitimising function for the development of NETs and that especially BECCS plays into a certain national understanding of Sweden as a frontrunner in the fight against climate change.

Furthermore, NETs development partly supports an imaginary of techno-markets, where technological innovation and market-based policy solutions can ensure climate protection and restoration without compromising current socioeconomic lifestyles. However, a line of disagreement may appear between those favouring more liberal approaches to NETs, where technologies can, e.g. be used in industries to balance out emissions, contra those who prefer greater governmental control of the use of NETs.

In line with the idea of techno-markets, the main governance mechanism to regulate NETs appears to become a reverse auction system, where private actors receive payment for providing negative emissions. Such a governance regime may, however, shift rights and responsibilities in society by abandoning the assumption that the public has the right to a clean environment in favour of an assumption that private actors have the right to receive payment for providing a clean environment. Considering that deployment of NETs at the scale assumed in IAMs will entail substantial costs, if the public is expected to support that tax money is allocated to climate recovery through NETs, broader societal discussions need to take place to avoid polarisation.

It remains that even if Sweden develops NETs, it will not necessarily entail the successful limitation of climate change. If NETs are only used to offset continued emissions and not actively used in a climate recovery strategy, reaching the goals of the Paris Agreement will be difficult. However, to be used in

a climate recovery strategy requires assigning international responsibility for historical emissions, which may prove only to exacerbate the struggles of current international climate negotiations. Solving this issue is crucial for the effectiveness of NETs as a solution to climate change.

9 References

Aberbach, J. D., & Rockman, B. A. (2002). Conducting and Coding Elite Interviews. *PS: Political Science and Politics*, *35*(4), 673–676. https://doi.org/10.1017/S1049096502001142

Anderson, K. (2015). Talks in the city of light generate more heat. *Nature*, *528*(7583), 437–437. https://doi.org/10.1038/528437a

Anderson, K., & Peters, G. (2016). The trouble with negative emissions. *Science*, *354*(6309), 182–183. https://doi.org/10.1126/science.aah4567

Anzilotti, E. (2018, June 13). Climate positive, carbon neutral and carbon negative: What do they mean? *Fast Company*. https://www.fastcompany.com/40583176/climate-positive-carbon-neutral-carbon-negative-what-do-they-mean

Asayama, S., & Hulme, M. (2019). Engineering climate debt: Temperature overshoot and peak-shaving as risky subprime mortgage lending. *Climate Policy*, *19*(8), 937–946. https://doi.org/10.1080/14693062.2019.1623165

Beck, S., & Mahony, M. (2017). The IPCC and the politics of anticipation. *Nature Climate Change*, *7*(5), 311–313. https://doi.org/10.1038/nclimate3264

Beck, S., & Mahony, M. (2018). The politics of anticipation: The IPCC and the negative emissions technologies experience. *Global Sustainability*, *1*, e8, 1-8. https://doi.org/10.1017/sus.2018.7

Bednar, J., Obersteiner, M., & Wagner, F. (2019). On the financial viability of negative emissions. *Nature Communications*, *10*(1), 1783. https://doi.org/10.1038/s41467-019-09782-x

Bellamy, R. (2018). Governing BECCS: 'Slippery Slope' or 'Uphill Struggle'. In M. Fridahl (Ed.), *Bioenergy with carbon capture and storage—From global potentials to domestic realities* (pp. 45–56). Fores and European Liberal Forum.

Bernstein, S. (2002). Liberal Environmentalism and Global Environmental Governance. *Global Environmental Politics*, *2*(3), 1–16. https://doi.org/10.1162/152638002320310509

Bogner, A., Littig, B., & Menz, W. (2009). Introduction: Expert Interviews—An Introduction to a New Methodological Debate. In A. Bogner, B. Littig, & W. Menz (Eds.), *Interviewing Experts* (pp. 1–13). Palgrave Macmillan UK. https://doi.org/10.1057/9780230244276_1

Brunnée, J., & Streck, C. (2013). The UNFCCC as a negotiation forum: Towards common but more differentiated responsibilities. *Climate Policy*, *13*(5), 589–607. https://doi.org/10.1080/14693062.2013.822661

Buck, H. J. (2012). Geoengineering: Re-making Climate for Profit or Humanitarian Intervention? *Development and Change*, *43*(1), 253–270. https://doi.org/10.1111/j.1467-7660.2011.01744.x

Buck, H. J. (2019). *After geoengineering: Climate tragedy, repair, and restoration*. Verso Books.

Burri, R. V. (2015). Imaginaries of Science and Society: Framing Nanotechnology Governance in Germany and the United States. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (pp. 233–253). University of Chicago Press.

Campbell-Arvai, V., Hart, P. S., Raimi, K. T., & Wolske, K. S. (2017). The influence of learning about carbon dioxide removal (CDR) on support for mitigation policies. *Climatic Change*, *143*, 321–336. https://doi.org/10.1007/s10584-017-2005-1

Carton, W. (2019). “Fixing” Climate Change by Mortgaging the Future: Negative Emissions, Spatio-temporal Fixes, and the Political Economy of Delay. *Antipode*, *51*(3), 750–769. https://doi.org/10.1111/anti.12532

Cash, D. W., Adger, W. N., Berkes, F., Garden, P., Lebel, L., Olsson, P., Pritchard, L., & Young, O. (2006). Scale and Cross-Scale Dynamics: Governance and Information in a Multilevel World. *Ecology and Society*, *11*(2), 8. https://doi.org/10.5751/ES-01759-110208

Clark, W. C., & Dickson, N. M. (2003). Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences*, *100*(14), 8059–8061. https://doi.org/10.1073/pnas.1231333100

Colvin, R. M., Kemp, L., Talberg, A., De Castella, C., Downie, C., Friel, S., Grant, W. J., Howden, M., Jotzo, F., Markham, F., & Platow, M. J. (2020). Learning from the Climate Change Debate to Avoid Polarisation on Negative Emissions. *Environmental Communication*, *14*(1), 23–35. https://doi.org/10.1080/17524032.2019.1630463

Cox, R. W. (1981). Social Forces, States and World Orders: Beyond International Relations Theory. *Millennium: Journal of International Studies*, *10*(2), 126–155. https://doi.org/10.1177/03058298810100020501

Dooley, K., Christoff, P., & Nicholas, K. A. (2018). Co-producing climate policy and negative emissions: Trade-offs for sustainable land-use. *Global Sustainability*, *1*, e3, 1-10. https://doi.org/10.1017/sus.2018.6

Falkner, R. (2016). The Paris Agreement and the new logic of international climate politics. *International Affairs*, *92*(5), 1107–1125. https://doi.org/10.1111/1468-2346.12708

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, *5*(1), 80–92. https://doi.org/10.1177/160940690600500107

Flyvbjerg, B. (2004). Phronetic planning research: Theoretical and methodological reflections. *Planning Theory & Practice*, *5*(3), 283–306. https://doi.org/10.1080/1464935042000250195

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, *12*(2), 219–245. https://doi.org/10.1177/1077800405284363

Fridahl, M. (2018). Introduction. In *Bioenergy with carbon capture and storage—From global potentials to domestic realities* (pp. 1–6). Fores and European Liberal Forum.

Fridahl, M., & Bellamy, R. (2018). Multilevel Policy Incentives for BECCS in Sweden. In M. Fridahl (Ed.), *Bioenergy with carbon capture and storage—From global potentials to domestic realities* (pp. 57–68). Fores and European Liberal Forum.

Friman, M., & Hjerpe, M. (2015). Agreement, significance, and understandings of historical responsibility in climate change negotiations. *Climate Policy*, *15*(3), 302–320. https://doi.org/10.1080/14693062.2014.916598

Fuss, S., Canadell, J. G., Peters, G. P., Tavoni, M., Andrew, R. M., Ciais, P., Jackson, R. B., Jones, C. D., Kraxner, F., Nakicenovic, N., Le Quéré, C., Raupach, M. R., Sharifi, A., Smith, P., & Yamagata, Y. (2014). Betting on negative emissions. *Nature Climate Change*, *4*(10), 850–853. https://doi.org/10.1038/nclimate2392

Geden, O. (2016). The Paris Agreement and the inherent inconsistency of climate policymaking. *WIREs Climate Change*, *7*, 790–797. https://doi.org/10.1002/wcc.427

Gerring, J. (2004). What Is a Case Study and What Is It Good for? *The American Political Science Review*, *98*(2), 341–354. https://doi.org/10.1017/S0003055404001182

Gough, C., & Mander, S. (2019). Beyond Social Acceptability: Applying Lessons from CCS Social Science to Support Deployment of BECCS. *Current Sustainable/Renewable Energy Reports*, *6*(4), 116–123. https://doi.org/10.1007/s40518-019-00137-0

Government Offices of Sweden. (2020). *Sweden's carbon tax* (pp. 1–5). https://www.government.se/government-policy/taxes-and-tariffs/swedens-carbon-tax/

Grubler, A., Wilson, C., Bento, N., Boza-Kiss, B., Krey, V., McCollum, D. L., Rao, N. D., Riahi, K., Rogelj, J., De Stercke, S., Cullen, J., Frank, S., Fricko, O., Guo, F., Gidden, M., Havlík, P., Huppmann, D., Kiesewetter, G., Rafaj, P., … Valin, H. (2018). A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. *Nature Energy*, *3*(6), 515–527. https://doi.org/10.1038/s41560-018-0172-6

Haikola, S., Hansson, A., & Anshelm, J. (2019). From polarization to reluctant acceptance–bioenergy with carbon capture and storage (BECCS) and the post-normalization of the climate debate. *Journal of Integrative Environmental Sciences*, *16*(1), 45–69. https://doi.org/10.1080/1943815X.2019.1579740

Haikola, S., Hansson, A., & Fridahl, M. (2018). Views of BECCS Among Modelers and Policymakers. In M. Fridahl (Ed.), *Bioenergy with carbon capture and storage—From global potentials to domestic realities* (pp. 17–30). Fores and European Liberal Forum.

Hajer, M. A. (1995). *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process*. Oxford University Press.

Hansing, A. A., & Fridahl, M. (2018). European and Swedish Point Sources of Biogenic Carbon Dioxide. In M. Fridahl (Ed.), *Bioenergy with carbon capture and storage—From global potentials to domestic realities* (pp. 31–44). Fores and European Liberal Forum.

Heyward, C. (2013). Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change. *PS: Political Science & Politics*, *46*(1), 23–27. https://doi.org/10.1017/S1049096512001436

Honegger, M., & Reiner, D. (2018). The political economy of negative emissions technologies: Consequences for international policy design. *Climate Policy*, *18*(3), 306–321. https://doi.org/10.1080/14693062.2017.1413322

Horton, J. B., Keith, D. W., & Honegger, M. (2016). *Implications of the Paris Agreement for Carbon Dioxide Removal and Solar Geoengineering* (pp. 1–10) [Viewpoints]. The Harvard Project on Climate Agreements.

Jänicke, M. (2008). Ecological modernisation: New perspectives. *Journal of Cleaner Production*, *16*(5), 557–565. https://doi.org/10.1016/j.jclepro.2007.02.011

Jasanoff, S. (2015a). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (pp. 1–33). University of Chicago Press.

Jasanoff, S. (2015b). Science and technology studies. In E. Lövbrand & K. Backstränd (Eds.), *Research Handbook on Climate Governance* (pp. 36–48). Edward Elgar Publishing Limited.

Jasanoff, S., & Kim, S.-H. (2009). Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva*, *47*, 119-146. https://doi.org/10.1007/s11024-009-9124-4

Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E., Hickler, T., Hornborg, A., Kronsell, A., Lövbrand, E., & Persson, J. (2011). Structuring sustainability science. *Sustainability Science*, *6*, 69–82. https://doi.org/10.1007/s11625-010-0117-x

Jessop, B. (2010). Cultural political economy and critical policy studies. *Critical Policy Studies*, *3*(3–4), 336–356. https://doi.org/10.1080/19460171003619741

Jones, C. D., Ciais, P., Davis, S. J., Friedlingstein, P., Gasser, T., Peters, G. P., Rogelj, J., van Vuuren, D. P., Canadell, J. G., Cowie, A., Jackson, R. B., Jonas, M., Kriegler, E., Littleton, E., Lowe, J. A., Milne, J., Shrestha, G., Smith, P., Torvanger, A., & Wiltshire, A. (2016). Simulating the Earth system response to negative emissions. *Environmental Research Letters*, *11*(9), 095012. https://doi.org/10.1088/1748-9326/11/9/095012

Karlsson, H., Delahaye, T., Johnsson, F., Kjärstad, J., & Rootzén, J. (2017). *Immediate deployment opportunities for negative emissions with BECCS: A Swedish case study* [Working paper]. Biorecro and Chalmers University of Technology.

Kvale, S. (2007). Planning an interview study. In *Doing interviews* (pp. 34–50). SAGE Publications Ltd.

Larkin, A., Kuriakose, J., Sharmina, M., & Anderson, K. (2018). What if negative emission technologies fail at scale? Implications of the Paris Agreement for big emitting nations. *Climate Policy*, *18*(6), 690–714. https://doi.org/10.1080/14693062.2017.1346498

Lehtveer, M. (2018). BECCS in Climate Scenarios. In M. Fridahl (Ed.), *Bioenergy with carbon capture and storage—From global potentials to domestic realities* (pp. 7–16). Fores and European Liberal Forum.

Levy, D. L., & Spicer, A. (2013). Contested imaginaries and the cultural political economy of climate change. *Organization*, *20*(5), 659–678. https://doi.org/10.1177/1350508413489816

Lomax, G., Workman, M., Lenton, T., & Shah, N. (2015). Reframing the policy approach to greenhouse gas removal technologies. *Energy Policy*, *78*, 125–136. https://doi.org/10.1016/j.enpol.2014.10.002

Lövbrand, E. (2009). Revisiting the politics of expertise in light of the Kyoto negotiations on land use change and forestry. *Forest Policy and Economics*, *11*(5–6), 404–412. https://doi.org/10.1016/j.forpol.2008.08.007

Low, S., & Schäfer, S. (2020). Is bio-energy carbon capture and storage (BECCS) feasible? The contested authority of integrated assessment modeling. *Energy Research & Social Science*, *60*, 101326, 1-9. https://doi.org/10.1016/j.erss.2019.101326

Lund, C. (2014). Of What is This a Case?: Analytical Movements in Qualitative Social Science Research. *Human Organization*, *73*(3), 224–234. https://doi.org/10.17730/humo.73.3.e35q482014x033l4

Mahmoud, Y., Jerneck, A., Kronsell, A., & Steen, K. (2018). At the nexus of problem-solving and critical research. *Ecology and Society*, *23*(4), 40. https://doi.org/10.5751/ES-10458-230440

Markusson, N., McLaren, D., & Tyfield, D. (2018). Towards a cultural political economy of mitigation deterrence by negative emissions technologies (NETs). *Global Sustainability*, *1*, e10, 1-9. https://doi.org/10.1017/sus.2018.10

Mauerhofer, V., Hubacek, K., & Coleby, A. (2013). From Polluter Pays to Provider Gets: Distribution of Rights and Costs under Payments for Ecosystem Services. *Ecology and Society*, *18*(4), 41. https://doi.org/10.5751/ES-06025-180441

McLaren, D. P., Tyfield, D. P., Willis, R., Szerszynski, B., & Markusson, N. O. (2019). Beyond 'Net-Zero': A case for separate targets for emissions reduction and negative emissions. *Frontiers in Cli-mate*, *1*(4), 1-5. https://doi.org/10.3389/fclim.2019.00004

Meadowcroft, J. (2013). Exploring negative territory Carbon dioxide removal and climate policy initiatives. *Climatic Change*, *118*(1), 137–149. https://doi.org/10.1007/s10584-012-0684-1

Ministry of Environment. (2019). *Regeringen satsar på negativa utsläpp [The government invests in negative emissions]* (pp. 1–2) [Press release]. Government Offices of Sweden. https://www.regeringen.se/pressmeddelanden/2019/06/regeringen-satsar-pa-negativa-utslapp/

Ministry of Environment. (2020a). *Vägen till en klimatpositiv framtid [The road to a climate-positive future]* (Investigation SOU 2020:4; Statens offentliga utredningar, pp. 1–850). Government Offices of Sweden. https://www.regeringen.se/48ec20/contentassets/1c43bca1d0e74d44af84a0e2387bfbcc/vagen-till-en-klimatpositiv-framtid-sou-20204

Ministry of Environment. (2020b). *Remiss av SOU 2020:4 Vägen til en klimatpositiv framtid [Referral of SOU 2020: 4 The road to a climate-positive future]* (pp. 1–8) [Referral]. Government Offices of Sweden. https://www.regeringen.se/remisser/2020/02/remiss-av-sou-20204-vagen-till-en-klimatpositiv-framtid/

Ministry of Environment and Energy. (2018a). *The Swedish climate policy framework* (pp. 1–6). Government Offices of Sweden. https://www.government.se/information-material/2018/03/the-swedish-climate-policy-framework/

Ministry of Environment and Energy. (2018b). *Kompletterande åtgärder för att nå negativa utsläpp av växthusgaser [Complementary measures to reach the negative greenhouse gas emissions]* (pp. 1–14) [Committee terms]. Government Offices of Sweden. https://www.regeringen.se/4a0f72/contentassets/7175eecb87cc40b2bc6725c7cd3f7ab1/kompletterande-atgarder-for-att-na-negativa-utslapp-av-vaxthusgaser-dir.-201870

Minx, J. C., Lamb, W. F., Callaghan, M. W., Fuss, S., Hilaire, J., Creutzig, F., Amann, T., Beringer, T., de Oliveira Garcia, W., Hartmann, J., Khanna, T., Lenzi, D., Luderer, G., Nemet, G. F., Rogelj, J., Smith, P., Vicente Vicente, J. L., Wilcox, J., & del Mar Zamora Dominguez, M. (2018). Negative

emissions—Part 1: Research landscape and synthesis. *Environmental Research Letters*, *13*(6), 063001. https://doi.org/10.1088/1748-9326/aabf9b

Moe, E., & Røttereng, J.-K. S. (2018). The post-carbon society: Rethinking the international governance of negative emissions. *Energy Research & Social Science*, *44*, 199–208. https://doi.org/10.1016/j.erss.2018.04.031

Mol, A. P. J., & Spaargaren, G. (2000). Ecological modernisation theory in debate: A review. *Environmental Politics*, *9*(1), 17–49. https://doi.org/10.1080/09644010008414511

Newell, P. (2015). Political economy. In E. Lövbrand & K. Backstränd (Eds.), *Research Handbook on Climate Governance* (pp. 25–35). Edward Elgar Publishing Limited.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Popp, A., Calvin, K., Fujimori, S., Havlik, P., Humpenöder, F., Stehfest, E., Bodirsky, B. L., Dietrich, J. P., Doelmann, J. C., Gusti, M., Hasegawa, T., Kyle, P., Obersteiner, M., Tabeau, A., Takahashi, K., Valin, H., Waldhoff, S., Weindl, I., Wise, M., … Vuuren, D. P. van. (2017). Land-use futures in the shared socio-economic pathways. *Global Environmental Change*, *42*, 331–345. https://doi.org/10.1016/j.gloenvcha.2016.10.002

Rajamani, L. (2016). Ambition and Differentiation in the 2015 Paris Agreement: Interpretative possibilities and underlying politics. *International and Comparative Law Quarterly*, *65*(2), 493–514. https://doi.org/10.1017/S0020589316000130

Realmonte, G., Drouet, L., Gambhir, A., Glynn, J., Hawkes, A., Köberle, A. C., & Tavoni, M. (2019). An inter-model assessment of the role of direct air capture in deep mitigation pathways. *Nature Communications*, *10*(1), 3277. https://doi.org/10.1038/s41467-019-10842-5

Reynolds, J. L. (2018a). Governing Experimental Responses: Negative Emissions Technologies and Solar Climate Engineering. In A. Jordan, D. Huitema, H. van Asselt, & J. Forster (Eds.), *Governing Climate Change* (1st ed., pp. 285–302). Cambridge University Press. https://doi.org/10.1017/9781108284646.017

Reynolds, J. L. (2018b). The politics and governance of negative emissions technologies. *Global Sustainability*, *1*, e12, 1-3. https://doi.org/10.1017/sus.2018.13

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kobayashi, S., Kriegler, E., Mundaca, L., Séférian, R., Vilariño, M. V., Calvin, K., Emmerling, J., Fuss, S., Gillett, N., He, C., Hertwich, E., Höglund-Isaksson, L., … Schaeffer, R. (2018). Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, S. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield, *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (p. 82).

Rosen, H., & Gayer, T. (2014). *Public Finance* (10th ed.). McGraw-Hill Custom Publishing.

Sarasini, S. (2009). Constituting leadership via policy: Sweden as a pioneer of climate change mitigation. *Mitigation and Adaptation Strategies for Global Change*, *14*, 635–653. https://doi.org/10.1007/s11027-009-9188-3

Schneider, L. (2019). Fixing the Climate? How Geoengineering Threatens to Undermine the SDGs and Climate Justice. *Development*, *62*, 29–36. https://doi.org/10.1057/s41301-019-00211-6

Shepherd, J. (2009). *Geoengineering the climate: Science, governance and uncertainty*. The Royal Society. https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2009/8693.pdf

Smith, P., Davis, S. J., Creutzig, F., Fuss, S., Minx, J., Gabrielle, B., Kato, E., Jackson, R. B., Cowie, A., Kriegler, E., van Vuuren, D. P., Rogelj, J., Ciais, P., Milne, J., Canadell, J. G., McCollum, D., Peters, G., Andrew, R., Krey, V., … Yongsung, C. (2016). Biophysical and economic limits to negative CO2 emissions. *Nature Climate Change*, *6*(1), 42–50. https://doi.org/10.1038/nclimate2870

Spangenberg, J. H. (2011). Sustainability science: A review, an analysis and some empirical lessons. *Environmental Conservation*, *38*(3), 275–287. https://doi.org/10.1017/S0376892911000270

Stockholm Exergi. (n.d.). *Så arbetar vi för att skapa minusutsläpp [This is how we work to create negative emissions]*. Retrieved 3 January 2020, from https://www.stockholmexergi.se/minusutslapp/

Swedish Environmental Protection Agency. (2019, September 23). *The Swedish Environmental Code*. http://www.swedishepa.se/Guidance/Laws-and-regulations/The-Swedish-Environmental-Code/

Talberg, A., Christoff, P., Thomas, S., & Karoly, D. (2018). Geoengineering governance-by-default: An earth system governance perspective. *International Environmental Agreements: Politics, Law and Economics*, *18*, 229–253. https://doi.org/10.1007/s10784-017-9374-9

Turnhout, E. (2018). The Politics of Environmental Knowledge. *Conservation and Society*, *16*(3), 363–371. https://doi.org/10.4103/cs.cs_17_35

Turnhout, E., Skutsch, M. M., & de Koning, J. (2015). Carbon accounting. In E. Lövbrand & K. Backstränd (Eds.), *Research Handbook on Climate Governance* (pp. 366–376). Edward Elgar Publishing Limited.

Tyfield, D. (2012). A cultural political economy of research and innovation in an age of crisis. *Minerva*, *50*, 149–167. https://doi.org/10.1007/s11024-012-9201-y

van Vuuren, D. P., Hof, A. F., van Sluisveld, M. A. E., & Riahi, K. (2017). Open discussion of negative emissions is urgently needed. *Nature Energy*, *2*, 902–904. https://doi.org/10.1038/s41560-017-0055-2

van Vuuren, D. P., Stehfest, E., Gernaat, D. E. H. J., van den Berg, M., Bijl, D. L., de Boer, H. S., Daioglou, V., Doelman, J. C., Edelenbosch, O. Y., Harmsen, M., Hof, A. F., & van Sluisveld, M. A. E. (2018). Alternative pathways to the 1.5 °C target reduce the need for negative emission technologies. *Nature Climate Change*, *8*, 391–397. https://doi.org/10.1038/s41558-018-0119-8

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*, 203–218. https://doi.org/10.1007/s11625-011-0132-6

Williamson, P. (2016). Emissions reduction: Scrutinize CO2 removal methods. *Nature*, *530*, 153–155. https://doi.org/doi:10.1038/530153a

Workman, M., Dooley, K., Lomax, G., Maltby, J., & Darch, G. (2020). Decision making in contexts of deep uncertainty—An alternative approach for long-term climate policy. *Environmental Science and Policy*, *103*, 77–84. https://doi.org/10.1016/j.envsci.2019.10.002

Zannakis, M. (2015). The blending of discourses in Sweden's "urge to go ahead" in climate politics. *International Environmental Agreements: Politics, Law and Economics*, *15*, 217–236. https://doi.org/10.1007/s10784-013-9235-0

Zickfeld, K., MacDougall, A. H., & Matthews, H. D. (2016). On the proportionality between global temperature change and cumulative CO2 emissions during periods of net negative CO2 emissions. *Environment Research Letters*, *11*(5). https://doi.org/10.1088/1748-9326/11/5/055006

Appendix: Interview guide

For each interview, I developed an individual interview guide. I based the questions on the knowledge I expected the interviewee to possess, the professional position of the interviewee, and the amount of time the interviewee could allocate to the interview. The questions below are the questions I most often asked in the interviews. For each interview, there were, therefore, specific questions about their position, which do not feature in the interview guide below.

All interviewees, including their institution, were thoroughly researched before interviews to ensure that I was up to date with recent public statements. I did this through the portal *Retriever* that surveys a range of Swedish media.

The interviews were all semi-structured to allow for flexibility if interesting aspects came up. Therefore, while the intention was to start with broader questions and end with more narrow questions, if an interviewee touched upon an issue I intended to ask about later, I would follow up with more narrow questions, before returning to the originally intended order of the questions.

I intentionally never asked about "negative emissions technologies" but only about "negative emissions" to avoid connotations in favour of more technical solutions such as bioenergy with carbon capture and storage or direct air carbon capture and storage at the expense of more nature-based solutions such as reforestation or soil carbon sequestration. That way, I hoped the interviewees would focus on the NETs which are most debated and considered in Sweden.

Question	**Purpose**
Will you introduce yourself and how you work with negative emissions?	The question was not asked to politicians but was asked to the other interviewees to get a clearer understanding of their experience with NETs to adjust subsequent questions to their particular knowledge.
Sweden has set a goal of becoming climate-positive after 2045, can you tell me a bit about this goal and how you set this goal?	I primarily asked this question to politicians and civil servants. The purpose was to get an understanding of the ideas and visions behind the goal of becoming climate-positive.
What do you see as some of the main opportunities regarding negative emissions in Sweden? Follow up question: Why are those opportuni-	The question was asked to all interviewees to gain an understanding of the perceived benefits and reasons for deploying NETs.

ties?	
What do you see as some of the main challenges regarding negative emissions in Sweden? Follow up question: Why are those challenges?	The question was asked to all interviewees to gain an understanding of the perceived challenges and concerns of NETs.
How does your institution work with negative emissions and the goal of becoming climate-positive?	I asked this question to all interviewees except the politicians to get a clearer understanding of the institution's work and position regarding NETs.
How do you experience the discussion on negative emissions in Sweden? Follow up questions: Who is part of the discussion? What do you discuss? How does the discussion differ from other climate change discussions? Is the public engaged in the discussion?	I asked this question to all interviewees to understand how the interviewee perceived the discussion and to make them reflect on the issues which they discuss the most, who engage in the discussion, and how it differs from other discussions.
What do you think will be the main discussions regarding negative emissions going ahead?	I asked this question to all interviewees to understand what kind of discussions the interviewee thought would be most important in the years to come.
How do you see your role, as a politician, in regulating negative emissions? Follow up question: How do you believe negative emissions should be regulated? What kind of policy instruments should be used? Why those?	The question was only asked to politicians to understand which policy instruments could be used to regulate NETs and in general how the politicians saw their role vis-à-vis the private sector or other actors.
In your experience, how do you think negative emissions will be regulated?	The question was asked to civil servants to understand which policy instruments and what kind of regulation they expected to be central in governing NETs.
What would you recommend the politicians to do regarding negative emissions? Anything you would advise them not to do?	I did not ask this question to politicians and civil servants. I asked the question to understand how the private sector and civil society envisioned governance regimes.
How do you think the development, implementation, and use of negative emissions should be financed?	The question was asked to all interviewees to gain an understanding of where the interviewees saw potential financing issues.
To me there are two ways that negative emissions can be used: it can either be used to compensate for continued emissions or used to compensate for historical emissions, where	The question was asked to all interviewees. The question was only asked at the end of the interviews unless the interviewee had touched upon a similar distinction earlier in the interview. The

you reduce the greenhouse gas level in the atmosphere. How do you consider that distinction in your work and the discussion?	question was intended to explore to what extent and how Meadowcrofts' (2013) distinction was present in the discussion and how it was considered.
Internationally, there has been a critique against negative emissions that if we focus too much on negative emissions, we may forget to talk about traditional mitigation measures. How do you consider that critique? Is it relevant here in Sweden?	The question was asked to all interviewees. The question was only asked at the end of the interviews unless the interviewee touched upon the critique themselves. The question was intended to understand how the stakeholders consider the moral hazard issue. I explicitly framed the question as being prompted by an international discussion and not a Swedish national debate, to avoid making assumptions about the Swedish debate.
Internationally, there has also been a critique of the IPCC that they rely too much on negative emissions in their climate models. How do you consider that critique? Is it relevant here in Sweden?	The question was asked to all interviewees. The question was only asked at the end of the interviews unless the interviewee touched upon the critique themselves. The question was asked to understand how the interviewee considers the heated academic debate there has been on the inclusion of NETs into climate models.
Do you have anything else you would like to mention, or think is important regarding the negative emissions and the discussion you have here in Sweden?	The question was asked at the end of every interview to allow for the interviewee to have a final reflection on NETs.