Managing Carbon, Managing Futures

A Study of Sociotechnical Imaginaries in the Rollout of CCUS in Denmark

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Abstract

Carbon capture utilization and storage (CCUS) is set to play a key role in decarbonization. Most of the technologies are yet to be seen on commercial scale. Denmark is in the process of establishing some of the first large-scale CCUS value-chains.

Through a combination of document analysis and interviews, I study the ideas driving the current roll-out of CCUS in Denmark. To do this, I make use of the analytical concept of sociotechnical imaginaries.

Through my work, I find that CCUS is mobilised as a necessary tool for halting climate change. It is also envisioned as a profitable business adventure and with potential to secure Denmark's image as a climate frontrunner. This leads me to discuss how the rollout of CCUS is driven by an approach to climate mitigation which centres technological development and market-driven mechanisms.

I conclude that, while CCUS might be deemed necessary for industrial decarbonisation, the technologies are unlikely to foster wide-reaching change, thus it remains key to continuously scrutinize its role in climate mitigation and the construction of more climate-friendly societies.

Keywords: CCUS, industrial decarbonisation, carbon infrastructure, climate change mitigation, sociotechnical imaginaries, ecomodernism,

Word count: 10.951

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Proud and honoured to walk in the light of Sankt Nicklas, patron of all procrastinators and late deliverers.

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Abbreviations

Intergovernmental Panel on Climate Change (IPCC)

International Energy Agency (IEA)

Carbon capture storage (CCS)

Carbon capture utilisation (CCU)

Carbon capture utilisation and storage (CCUS)

Bioenergy with carbon capture and storage (BECCS)

Direct air capture (DAC)

Direct air carbon capture and sequestration (DACCS)

Negative emissions technology (NET)

Enhanced oil recovery (EOR)

Power-to-X (Pt-X)

Science and Technology Studies (STS)

Memorandum of Understandings (MoUs)

Small and medium enterprises (SMEs)

1 Introduction

"The potential is enormous, and that is why it is so important for us to get the market started now" (Klima-, energi- og forsyningsministeriet, 2021)

"We need to develop tools like CO2-capture and storage in parallel with expanding renewable energies and transitioning from black to green. It is not the easy solution – but it is the necessary one" (Klima-, energi- og forsyningsministeriet, 2024)

The two quotes are from 2021 and 2024 respectively, both said in relation to political agreements that demonstrate the focus on developing and implementing different solutions for capturing and storing carbon in Denmark. Firstly, Dan Jørgensen, the Danish Minister of Climate at the time, notes with joy and pride, how the political agreement from 2021 marks the first steps towards establishing solutions for carbon capture storage and utilisation in Denmark – with the first storage facilities, predicted at the time, to be ready in 2025. In 2024, Lars Aagard, the current Danish Minister of Climate, echoes the same sentiments. As a large-scale tender round, delivering financial support for carbon capture and storage-solutions in Denmark with up to 28billion DKK, opens for applications, he notes with pride and joy how this marks the next step in establishing the tools that are necessary in reaching the Danish and European climate targets of emission reductions.

The comments from the two Danish politicians – and more so all the actions and developments running to and from these two public statements – mark the increased focus on solutions for managing carbon emissions through capture, storage and utilisation. As noted by the International Energy Agency (IEA), carbon capture utilisation and storage (CCUS) hold the potential to redirect carbon from getting released directly into the atmosphere. Supposedly, it has the potential to support decarbonisation by producing alternative fuels for trucks, ships and planes, necessary to eliminate the reliance on fossil fuels. And, supposedly, it has the potential to eliminate emissions by capturing and storing carbon underground. Furthermore, it also holds the potential to reduce the total amount of atmospheric carbon dioxide through negative emissions (IEA, 2023). Heralded as a box of unavoidable tools in reaching targets for emissions and decarbonisation, CCUS is slowly becoming the word on everybody's lips, when it comes to balancing climate mitigation, decarbonisation and industrialised activity.

In Denmark, Ørsted, a Danish energy company of which the Danish government holds the majority of shares, is getting ready to demonstrate one of the world's first large-scale value chains for carbon capture and storage (Energistyrelsen, 2024a; Ørsted, 2025). Simultaneously, Denmark has multiple instruments of incentivisation and strategies for continued implementation and upscaling of CCUS in place (Energistyrelsen, 2024b; Klima-, energi- og forsyningsministeriet, 2025), in addition to a potentially key geopolitical position in relation to future European carbon infrastructure (Joint Research Centre, 2024). In this way, Denmark's CCUS deployment resembles a critical case study in the sense that it is part of a few countries, all taking steps to realising increasingly large-scale rollout of CCUS. At the same time, the deployment is mobilised explicitly as part of both national and European goals of decarbonisation and climate mitigation, thus making it a key point of interest for understanding current trends of sustainability and transition.

For this thesis, I will be looking at how different cultural ideas and visions in connection to CCUS play into the development and deployment of carbon management solutions in Denmark. In order to study this, I will make use of the concept of sociotechnical imaginaries, which pays particular interest to the intersection between collectively held beliefs, technological development and relations of power and interest. I will work with the following problem statement and research questions.

1.1 Problem Statement

What dominant sociotechnical imaginaries shape the rollout of CCUS in Denmark?

- What are the political ambitions and goals of CCUS in Denmark?
- How are the dominant sociotechnical imaginaries of CCUS in Denmark characterised?
- Whose interests are served by the dominant sociotechnical imaginaries?

In working with the questions, I am continuously drawing on the concept of sociotechnical imaginaries in order to explore CCUS in Denmark. In this way, the thesis is done with the ambition to understand how institutional norms, cultural values and ideas of technology and the climate all interact in shaping possible paths for climate mitigation. By invoking this approach to CCUS, I am interested in exploring as well as critically examining and challenging the ways in which technologies and climate mitigation gets imagined in relation to each other.

The thesis is structured as follows. In the following section, I'll present clarification on the basic concepts and general landscape of carbon management technologies. This will be followed by the theoretical framework and methodology, leading up to the presentation of findings, analysis and discussion. And ultimately, a conclusion.

2 Context

2.1 How to talk about carbon management technologies

Since the Paris Agreement, there has been an increasing prevalence of companies and countries setting net-zero targets and goals, usually in the form of identifying a desired amount of reduction of emissions by a certain year or time (Green et al., 2025). This has also led to discussion around the use of targets in relation to their operationalisation, robustness and realisability (Hale et al., 2022; Rogelj et al., 2021). Along with this, there has been an increasing focus on decarbonisation and technologies for CCUS (McLaughlin et al., 2023). The dynamics between net-zero targets, CCUS and carbon dioxide removal have been approached in numerous ways. Some scholars have studied the function of models, with a particular attention to the role of IPCC, showcasing how modelling can help position specific pathways as more tenable than others (D. McLaren & Markusson, 2020; van Beek et al., 2020; Van Beek et al., 2022). Elsewhere, scholars have argued for the necessity of considering how net-zero gets defined in order to ensure a balance between the promise of future reductions and the need for reductions in the present (Markusson et al., 2024; D. P. McLaren et al., 2019), while stressing the importance of considering relations of power in the process (Carton et al., 2023; J. F. Lund et al., 2023). Others still have focused more on understanding how best to integrate technologies into existing supply-chains and industrial relations (Edelenbosch et al., 2024; Matos et al., 2024; Paltsev et al., 2021).

For the purpose of this thesis, I will briefly go through the different technologies connected to CCUS below, while noting some of the key differences of importance. Figure 1 below shows a simplified version of a CCUS chain. In the illustration you can see how it entails,

1. Capturing carbon from a source, either at point sources such as power stations or industrial facilities, or directly from the air,
2. A mode of transport, either via pipelines, trucks or ships,
3. Ending up at a site of geological storage, either on-shore or off-shore,
4. Or gets transported to a site for utilisation for other purposes, e.g. enhanced-oil-recovery or other products such as fertiliser, building materials or synthetic fuels

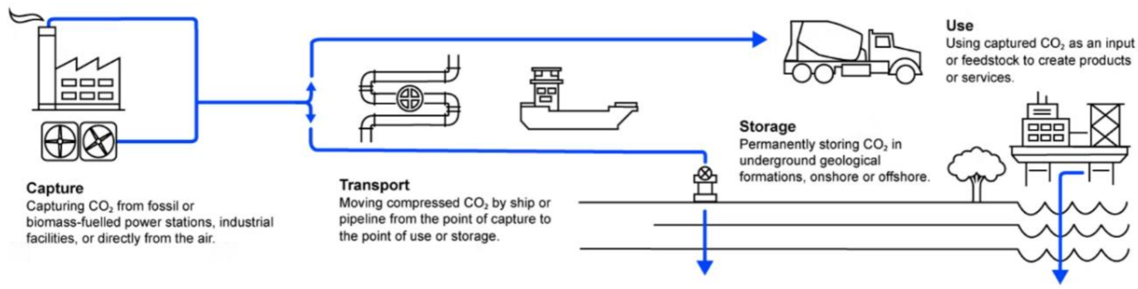


Figure 1. A simplified illustration of potential CCUS chains (IEA, 2024)

In this way, the illustration showcases how CCUS entails different solutions under one composite term. At the same time the illustration also showcases how, from a system perspective, the technologies run along some of the same infrastructure (McLaughlin et al., 2023). The composite term of CCUS can be divided by its end-use: Storage (CCS) or Utillisation (CCU).

2.2 Carbon Capture and Storage

CCS is, as the name implies, aimed ultimately at storing carbon permanently, thus preventing it from getting released into the atmosphere, either by injecting it into oil- and gas fields or in suited geological structures. Much of the interest and deployment has been in capturing carbon directly from point sources in for example waste incineration facilities or cement production plants in order to tackle hard-to-abate sectors and residual emissions, which otherwise are technically impossible to eliminate – as well as to capture emissions from fossil fuel plants in an effort to decrease the carbon footprint of e.g. coal production. While receiving a lot of attention in the 2000s for the potentials listed above, deployment of capture and storage facilities have high initial costs and no clear payoffs, which in turn has been pointed out as reasons for a limited large-scale deployment of the technology (Martin-Roberts et al., 2021; Wang et al., 2021). Along with this, it has also been criticised for the potential of creating fossil fuel lock-ins, in particular in relation to its application on coal plants (Vergragt et al., 2011).

With the interest in achieving negative emissions, the ability of storing carbon has received particular attention in the combination with bioenergy production (BECCS) as well as in combination with direct air capture (DACCS). Installing carbon capture facilities on bioenergy plants and subsequently storing the biogenic carbon has the potential for negative emissions. At the same time, BECCS has received criticism for its perceived sustainability, particularly in relation to the issue of securing the biomass used for production is sustainably sourced. Operations and in particular scaling up comes with potential issues of land use and biodiversity (Babin et al., 2021; Gough et al., 2018). Direct air capture consists of pulling carbon from the air. By storing it afterwards you would decrease total amount of atmospheric carbon. The large-scale deployment is still unsure due to technological immaturity and high energy penalties. It is thus a challenge how to balance it in relation to a wider energy system (Lehtveer & Emanuelsson, 2021).

2.3 Carbon Capture and Utilisation

Opposed to storage, utilisation is aimed at different processes on utilising captured carbon. Historically, and somewhat infamously, captured carbon has been used for enhanced oil recovery, which utilises carbon dioxide to increase the total amount of oil extracted from oil wells (Martin-Roberts et al., 2021; McLaughlin et al., 2023). While this continues to be a practice, the debate on utilisation is increasingly focused on the possibilities of utilising captured carbon for creation of other products, in a form of carbon upcycling (Mertens et al., 2020, 2023) (see Appendix A for a combined and extended overview of utilisation processes and their estimated climate benefits). One particular interest is the topic of e-fuels, which can serve as an alternative to fossil-based fuel for ships and trucks (Dell'Aversano et al., 2024; Singh et al., 2022; Zhao, 2025) (see also Appendix B for an overview of e-fuel production). The climate impact of CCU continues to be a point of heavy debate. Some argue that CCU helps reduce total carbon emissions by reducing the need for additional fossil-based carbon. In continuation of this, by securing that the utilised carbon is non-fossil based, proponents argue that systems of CCU represent an essential cornerstone of post-fossil future societies, as it allows for the creation of some of the products that have become stables of a fossil-based economy, but without using additional fossil-sourced carbon (Bang et al., 2024; Mertens et al., 2023; Zhao, 2025). Others argue that the climate impacts are near to impossible to measure, and in the current practical reality, they mostly represent a slight delay of emissions via upholding carbon in additional products before being released into the atmosphere (Peplow, 2022). The process of electrolysis needed for the production of e-fuels also comes with a high energy penalty, which contributes to the critique of its viability and potential as a sustainable solution (Ueckerdt et al., 2021).

2.4 Distinguishing CCUS

In the long-term, finding ways of designing and implementing carbon management is a central part of decarbonisation. As mentioned earlier, solutions of CCS and CCU often operate on some of the same infrastructures. At the same time, it is a continuous point of debate how to treat the potentials of storage and utilisation in planning for future climate mitigation and decarbonised societies, considering their differences in climate benefits and impacts (Bruhn et al., 2016; Kleijne et al., 2022; McLaughlin et al., 2023; Talus & Maddahi, 2024).

Meanwhile, in general, there are no clear-cut principles for when to speak of CCS and when to speak of CCU, with them also often being treated in relation to each other under the composite term of CCUS, as seen in examples from articles (McLaughlin et al., 2023), policies (European Commission, 2024) as well as by organisations such as the IEA (IEA, 2023). The encompassing nature of CCUS makes for a both empirically slightly muddled and analytically interesting overlap, considering the different potential deployments and scenarios which all exist under one umbrella. This applies for the case of Denmark as well, which will be highlighted later in the thesis. I will, for the sake of this thesis, opt for using the composite term of CCUS and then elaborate, analyse and discuss the differences in technological solutions as they become relevant throughout the thesis.

3 Methodology

3.1 Designing and Identifying the Case

In working with the problem statement of the thesis, I employed a composite set of methods for data collection and analysis. I'll go through them in the following sections and discuss how they shaped my findings and points of discussion.

In approaching the topic, I designed the study to be an explorative study of CCUS explicitly as a novel phenomenon in Denmark. It is fundamentally qualitative in approach and ambition (C. Lund, 2014; Rule, 2024). I opted for an explorative and qualitative approach due to an interest in understanding how CCUS is viewed, understood and worked with – both politically and in the fields of research and deployment (Bryman, 2012). Denmark has funding schemes as well as research and development targeted directly at scaling up CCUS. Efforts that are explicitly tied to the country's climate targets. While they are not the only country explicitly focusing on CCUS development (both Norway, Sweden and the Netherlands in particular have similar efforts of scaling up CCUS), the amount of unexplored territory within large-scale CCUS deployment arguably makes all national and large-scale deployment efforts a critical case. Additionally, Denmark may be set to play a critical role in future infrastructures, with its geographical position connecting Central Europe with Scandinavia.

3.2 Data Collection

The data collection was done through different methods. I accessed publicly available information through documents, political agreements and websites as well as attended several public events related to CCUS in Denmark. While establishing a foundational understanding of the field, it also helped me identify CCUS actors of interest for interviews as well as prepare relevant interview guides. In turn, I conducted an in-depth document analysis of a series of documents related to the political agreements and strategies surrounding CCUS in Denmark (Morgan, 2022).

Additionally, I conducted six semi-structured interviews with actors involved in the rollout of CCUS in Denmark (Tanggaard & Brinkmann, 2020). Four was done online, two in-person at the interviewees place of work. The interviewees were chosen to get different perspectives on CCUS. They were positioned at state agencies, engineering consultancies, research institutions as well as two different institutions facilitating research and development as well as industry relations within the field of CCUS in Denmark. The focus of the interviews was two-fold. I was interested in the work done in relation to the rollout of CCUS on the one hand, and the understandings and visions they had of CCUS on the other. To capture this, the interviews consisted of questions tailored specifically to the interviewee's work, which were rather specific, and then a series of more open questions regarding how they view the potential and challenges of CCUS in Denmark, its relation to international contexts, climate change and the Danish climate targets. Ultimately, I also had the interviewees describe their future visions of CCUS in Denmark in 10, 30, and 50 years (see Appendix C for interview guides).

3.3 Processing and Analysis

I used NVIVO to structure the coding and preliminary analysis of my material. Both sets of material (consisting of documents and interview data respectively) were analysed in the style of a content and thematic analysis with the overall ambition of discerning patterns and themes of interest (Bryman, 2012). As the two sets of material were designed to answer different parts of my research questions, the coding and analysis were done separately. Firstly, I conducted the document analysis, which helped me identify a set of themes. In turn, this served as a vantage point for the subsequent coding and analysis of the interviews (see Appendix D for codebooks used for the document analysis and the interviews respectively).

As CCUS is a composite term (see Context section), it was a particular challenge during the work of the thesis to find ways to ensure how and in what ways the interviewees spoke to the same phenomenon. I tried to accommodate this by incorporating the tensions between CCS and CCU as part of my analysis and findings, e.g. by coding for utterances positioning CCS in relation to CCU and by staying aware of the connection between the interviewees position and work and their respective perspectives. The different data sources and positions of the interviewees also help illustrate how the emerging field of CCUS in Denmark takes the form of a patchwork of institutions, sectors, actors and interests (see Appendix G).

The figure below is a simplified illustration of the research design. In the style of a triangulation, it showcases how the individual methods help answer different research questions, in turn helping to answer the central problem statement. At the same time, the entire process is influenced by the theoretical perspective.

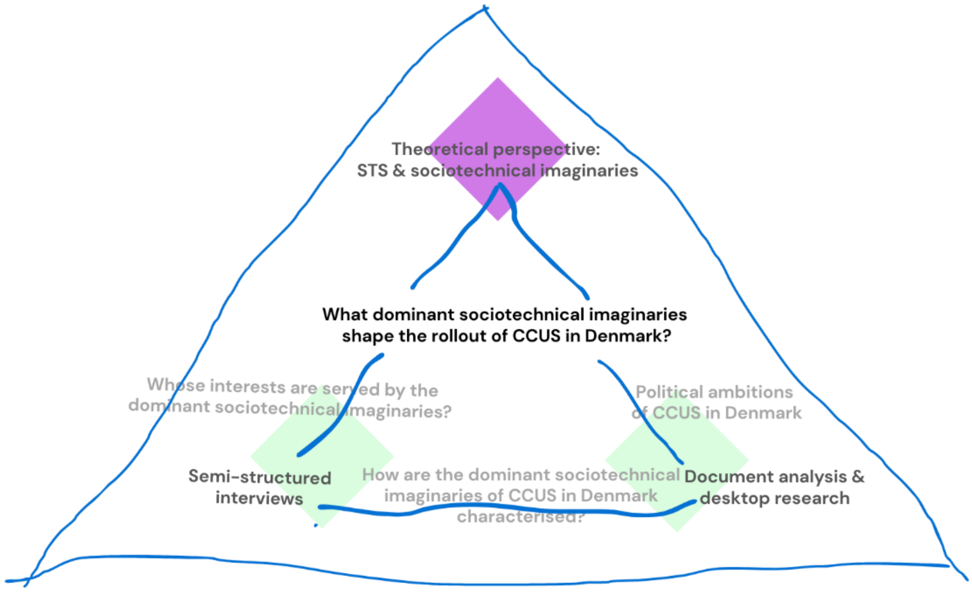


Figure 1 Simple illustration of research and analytical design made by author

4 Theory

To guide my analysis, I am drawing primarily on the concept of sociotechnical imaginaries as it has been developed within the field of Science and Technology Studies (STS). In the following section, I will give a brief introduction to STS, the concept of imaginaries broadly and more specifically sociotechnical imaginaries, while highlighting how I understand and use it for the work done in this thesis.

4.1 Science and Technology Studies

STS is an interdisciplinary scholarly tradition which posits that science and technology must be understood in its social and political context. It has an interest in investigating and contextualising scientific practices and posits that technologies carry meanings beyond just their technological and physical properties. They are also tools of power, which play a part in structuring cultural and societal meanings. According to STS scholars it is necessary and meaningful to look into how such a structuring takes place. As such, the traditions of STS have sought to be critical of what they see as a false idea of science and technology as objective and isolated, instead opting for a view of scientific knowledge as partial and technology as embedded in societal, economic and cultural norms (Felt et al., 2017; Jasanoff, 2015b).

Particularly, STS scholars have been interested in the role of science and technology and how it connects to the ways on which contemporary societies imagine "past, present and future" (Felt et al., 2017). In order to explore these questions, STS scholars have made use of the concept of imaginaries. While it is theorised in different ways, there is a common understanding of imaginaries as something that is "held collectively and draw attention to embedded visions of the social in operation, in particular technological and scientific developments and regimes" (McNeill et al., 2017, p. 438). In their genealogically informed review of the concept within STS, McNeil et al., (2017) discern and identify three overall strands of studies utilising imaginaries to explore different subject matter:

1. A conceptualisation of imaginaries in relation to communities, cultures and practice, thus interested in how imaginaries tie together and imbue certain collective practices with meaning,
2. A conceptualisation of imaginaries in relation to understanding of bodies, subjects and differences, thus interested in how imaginaries shape and enforce specific ideas of how to perform as a subject, while clouding others,

3. A conceptualisation of imaginaries particularly interested in the role of imaginaries in enforcing and reproducing the power of institutions, states and policies,

4.2 Sociotechnical Imaginaries

For the purpose of this thesis, I am drawing primarily on the third branch and particularly the concept of sociotechnical imaginaries (Jasanoff, 2015a). It was first developed explicitly in relation to and targeted at understanding the connections between technological regimes and state power in articulating national technoscientific cultures (Jasanoff & Kim, 2009). The concept has since been expanded, noting how sociotechnical imaginaries are “not limited to nation-states but can be articulated by other organised groups, such as corporations, social movements, and professional societies” (Jasanoff, 2015a, p. 5). Jasanoff defines sociotechnical imaginaries as “collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology” (Jasanoff, 2015a, p. 7). Furthermore, she notes how the concept is developed in order to investigate how, “through the imaginative work of varied social actors, science and technology, become enmeshed in performing and producing diverse visions of the collective good, at expanding scales of governance from communities to nation-states to the planet“ (Jasanoff, 2015a, p. 7). Writing in continuation of the literature on imaginaries, Lefstad et al. utilises the concept in relation to carbon capture and storage technologies in Scandinavia. In their paper they posit that imaginaries can be “identified by the interests they serve”. Their theorisation of the concept thus puts the performative power of imaginaries front and centre in the sense that specific imaginaries necessarily serve something or someone, by bringing forward specific, desirable futures and realities and at the same cloud others (Lefstad et al., 2024).

The field of STS guides my understanding of the role of science and technology as intersecting with political and cultural systems. Furthermore, the concept of sociotechnical imaginaries more specifically helps me understand the ways in which collective understandings of technological possibility, societal good and governance merge with ideas about climate change and climate mitigation. This seems particularly useful to capture the elements of interest in my empirical case; it is a long-term plan for technological development and rollout centred around reaching national climate targets years into the future. In this regard, the theoretical concept helps capture the ways in which imagined and desired technological and climatic futures fold themselves into the present, thus in turn structuring understandings of what constitutes possible and necessary actions when striving to mitigate climate change and enforce decarbonisation.

5 Findings

5.1 CCUS: A Political Ambition

For the first part of my findings, I will go through the political ambitions of CCUS in Denmark, as seen through an analysis of selected documents. The collection of documents for the analysis consists of a series of political agreements agreed upon between 2020 and 2024 as well as related press releases and material from the Danish Ministry of Climate, Energy and Utilities all in relation to CCUS. The broad agreement on "Climate, Energy and Industry" from 2020 marks the first inclusion of CCUS into the political planning of climate and energy in Denmark. Throughout 2021 a two-part political agreement sketched the overall strategy on CCUS in Denmark in more detail. These were since extended with an agreement from June 2022 and another from 2023, which set up and strengthened the basic conditions. It was followed by an agreement from 2024 specifically targeting the utilities sector. Along with these, throughout 2024, Denmark signed a series of bilateral agreements with European countries on transport of CO_2 across national borders and knowledge exchange. See also Appendix G, which presents a condensed summary and timeline of CCUS deployment in Denmark. Through a thematic analysis of the documents, I identified a series of key themes that characterise the political ambitions of CCUS in Denmark, which can be seen in the table below.

Table 1. Key themes identified through document analysis

1. Storage now, utilisation later	There is a predominant focus on carbon capture and storage in the political agreements. The agreements and considerations are largely dealing with questions related to capture, transportation and storage. In this regard, utilisation is imagined as a future potential project to be taken into consideration when developing infrastructure. This is also seen in related political agreements on PtX, e-fuels and hydrogen, which highlight the wish to look into potential synergies between future hydrogen-infrastructure and CO_2-infrastructure. It is also noted that structures developed for storage now, could be switched to utilisation in the future if it proves to be more desirable, while there is a political wish to look into possible ways of accounting and measuring utilisation's potential in contributing to decarbonisation (Doc2, Doc3, Doc9, Doc10) .

2. CCUS is necessary for emission reductions and climate goals	The political agreements continuously highlight the potential and inevitability of CCS in reaching emission reduction targets. In doing so, they make references to IPCC and the IEA in arguing for the need to remove carbon dioxide from the atmosphere in order to achieve climate goals (Doc2, Doc3, Doc4, Doc5, Doc6). As a foundational feature of CCS in Denmark, they note that the technology is not to be used for enhanced oil recovery – and that it is also not an expression for lowered climate ambitions in general. CCS in Denmark is to be targeted at industries, where emission reductions are otherwise impossible to achieve or in instances where they can lead to negative emissions (Doc3). The current political agreements and funding structures expect to lead to 3.2 million tonnes stored Co2 from 2029 (Doc10).
3. CCUS should run on market terms in the long run – but public funds are necessary to kick-start	The ambition is to make CCUS run on market terms. The political agreements continuously note that the wish is to make CCUS operate on market terms. In this regard, tools such as the European emission trading scheme and future tax on carbon are mentioned as necessary to steer this development (Doc3). In this way, it also ties into the ongoing work on a Danish carbon tax. Meanwhile, it is also decided to establish a series of funds operated by the Danish Energy Agency to be distributed through a series of public tender rounds to help kickstart CCUS projects with the first full-scale project to be done in 2025 and a series of projects to be ready by 2030 – specifically as a product of the public funding and tender round (Doc 2, Doc3, Doc5).
4. CCUS is of national interest for Denmark	Throughout the political agreements, CCUS is noted as containing a lot of opportunities for Denmark. By playing a part in developing and be some of the first deploying the different technologies,

	Denmark can position itself in a leading position in a completely new industry. In this regard, it is also expected that CCUS will help secure and attract both economic profit and activity for Denmark in the future. At the same time, CCUS is set to play a critical role in the future. The political steps currently taken is thus also to ensure Denmark a position in relation to future climate mitigation infrastructure (Doc2, Doc5) This is also mentioned in relation to the potential of possible carbon storage in Denmark. They note that the potential of geological storage surpasses the Danish domestic emissions, thus leaving room for “both Danish and foreign captured CO2” in Danish storage sites (Doc5). CCUS is thus not only a technological development project but is also tied to international political interests and ambitions (Doc4, Doc5).
5. Future CCUS should include cross-border infrastructure	The domestic political agreements imagine future CCUS deployment to include cross-border infrastructure and agreements. This is seen already in the earliest agreements and eventually established further by a series of bilateral agreements. Memorandum of Understandings (MoUs) between Denmark and the Netherlands, Belgium, Norway and Sweden respectively all concerned with the potential of transporting carbon across borders with the intention of permanent storage (Doc13, Doc14, Doc16, Doc17). Additionally, MoUs between Denmark and France and Austria respectively concerned with exchange of knowledge and experiences of CCUS (Doc15, Doc18). This ambition ties back into beforementioned tools, which include the EU Emissions Trading Scheme as well as the potential of using Danish storage potential to store imported carbon.

6. **Full value-chains must be considered**	Finally, as a sixth recurring theme, there is a continued emphasis on the importance of CCUS deployment to consider full value-chain operations in order to be successful. This underlines both the novel status of CCUS (nothing is established yet), as well as the many different actors involved in the stages of deployment and implementation (Doc5).

Through the political agreements we see the multi-year ongoing work focused on initiating and steering the rollout of CCUS in Denmark. Through its combination of state-planning and governance, the rollout also mobilises a specific sociotechnical imaginary. CCUS is imagined not only as a climate mitigation tool, but also as a central pillar in a decarbonised and "green" industrial future. At the same time, it envisions carbon storage as a solution that precedes utilisation – while leaving space for future technological innovation and reconfiguration of infrastructure, i.e. utilisation for production of e-fuels. There is a future reliance on market-based operations coupled with initial state investment, which includes extensive public-private collaboration. The emphasis on full value chains also casts CCUS as a phenomenon that incorporates multiple actors and institutions. In this way, it is mobilised not only as a technical matter, but a solution that needs to be integrated with current systems, institutions and actors. This also works to mobilise an imaginary, which proscribe CCUS with potential not only for climate mitigation, but for industrial and societal relations. CCUS is, at the same time, envisioned as able to favour Denmark's international position and deliver economic gain through the establishment of Denmark as a European CO2-hub. Overall, the political ambitions and visions around CCUS reflects an imaginary in which technological development, economic competitiveness and environmental responsibility and climate mitigation all co-exist and are able to develop in close relation with each other.

5.2 Envisioning large-scale CCUS: Potentials and Challenges

In order to understand how the political ambitions and agreements play out, I will now turn to an analysis centred on my interviews. Through the interviews, I will explore how CCUS is viewed, including its potentials and challenges – and through this distil some of the sociotechnical imaginaries which exist around CCUS.

5.2.1 CCUS as a Climate Necessity

Continuously across interviews, CCUS is specifically highlighted for its potential in relation to so-called ”hard-to-abate” emissions from industries that do not have other viable alternatives: ”there are no other alternative solutions … cement production, steel production, and waste incineration” (Int4). This sentiment is expressed across the interviews, where specifically the ability to capture carbon from point sources of industrial processes, where emissions are otherwise impossible to avoid, is brought forward as one of its keys potentials, ”we can count our chimneys … catch the CO2 and put it into the ground, and we have plenty of space” (int5), as one succinctly puts it. In this regard, CCUS represents a key part of what is seen as the only viable path to close Denmark’s remaining emissions gap and anchor the country’s long-term strategy of reaching climate goals.

As one of the interviewees highlight, even after having successfully managed a full electrification and fuel-switching, CCUS would be ”hard not to do” if we want to balance biogenic and processes emissions and still reach net zero (Int3), or ”it allows us to reach our climate targets … not much else will allow us to” (int5), or ”Politically, it has been decided that CCUS is a thing, we need to do something about, otherwise we won’t reach out 2030-targets” (Int2). In this way, CCUS is continuously highlighted as a necessity in achieving the climate targets. This is in turn underlined by reference to external organisations such as IPCC, which has also highlighted the need for carbon dioxide removal in order to limit climate change (IPCC, 2023). Or more specifically in relation to geological storage of carbon: ”IPCC tell us that geological storage has a durability of thousands of years … we view the geological storage as permanent” (Int1), thus demonstrating how IPCC provides scientific legitimacy to the focus on carbon storage. Furthermore, beyond achieving climate neutrality, the ability to achieve negative emissions is also continuously brought forward, with one interviewee noting how it, hypothetically, would allow us to pay a ”carbon debt”, confidently saying how we could, for every tonne of CO2 emitted, would be able to ”put 3-4 back into the ground”, and in this way, in time, compensate for emissions also outside the region of Denmark (Int3). In this way, the climate potential of CCUS is continuously brought forward.

Furthermore, one interviewee also posits how there has been a shift of focus following the political focus on CCUS since 2020. Speaking in relation to small and medium enterprises (SMEs) which he works with, he notes how, four years ago, SMEs regarded CCUS as “a foreign concept”; today many are actively exploring how it would make sense for them to engage in carbon management (Int2). He goes on to note how fossil-centric firms like INEOS, a major petrochemical company, are now piloting CCS vessels and platforms, accepting immediate losses “to compensate for all the fossil fuel” because they recognize that “fossil fuels one day will be over” (Int2). In this way, for him, CCUS represents many different elements, which all tie into developing fossil-free solutions – be it from fossil-fuel companies or else.

In this way, despite variations, the interviews demonstrate how CCUS has shifted from being viewed as an optional add-on to becoming a core element of Denmark’s climate strategy: for the interviewees, CCUS holds the potential to provide a way of removing emissions from the most challenging sectors and support net-zero and even net-negative pathways. This collective framing is a core example of a sociotechnical imaginary – a shared, institutionally embedded vision of desirable futures in which technological innovation both enables and embodies societal goals. By repeatedly characterizing CCUS as the main viable route to close Denmark’s “hard-to-abate” gaps, interviewees enact and reinforce an imaginary in which a key part of climate mitigation is a matter of deploying advanced capture, transport, and storage systems.

***5.**2.2 More Than Just Climate Potential*

Furthermore, when asked about the potentials, CCUS is highlighted not only as a necessary lever for meeting Denmark’s climate targets but also as a bourgeoning industry with significant commercial and geopolitical potentials. By embedding CCUS within Denmark’s broader decarbonization strategy, policymakers have mobilized “x number of billions” in public funding to “develop the industry, to help support that it hopefully can become a commercial industry at some point” (Int2). Additionally, Denmark is highlighted as having specific properties making it suitable for a large-scale investment of CCUS.

One of these is a particular geological structure. The Danish capacity for geological underground storage is so ample that, once domestic emissions are sequestered, there remains a vast potential “business adventure” in hosting CO_2 from neighbouring emitters (Int2, Int5). The possibility of new importing and exporting opportunities around carbon management is repeatedly brought forward as a future profitable endeavour. As several interviewees note, there is a potential of turning Denmark into a ”European CO2 Hub”. By installing CCUS infrastructures now, it would allow for Denmark to position themselves as a key player in relation to something set to play a critical role in the future as managing emissions is central to achieving climate neutrality. In continuation, as one interviewee notes, CCUS is made up of a long list of different processes, value-chains and technologies – capturing, transport, storing and utilisation – and along all of these, there exist potential and opportunity for new business and job opportunities (Int2, Int6). As such, CCUS is tied to the possibility of delivering job opportunities as well as a way of securing Danish relevance on an international (potentially soon to be established) market. ”By being first mover now on this, [Denmark] has successfully jump started an industry for storage … which is aimed towards a European market more so than a Danish market. So, if you consider industrial policy in relation to this, that would perhaps be the most central contribution” (Int1), as one interviewee notes, when asked about potentials in relation to CCUS deployment. While the quote above was said specifically in relation to the notion of carbon storage, similar sentiments are expressed towards other parts of CCUS solutions.

At the same time, this is also tied to a notion of Denmark both historically being a ”first mover” in terms of green technology and climate action. Several interviewees compare the process of large-scale CCUS development to the development of the Danish wind turbine industry (Int2, Int5). Other interviewees mention how Denmark historically has been a place for setting high environmental standards, which in turn then diffuse to the rest of the world (Int3, Int4). In this way, it would “only make sense” that a similar thing was to happen in relation to CCUS. Beyond economic and industrial promise, demonstrating that complex, large-scale capture and storage is possible would both serve as a powerful geopolitical signal and a soft-power asset for Denmark, as well as confirm already existing cultural ideas of Denmark as a country which is acting on climate change.

In summary, the potentials of CCUS are viewed as technical but at the same time as much more than that; it is a large-scale process which cultivates a socio-technical imaginary that links climate ambition with commercial opportunity and national prestige. By emphasising geological capacity, world-class clean technologies and a history for climate action, CCUS is seen as laying the groundwork for a future profitable industry and an area with potentials for increasing Denmark’s soft power geopolitically – thereby transforming climate necessity into a competitive advantage on an international stage.

5.2.3 Uncertainties in CCUS Deployment

At the same time, the data shows a series of significant hurdles and challenges in relation to the continued development of CCUS.

Consistently, it is noted how the economics of CCUS currently are not there. Investing in different CCUS infrastructure requires a high amount of up-front costs and the markets of both capture, transport, storage and utilisation are still immature. The state support in the shape of tender rounds is designed to help alleviate this. Alternatively, there is a need for solid revenue streams from other sources to make CCUS installations a viable option. As mentioned by one interviewee, CCUS is, in this way, a playing field mainly for a few major players, who have the leverage to engage in it (Int3). This points to a question of scale. CCUS deployment implicates actors across scales, from small biogas demonstration units to major emitters and potential multi-megaton storage and processing hubs. In relation to their work specifically on carbon capture, an interviewer notes how “we work at all scales”, however, they also point out how currently, CCUS remains an undertaking available only for big companies and major players (Int3). As one interviewee simply puts it, there is still “a long way to go before the price will reduce … before it’s sensible for all companies” (Int2).

While large-scale pipelines and geological reservoirs might result in the greatest CO_2 throughput and cost efficiency, they also demand substantial upfront capital and a constant CO_2 flow when in operation. For more dispersed, smaller point sources and emitters it would be difficult and expensive to connect it to a centralised pipeline network, ”a 70–90-kilometre pipeline … it simply would not make sense … it would be too expensive” (Int2). Thus, the CCUS landscape is potentially going to be characterised by different infrastructural cut-offs: While emitters above a certain scale potentially will connect to pipelines, others will have to opt for more localised, on-site solutions, await grid extensions or pay a larger amount of carbon tax because limited decarbonisation opportunities exist in close proximity. In this way, the deployment of CCUS also includes a trade-off between national coordination and local action as CCUS goes from demonstration projects to large-scale deployment and integration (Int2, Int6).

Additionally, one major challenge is the combined novelty and complexity of CCUS value-chains: “you do not start building a storage facility before you are sure it can be transported and stored … it is a challenge … the chicken-and-the-egg-problem” (Int1). While the public tender is supposed to alleviate this by covering necessary funding gaps, the complexity and uncertainties is a continuous struggle in the continued development of CCUS. Related to this, interviewees note how there is a need for clearer policies to lay the groundwork for companies to see CCUS as an economically viable business case. While fossil emitters under the EU ETS can claim allowances for stored CO2, “the quota price is not high enough for [companies] to self-finance their CCS activities” (Int1). There are even fewer incentives when it comes to the question of biogenic carbon emitters. within the current structures. Several interviewees refer to the need – and ongoing work – of including negative emissions into the ETS. While there is an option of biogenic emitters to sell voluntary credits, as in the case of Ørsted’s CCS projects, which included a sale of carbon credits to Microsoft, the market is still “very immature” (Int1). Related, another interviewee clarifies: “if this is to run by itself, there must be a carbon tax … otherwise it will die”, going on to say how, “if there is not a clear business case in keeping things running, it will of course stop” (Int3). Taken together, this showcases mainly two things. First, ongoing work in policies has the potential to determine the prospects of CCUS. Second, CCUS in all its entirety, while representing a new market in some ways, is at the same time heavily contingent on having leverage points within current market structures, i.e. in the form the European Emissions Trading Scheme or similar carbon markets.

These deployment uncertainties illuminate the gap between the aspirational CCUS vision and on-the-ground realities. They stand in contrast to a dominant sociotechnical imaginary of CCUS, as seen in both the political agreements and throughout the interviews, which casts it as a market-driven pathway to decarbonisation and as a "business adventure" with environmental benefits. In practice, CCUS remains underwritten by public funds: not only through the high-profile tender rounds, but also via extensive R&D grants, demonstration subsidies, and bilateral knowledge-exchange agreements. At the same time, it mobilises an idea of entrepreneurialism and large-scale ambitions (e.g., national pipeline networks and multi-megaton carbon hubs).

Finally, another factor brought forward is the question of social acceptance – particularly in relation to onshore carbon storage projects. Referring to past experiences with large land-based construction projects, it will become a need to balance local and public acceptance of CCUS projects and avoid falling prey to "not in my backyard"-pushbacks. This is highlighted particularly in connection to the highly technical nature of CCUS as a particular challenge: "when the technicians have forgotten to take a course in communication, interesting stuff happens" (Int5). As onsite projects starts to take place, paying attention to community support and acceptance will thus become an increasing challenge (Int6).

5.2.4 CCS or CCU: A False Unification?

In addition to the above-mentioned potentials and challenges in the rollout of CCUS, the findings from the interviews also deliver an insight into the ambivalent relationship which exists between CCS and CCU. While often bundled under a single acronym, the interviews also showcase the limits of thinking about CCS and CCU as one unified category. At the operational level, CCS and CCU converge in certain technical and infrastructural aspects – such as capture and transport – but they diverge when it comes to the end-use: "CCUS, it is a kind of contraction of two things which are, in nature, opposite", as one interviewee puts it (Int1).

One thing brought forward in relation to CCS versus CCU is the difficulty of calculating carbon impacts and climate benefits. When discussing the difference between CCS and CCU, when looking at CCU and Pt-X, "it is very hard to manage, because then you end up with some CCU-product. Can you be sure that it actually counts towards the Danish climate accounting, or are you risking that it will be exported, and how are you going to calculate the substitution effect? ... Besides that, it is also quite expensive. You will get more climate [benefit] per unit invested by doing CCS compared to doing CCU" (Int1). The interviewee speaks to the fact that storage offers an easier way to direct, countable reductions, whereas utilisation faces accounting and methodological uncertainties. In relation to the same topics, someone else notes, “I think, the reason why there has not been as much political focus on [CCU] is because there is not as clear a way to say, when you do this thing, then you remove this amount of CO2. There are a few more steps going from the thing you do and then for you to be able to see the climate effect. And also, it is the very, very, very high-hanging fruits, you can harvest from utilisation. But if we don’t develop all of these ways of production and alternatives, then we will never arrive at a fossil-free world” (Int5). In the quote we see how CCU[1] is viewed as less mature than CCS when considering direct, measurable climate benefits. At the same time however, it is highlighted how, in the long run, it is a necessary tool to reach a fossil-free world. In this way, the quote highlights the necessity of both CCS and CCU, while exemplifying their difference in current political assessments – which, for the moment, prioritises CCS over CCU. One interviewee explains how the landscape of carbon management is steered towards storage over utilisation: “because there is so much state funding in [CCS], that’s the way the industry is currently tilting. Then it might be that the U-part makes more sense at a later time. Right now, it is being stored because that is what you know to be, or perhaps think, is the most mature” (Int2). At the same time, the slight addition of “or perhaps think” suggests that the interviewee themself might not be in full agreement with the political strategy, thus showcasing how multiple ideas and imaginaries in relation to CCUS exist in practice.

Meanwhile, the tension of balancing storage and utilisation is voiced in several interviews. There is an effort to be adaptive and pragmatic by for example considering if infrastructure decisions made for storage today in the future could switch to be used for utilisation, “you are kind of trying to be open to all the possibilities there are” (Int3). Similarly, the contracts for public funding, which currently is steered explicitly towards CCS, also has a function for the individual project to opt out of the contract in the future, if it becomes more viable to do CCU over CCS – in order to allow for an openness towards future CCU opportunities (Int1). At the same time, another interviewee says, “out in the practical world, when I engage in discussion, when we talk with different actors, then it is a kind of either-or-situation that they are facing”, and argues that, while pragmatism might be desirable, a high number of industry actors have to decide on either storage or utilisation as their business case and goes on to note how, obviously, current infrastructure steps comes with the risk of lock-ins one way or the other (Int6).

[1] In the context of the interview, CCU here refers to using captured atmospheric carbon for a variety of unspecified products as opposed to carbon from fossil sources

The discussion around CCS vs CCU also often ends up becoming a larger question of both time and perspective on transitions. Several interviewees note how CCS is the current focus, while CCU represents something more vague, more long-term. "You could easily set 2070-goals for CCU", as one interviewee says (Int5). The discussion around CCS or CCU highlights differences in envisioning the path towards a decarbonised society. As one puts it: "A lot of people would say, if we just deposit all CO2, that won't motivate us to transition away from fossil fuels, whereas others would say, well, CCU is, it does not motivate us to move away from carbon-based emissions over to hydrogen or ammoniac or over to electrification" (Int4). For one interviewee, this also relates to how to think about carbon management in future energy systems. By invoking the idea of the "waste hierarchy", they describe CCS as resembling a landfill situation, whereas options of CCU aligns more with the principles of "reduce, reuse, recycle". They present this in relation to the idea that we might be looking at a future where, in a post-fossil society, the carbon dioxide desired for achieving countable negative emissions is the same carbon dioxide desired for utilisation for Pt-X or other utilisation purposes, thus ending up making carbon dioxide a scarce resource – and necessitating a discussion on how best to manage it (Int6).

When asked about their future visions for CCUS in 10, 30, 50 years respectively, it was clear that projects on capture and storage took centre stage in the coming years. However, when asked to imagine further ahead, the storage solutions currently being sought funded and developed were already clouded by the blossoming of a plethora of other technologies such as direct air capture facilities, mineralisation, pyrolysis and an increasing prevalence of CCU infrastructures combined with Pt-X. In this vein, the current solutions in focus (such as point source capture combined with transport to geological storage sites, e.g. Ørsted's project) was, in the grander imaginaries of things, described as a transitional technology on the way to a post-fossil future (Int2, Int4, Int5, Int6).

5.2.5 Summarising the findings

The findings showcase the political ambition to deploy CCUS as well as some of the practical opportunities and challenges that arises along with the everyday work of realising such political ambitions. At the same time, the findings also showcase how there exists a variety of ideas about the future of CCUS. The findings demonstrate a series of overlapping sociotechnical imaginaries, which serve to mobilise and strengthen particular conceptualisations of CCUS. While composite and nuanced, these imaginaries are characterised by technological optimism, economic potential, geopolitical opportunity, and environmental responsibility, thus, casting CCUS as integral for climate mitigation functions to cast Denmark and Danish businesses strategically within future markets. Central to these imaginaries is the depiction of CCUS as an unavoidable climate necessity for tackling "hard-to-abate" sectors, where technological pathways such as electrification or fuel-switching are insufficient or impossible. The alignment of this vision with international scientific bodies, notably the IPCC and IEA, lends further legitimacy and urgency to these national strategies. Moreover, the state's active role in providing financial incentives through public funding frameworks highlights a market-driven but initially state-supported approach towards fostering CCUS as both an environmental imperative and an economic opportunity. Building on this, I will now move on to a discussion of my findings. I will start by discussion the role of technology, continue with a discussion surrounding the risk of lock-ins. This will lead into a discussion on the purpose of CCU, which will be followed by a brief concluding paragraph on the discussion.

6 Discussion

6.1 Technology, Future Promises and Ecomodernism

The emphasis on technological development as a foundational solution in the plans for how to reach climate goals within Denmark resembles a general tech-centred approach to climate mitigation. As I've shown, the Danish CCUS ambitions are deeply embedded within an imaginary that links it to a general belief in technological development and tech-optimism. As such, the imaginaries surrounding CCUS brings to mind the now-classic perspective and critique of ecological modernisation as an approach to sustainability and social change (Javed et al., 2025; Spaargaren & and Mol, 1992). Ecological modernisation generally emphasises the role of technological development in securing environmental and ecologically sound societies. It is characterised by the belief in a possible combination of environmental sustainability and continued development – both societal and technological. Central to this is the idea of decoupling, which posits that economic growth and societal development is possible to achieve free from negative environmental impacts through technological development (Asafu-Adjaye et al., 2015; Grunwald, 2018).

As highlighted throughout the interviews, there exists no apparent secure business cases surrounding CCUS instalment for industrial actors at the moment. The idea of deploying it is thus inherently contingent on the promise of future profitability, "as soon as it takes off" (Int2), as the phrasing goes. The deployment of CCUS is contingent on the promise of its future profitability, which will be acquired by, yes, restructuring and reforming some current structures (e.g. potentially incorporating NETs into the European Emissions Trading Scheme (Talus & Maddahi, 2024), but also by a strong reliance on innovation, market structures and eventually an economies of scale to stabilise CCUS over time. In this way, it bears strong resemblance to the ideas put forward in the paradigm of ecological modernisation

The question of scaling and delivering has been seen in the case of point source capture and storage since its first development, in which it was projected as having potential for handling emissions from fossil fuels. Consequently, while failing to deliver on the projected promises of climate benefits, discussions in turn have centred around understanding what went wrong as well as pointing to new pathways of scaling up (Gillespie & Townsend, 2020; Global CCS Institute, 2025; Martin-Roberts et al., 2021; Wang et al., 2021). This framing renders CCUS as generally fixable and scalable, relegating its problems not into the sphere of politics but in that of engineering.

The future-oriented promise of CCUS becomes even stronger, when considering the visions of carbon utilisation. As showcased, CCU is projected by proponents to play a key role in future plans for decarbonisation. Compared to (some) CCS technologies such as point-capture and geological storage, it is generally characterised by a lower level of realisation. However, the belief in technological innovation as the pathway to securing climate stability has never been clearer than when considering the myriads of technologies dominating the future visions of carbon management. However, as has been argued before, technological development rarely delivers on its promises as smoothly as its visions might foretell (Brechin & Lee, 2025; Grunwald, 2018; Sie, 2024). In relation to this, the concept of "Jevons paradox" serves as an example of how technological development designed for decreasing environmental impacts in turn, due to different, often unforeseen, rebound effects, can end up having the opposite effect (York & and McGee, 2016). While contingent on promises that lie in the future, CCUS is still deeply ingrained in current practices, structures and systems. It thus, from a transition perspective, also comes with the potential to both lock and reproduce parts of the current sociotechnical system of which it is a product.

6.2 CCUS, International Ambitions and Lock-ins

The ability to import CO2 and export technologies is furthermore framed as a way of strengthening Denmark's position as a nation pursuing climate action. The potential of becoming a European "CO2 Hub" is also mobilised by interest organisations on the Danish CCUS scene, who see it as an avenue for future profit and job-creation when faced with decarbonisation. The international orientation might successfully reinforce some of Denmark's geopolitical and economic aspirations – especially considering its alignment with international strategies and ambitions of EU's Carbon Management Strategy. Building on the aforementioned discussion of future-orientation and technological determinism, I want to highlight how CCUS, in particularly through international structures of import and export, comes with the potential of creating lock-ins and reinforcing technological path-dependencies throughout Europe (Faber et al., 2025).

Pursuing the idea of becoming a "CO2 Hub" and building business cases around the potential of storing imported CO2 from foreign emitters is based on the ability of entering into long-term contracts with large-scale emitters. In this way, the sociotechnical system is contingent on the continuation of carbon emissions to capture. When trying to assess the extent of carbon lock-in, it thus becomes a key question from what and which carbon-sources future storage sites would be used for (Faber et al., 2025), e.g. by excluding emissions from processes to which there are alternatives to fossil fuels. The differentiation between sources and types of carbon thus, once again also becomes a key point for future consideration of carbon management technologies. While, from a decarbonisation point of view, capture and storage from hard-to-abate sectors might be necessary in the long run, there is a chance that opening the same structures up for fossil fuels carries the risk of entrenching the current fossil fuel systems even further through carbon-lock in. In this way, designing and establishing an international carbon infrastructure could carry with it a prolongation of carbon dependency by shifting attention or motivation from the pressing issue of fossil phase out. On the other hand, if the carbon inflows end up being less than expected would result in a series of sunk costs in Denmark – which in turn highlights the ongoing question of whose risk it is to pay, considering the amount of public funding funnelled into current CCS projects.

Ultimately, the ambitions of importing and storing carbon emissions potentially aligns national policy and economic interests with the large corporate actors, who are set to be the main players in a scaled up international carbon market. Considering the overlap between oil and gas companies in both emission as well as storage projects (consider i.a. the presence of TotalEnergies, INEOS in Danish storage projects) also points to some of the invested interests existing in relation to the international CO2 infrastructure when considering carbon capture with the intention of storage. Hearkening back to the dominant sociotechnical imaginaries, which mobilises CCUS as a tool for climate mitigation, thus also tend to cloud these considerations in the same breath.

6.3 Finding the Purpose for CCU

Another line of discussion runs along the balance and differences between CCU and CCS. As showcased, actors working with CCUS point out how CCU to some extent has been politically neglected compared to CCS in Denmark. This is remarked as due to difficulties in assessing its direct climate impacts and emission reductions (see Findings). Meanwhile, it is also continuously brought forward as a cornerstone of long-term plans for decarbonisation with its potentials of replacing fossil-based fuels, as well as allowing for the creation of carbon-based products via a repurposing of captured atmospheric carbon (Mertens et al., 2020, 2023). This opens up for questions and discussions surrounding the salience of technological development. Furthermore, it also opens up for a discussion of which systems drive the pursuit of CCU – and to what extent and in which capacity it is necessary.

"If we want to keep flying" (Interview 3), "if we want to keep shipping products" (Interview 2), "it also depends on what we decide that we want, if we want to keep …" (Interview 6), and similar sentiments were frequently expressed in relation to the technological development of carbon utilisation and the potentials of e-fuels. Projections and models showcase the need to accelerate decarbonisation, which in turn are mobilised as arguments for the necessity of development and deployment of carbon management technologies (Lefstad et al., 2024). And while it might have merit that CCUS is necessary for delivering an elimination of carbon emissions and in turn also preventing climate collapse, it begs the question of what kind of climate mitigation it will foster; what kind of values will guide the deployment of future carbon infrastructures, and what kind of society is it designed for? As previously shown, there exists a major difference between CCS and CCU in terms of the end-use of the captured carbon. A specific sociotechnical imaginary is mobilised around CCU, which casts it as a necessary piece in future energy systems – either as an energy carrier in combination with hydrogen or as a material component (Mertens et al., 2020). At the same time, this also puts it in a potential tension with CCS. In order to align with decarbonisation efforts, carbon designated for utilisation necessarily has to be biogenic (or sourced from the atmosphere through direct air capture). At the same time, biogenic carbon is also of interest for storage, in an effort to achieve negative emissions. While it is yet to be explored in detail, it thus presents a future in which carbon (the right kind of carbon, i.e. biogenic) becomes a resource with multiple, opposite-pointing interests. This in turn raises questions of governance and management – how to make best use of a potentially scarce resource? It also raises the question of future vested interests and changing market opportunities for utilisation and storage respectively. Current business cases built around storing biogenic carbon might prove less fruitful in future systems, were the infrastructure around utilisation to flourish, and vice versa. Paying attention to the relation between CCS and CCU thus continues to be a key point of interest, especially considering the likely scaling up and continued focus on the palette of technological solutions.

The second point of discussion is related to the point of doing utilisation. The dominant sociotechnical imaginaries mobilise the potential of CCU as a necessity – we need it for the way societies are currently operating, thus we need them for the projected futures as well. Developing fossil-free fuel alternatives for airplanes, freight ships and heavy trucks is undoubtedly an important part of decarbonising transport. The development of the alternatives still highlights a question of how it relates to current systems of production and consumption. The material throughput of the current globalised economic system consisting of criss-crossing trade routes, shipping and freight is part of a continuous strain on the world's planetary systems (Boston, 2022; Devictor, 2017). The desirability of CCU-solutions currently exists in a direct relation with the perceived necessity of servicing current patterns of material consumption and use. Hearkening back to Jevons paradox as well as critiques raised by ecological economics, for CCU to be part of a suitable solution, it should arrive with a critical discussion surrounding its actual needs, as opposed to delegating its necessity to a matter of how current systems are operating. Otherwise, its opportunities for playing a part in an actual climate-friendly society lives at the risk of being washed out. The radical alternative to continuously chasing the development of new utilisation-purposes would be to pay attention to ways of lowering our material throughput instead – or at least make sure to consider them in direct tandem with each other. Especially considering the energy penalty which exists in relation to most CCU processes, which already puts strain on the need for scaling up renewables. Additionally, the need for questioning material throughput and relevance seems particularly relevant in the context of Denmark and Northern Europe in which consumption-based emissions ranks among the world's highest (Axelsson et al., 2024; Minter et al., 2023).

6.4 Distilling the imaginary

In the realm of CCUS deployment, the sociotechnical imaginary is characterised by a reliance on technological solutions and innovation coupled with a reliance on market mechanics, which comes with the risk of potential blind spots regarding equity and systemic transformations. As societies gear up for large-scale deployment of CCUS in different capacities, it therefore becomes imperative to engage critically with these imaginaries, in order to also explore diverse pathways and maintaining an openness to alternative and complementary solutions which go beyond technological fixes alone.

7 Conclusion

In this thesis, I have worked with the overarching problem statement: “What dominant sociotechnical imaginaries shape the rollout of CCUS in Denmark?”. This work has been done with an aim to understand the ideas and visions which exist around the development and deployment of CCUS in Denmark. To a further extent, this has also been done with a general interest in the connections between technologies, climate mitigation and tools of governance as societies hunt for ways to increasingly enforce decarbonisation. Throughout the thesis, I have shown some of the potentials and challenges of CCUS – while highlighting the technological difference between CCS and CCU, and showcased how they, while often treated in connection with each other, also can mobilise different ideas about transition and decarbonisation.

The sociotechnical imaginary around CCUS mobilises Denmark as a climate-ambitious nation. An imaginary which builds on previously established narratives of Denmark – and to a larger extent, the Nordic countries – as countries leading the way in establishing durable climate-friendly societies. Combined with the tendency of technologies to be considered politically neutral, the quest for climate mitigation in light of climate emergency allows for the pursuit of CCUS to be infused with green cards: It’s a climate-leading country lighting the way in the next step of transition; first they did the windmills, now they are delivering on CCUS. By emphasising the climate necessity in combination with the geopolitical and industrial potential for CCS, but even more so for the future of CCU and Pt-X, the imaginary surrounding CCUS also in practice come with the potential to sidecut questions of distribution: in favour of who and what systems the development of CCUS is taking place. The imaginary characterised by climate necessity creates a depoliticization of the process, thus neglecting to ask the question: Is this actually what we want? And if so, who is that we?

Based on the work in the thesis, further research could look into the relations between continued deployment of CCUS and a fossil-dependent world – in order to ensure that CCUS gets used to enforce decarbonisation and prevent fossil lock-ins.

Additionally, further research should look into the relation between CCUS and the reduction of material throughput – how to ensure CCUS gets deployed in a way that avoids Jevons paradox or other rebound effects as it seeks continued up-scaling.

8 References

Asafu-Adjaye, J., Blomqvist, L., Brand, S., Brook, B., Defries, R., Ellis, E., Foreman, C., Keith, D., Lewis, M., Lynas, M., Nordhaus, T., Pielke, Jr, R., Pritzker, R., Roy, J., Sagoff, M., Schellenberger, M., Stone, R., & Teague, R. (2015). *An Ecomodernist Manifesto*. The Breakthrough Institute. http://www.ecomodernism.org/manifesto-english

Axelsson, K., Gong, J., Dugast, C., Lambe, F., Maquet, P., & Suljada, T. (2024). *Consumption-based emissions: A new frontier for EU climate policy*. Stockholm Environment Institute. https://doi.org/10.51414/sei2024.025

Babin, A., Vaneeckhaute, C., & Iliuta, M. C. (2021). Potential and challenges of bioenergy with carbon capture and storage as a carbon-negative energy source: A review. *Biomass and Bioenergy*, *146*, 105968. https://doi.org/10.1016/j.biombioe.2021.105968

Bang, A., Moreno, D., Lund, H., & Nielsen, S. (2024). Regional CCUS strategies in the context of a fully decarbonized society. *Journal of Cleaner Production*, *477*, 143882. https://doi.org/10.1016/j.jclepro.2024.143882

Boston, J. (2022). Living Within Biophysical Limits: Green growth versus degrowth. *Policy Quarterly*, *18*(2), Article 2. https://doi.org/10.26686/pq.v18i2.7578

Brechin, S. R., & Lee, S. (Eds.). (2025). The Climate Change Crisis and the Limits of Technological Solutions. In *Routledge handbook of climate change and society* (Second edition). Routledge, Taylor & Francis Group.

Bruhn, T., Naims, H., & Olfe-Kräutlein, B. (2016). Separating the debate on CO2 utilisation from carbon capture and storage. *Environmental Science & Policy*, *60*, 38–43. https://doi.org/10.1016/j.envsci.2016.03.001

Bryman, A. (2012). *Social research methods* (4. ed). Oxford Univ. Press.

Carton, W., Hougaard, I., Markusson, N., & Lund, J. F. (2023). Is carbon removal delaying emission reductions? *WIREs Climate Change*, *14*(4), e826. https://doi.org/10.1002/wcc.826

Dell'Aversano, S., Villante, C., Gallucci, K., Vanga, G., & Di Giuliano, A. (2024). E-Fuels: A Comprehensive Review of the Most Promising Technological Alternatives towards an Energy Transition. *Energies*, *17*(16), 3995. https://doi.org/10.3390/en17163995

Devictor, V. (2017). The Biophysical Realities of Ecosystems. In C. L. Spash (Ed.), *Routledge handbook of ecological economics: Nature and society*. Routledge.

Edelenbosch, O. Y., Hof, A. F., van den Berg, M., de Boer, H. S., Chen, H.-H., Daioglou, V., Dekker, M. M., Doelman, J. C., den Elzen, M. G. J., Harmsen, M., Mikropoulos, S., van Sluisveld, M. A. E., Stehfest, E., Tagomori, I. S., van Zeist, W.-J., & van Vuuren, D. P. (2024). Reducing sectoral hard-to-abate emissions to limit reliance on carbon dioxide removal. *Nature Climate Change*, *14*(7), 715–722. https://doi.org/10.1038/s41558-024-02025-y

E-fuel. (2025). *About*. E-Fuel About. https://www.e-fuel.fi/about/

Energistyrelsen. (2024a, October 10). *Udbudsrunde på CCUS-pulje er afgjort: Energistyrelsen tildeler kontrakt til Ørsteds fuldskala CCS-projekt | Energistyrelsen*. https://ens.dk/presse/udbudsrunde-paa-ccus-pulje-er-afgjort-energistyrelsen-tildeler-kontrakt-til-oersteds

Energistyrelsen. (2024b, October 22). *CCS-udbud og anden støtte til udvikling af CCS | Energistyrelsen*. Ens.dk. https://ens.dk/forsyning-og-forbrug/ccs-udbud-og-anden-stoette-til-udvikling-af-ccs

European Commission. (2024, February 6). *Towards an ambitious Industrial Carbon Management for the EU*. European Commission. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2024:62:FIN

Faber, L., Busch, H., & Lefstad, L. (2025). A Trojan horse for climate policy: Assessing carbon lock-ins through the Carbon Capture and Storage-Hydrogen-Nexus in Europe. *Energy Research & Social Science*, *120*, 103881. https://doi.org/10.1016/j.erss.2024.103881

Felt, U., Fouché, R., Miller, C. A., & Smith-Doerr, L. (2017). Introduction. In *The Handbook of Science and Technology Studies* (4th ed, pp. 1–26). MIT press.

Gillespie, A., & Townsend, A. (2020). *Scaling Up the CCS Market to Deliver Net-Zero Emissions* (p. 20). Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2020/04/Thought-Leadership-Scaling-up-the-CCS-Market-to-Deliver-Net-Zero-Emissions-Digital-1.pdf

Global CCS Institute. (2025). *Home*. Global CCS Institute. https://www.globalccsinstitute.com/

Gough, C., Garcia-Freites, S., Jones, C., Mander, S., Moore, B., Pereira, C., Röder, M., Vaughan, N., & Welfle, A. (2018). Challenges to the use of BECCS as a keystone technology in pursuit of 1.5^{0}C. *Global Sustainability*, *1*, e5. https://doi.org/10.1017/sus.2018.3

Green, J. F., Hale ,Thomas N., & and Arceo, A. (2025). The net zero wave: Identifying patterns in the uptake and robustness of national and corporate net zero targets 2015–2023. *Climate Policy*, *25*(4), 642–655. https://doi.org/10.1080/14693062.2024.2405221

Grunwald, A. (2018). Diverging pathways to overcoming the environmental crisis: A critique of eco-modernism from a technology assessment perspective. *Journal of Cleaner Production*, *197*, 1854–1862. https://doi.org/10.1016/j.jclepro.2016.07.212

Hale, T., Smith ,Stephen M., Black ,Richard, Cullen ,Kate, Fay ,Byron, Lang ,John, & and Mahmood, S. (2022). Assessing the rapidly-emerging landscape of net zero targets. *Climate Policy*, *22*(1), 18–29. https://doi.org/10.1080/14693062.2021.2013155

IEA. (2023, July 12). *Tracking Clean Energy Progress 2023 – Analysis*. IEA. https://www.iea.org/reports/tracking-clean-energy-progress-2023

IEA. (2024, April). *Carbon Capture Utilisation and Storage*. IEA. https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage

IPCC. (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (First, p. 184). Intergovernmental Panel on Climate Change (IPCC). https://doi.org/10.59327/IPCC/AR6-9789291691647

Jasanoff, S. (2015a). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S.-H. Kim & S. Jasanoff (Eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (pp. 1–31). University of Chicago Press. https://press.uchicago.edu/ucp/books/book/chicago/D/bo20836025.html

Jasanoff, S. (2015b). Science and technology studies. In K. Bäckstrand & E. Lövbrand (Eds.), *Research handbook on climate governance* (pp. 36–48). Edward Elgar Pub. Ltd. https://doi.org/10.4337/9781783470600

Jasanoff, S., & Kim, S.-H. (2009). Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva*, *47*(2), 119–146.

Javed, M. H., Ahmad, A., Nizami, A.-S., Gastaldi, M., & D'Adamo, I. (2025). Sustainable development at the crossroads: Navigating eco-humanism and eco-modernism. *Current Opinion in Green and Sustainable Chemistry*, *53*, 101018. https://doi.org/10.1016/j.cogsc.2025.101018

Joint Research Centre. (2024, February 4). *CO2 transport infrastructure: Key to achieving climate neutrality by 2050 - European Commission*. https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/co2-transport-infrastructure-key-achieving-climate-neutrality-2050-2024-02-06_en

Kleijne, K. de, Hanssen, S. V., Dinteren, L. van, Huijbregts, M. A. J., Zelm, R. van, & Coninck, H. de. (2022). Limits to Paris compatibility of CO2 capture and utilization. *One Earth*, *5*(2), 168–185. https://doi.org/10.1016/j.oneear.2022.01.006

Klima-, energi- og forsyningsministeriet. (2021, December 14). *Ny aftale skal sikre anlæg til CO_2-fangst og lagring i drift i 2025*. https://www.kefm.dk/aktuelt/nyheder/2021/dec/ny-aftale-skal-sikre-anlaeg-til-co2-fangst-og-lagring-i-drift-i-2025

Klima-, energi- og forsyningsministeriet. (2024, October 9). *Fra fangst til lagring: Nu er døren til nyt milliardudbud åbnet*. https://www.kefm.dk/aktuelt/nyheder/2024/okt/fra-fangst-til-lagring-nu-er-doeren-til-nyt-milliardudbud-aabnet

Klima-, energi- og forsyningsministeriet. (2025). *NEKST-implementeringsforum for CCS*. https://www.kefm.dk/klima/nekst-implementeringsforum-for-ccs

Lefstad, L., Allesson, J., Busch, H., & Carton, W. (2024). Burying problems? Imaginaries of carbon capture and storage in Scandinavia. *Energy Research & Social Science*, *113*, 103564. https://doi.org/10.1016/j.erss.2024.103564

Lehtveer, M., & Emanuelsson, A. (2021). BECCS and DACCS as Negative Emission Providers in an Intermittent Electricity System: Why Levelized Cost of Carbon May Be a Misleading Measure for Policy Decisions. *Frontiers in Climate*, *3*. https://doi.org/10.3389/fclim.2021.647276

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

Lund, J. F., Markusson, N., Carton, W., & Buck, H. J. (2023). Net zero and the unexplored politics of residual emissions. *Energy Research & Social Science*, *98*, 103035. https://doi.org/10.1016/j.erss.2023.103035

Markusson, N., Buck, H. J., Carton, W., Hougaard, I.-M., Dooley, K., & Lund, J. F. (2024). Carbon removal and the empirics of climate delay. *Environmental Science & Policy*, *161*, 103884. https://doi.org/10.1016/j.envsci.2024.103884

Martin-Roberts, E., Scott, V., Flude, S., Johnson, G., Haszeldine, R. S., & Gilfillan, S. (2021). Carbon capture and storage at the end of a lost decade. *One Earth*, *4*(11), 1569–1584. https://doi.org/10.1016/j.oneear.2021.10.002

Matos, S. V., Schleper, M. C., Hall, J. K., Baum, C. M., Low, S., & Sovacool, B. K. (2024). Beyond the new normal for sustainability: Transformative operations and supply chain management for negative emissions. *International Journal of Operations & Production Management*, *44*(13), 263–295. https://doi.org/10.1108/IJOPM-06-2024-0487

McLaren, D., & Markusson, N. (2020). The co-evolution of technological promises, modelling, policies and climate change targets. *Nature Climate Change*, *10*(5), 392–397. https://doi.org/10.1038/s41558-020-0740-1

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 Climate*, *1*. https://doi.org/10.3389/fclim.2019.00004

McLaughlin, H., Littlefield, A. A., Menefee, M., Kinzer, A., Hull, T., Sovacool, B. K., Bazilian, M. D., Kim, J., & Griffiths, S. (2023). Carbon capture utilization and storage in review: Sociotechnical implications for a carbon reliant world. *Renewable and Sustainable Energy Reviews*, *177*, 113215. https://doi.org/10.1016/j.rser.2023.113215

McNeill, M., Arribas-Ayllon, M., Haran, J., Mackenzie, A., & Tutton, R. (2017). Conceptualizing Imaginaries of Science, Technology, and Society. In U. Felt, R. Fouché, C. A. Miller, & L. Smith-Doerr (Eds.), *The Handbook of Science and Technology Studies* (4th ed, pp. 435–463). MIT press.

Mertens, J., Belmans, R., & Webber, M. (2020). Why the Carbon-Neutral Energy Transition Will Imply the Use of Lots of Carbon. *C*, *6*(2), Article 2. https://doi.org/10.3390/c6020039

Mertens, J., Breyer, C., Arning, K., Bardow, A., Belmans, R., Dibenedetto, A., Erkman, S., Gripekoven, J., Léonard, G., Nizou, S., Pant, D., Reis-Machado, A. S., Styring, P., Vente, J., Webber, M., & Sapart, C. J. (2023). Carbon capture and utilization: More than hiding CO2 for some time. *Joule*, *7*(3), 442–449. https://doi.org/10.1016/j.joule.2023.01.005

Minter, M., Jensen, C. L., & Chrintz, T. (2023). *Danmarks globale forbrugsudledninger* (p. 44). https://concito.dk/en/udgivelser/danmarks-globale-forbrugsudledninger

Morgan, H. (2022). Conducting a Qualitative Document Analysis. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2022.5044

Ørsted. (2025). *Carbon capture and storage*. https://orsted.com/en/what-we-do/renewable-energy-solutions/bioenergy/carbon-capture-and-storage

Paltsev, S., Morris, J., Kheshgi, H., & Herzog, H. (2021). Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation. *Applied Energy*, *300*, 117322. https://doi.org/10.1016/j.apenergy.2021.117322

Peplow, M. (2022). The race to upcycle CO2 into fuels, concrete and more. *Nature*, *603*(7903), 780–783. https://doi.org/10.1038/d41586-022-00807-y

Rogelj, J., Geden, O., Cowie, A., & Reisinger, A. (2021). Net-zero emissions targets are vague: Three ways to fix. *Nature*, *591*(7850), 365–368. https://doi.org/10.1038/d41586-021-00662-3

Rule, P. (2024). Introduction: Case study research in the social sciences. In P. Rule & V. M. John (Eds.), *Handbook of Case Study Research in the Social Sciences* (pp. 1–14). Edward Elgar Publishing. https://doi.org/10.4337/9781803920320.00009

Sie, A. (2024). Climate Engineering: Worth the Risks? In *Routledge Handbook of Climate Change and Society* (2nd ed., p. 21). Routledge.

Singh, H., Li, C., Cheng, P., Wang, X., & Liu, Q. (2022). A critical review of technologies, costs, and projects for production of carbon-neutral liquid e-fuels from hydrogen and captured CO_2. *Energy Advances*, *1*(9), 580–605. https://doi.org/10.1039/D2YA00173J

Spaargaren, G., & and Mol, A. P. J. (1992). Sociology, environment, and modernity: Ecological modernization as a theory of social change. *Society & Natural Resources*, *5*(4), 323–344. https://doi.org/10.1080/08941929209380797

Talus, K., & Maddahi, R. (2024). Carbon capture and utilization under EU law: Impermanent storage of CO2 in products and pre-combustion carbon capture. *The Journal of World Energy Law & Business*, *17*(5), 295–308. https://doi.org/10.1093/jwelb/jwae009

Tanggaard, L., & Brinkmann, S. (2020). Kapitel 1: Interviewet. Samtalen som forskningsmetode. In L. Tanggaard & S. Brinkmann, *Kvalitative metoder: En grundbog* (3rd edition, pp. 33–63). Hans Reitzels forlag.

Ueckerdt, F., Bauer, C., Dirnaichner, A., Everall, J., Sacchi, R., & Luderer, G. (2021). Potential and risks of hydrogen-based e-fuels in climate change mitigation. *Nature Climate Change*, *11*(5), 384–393. https://doi.org/10.1038/s41558-021-01032-7

van Beek, L., Hajer, M., Pelzer, P., van Vuuren, D., & Cassen, C. (2020). Anticipating futures through models: The rise of Integrated Assessment Modelling in the climate science-policy interface since 1970. *Global Environmental Change*, *65*, 102191. https://doi.org/10.1016/j.gloenvcha.2020.102191

Van Beek, L., Oomen, J., Hajer, M., Pelzer, P., & Van Vuuren, D. (2022). Navigating the political: An analysis of political calibration of integrated assessment modelling in light of the 1.5 °C goal. *Environmental Science & Policy*, *133*, 193–202. https://doi.org/10.1016/j.envsci.2022.03.024

Vergragt, P. J., Markusson, N., & Karlsson, H. (2011). Carbon capture and storage, bio-energy with carbon capture and storage, and the escape from the fossil-fuel lock-in. *Global Environmental Change*, *21*(2), 282–292. https://doi.org/10.1016/j.gloenvcha.2011.01.020

Wang, N., Akimoto, K., & Nemet, G. F. (2021). What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects. *Energy Policy*, *158*, 112546. https://doi.org/10.1016/j.enpol.2021.112546

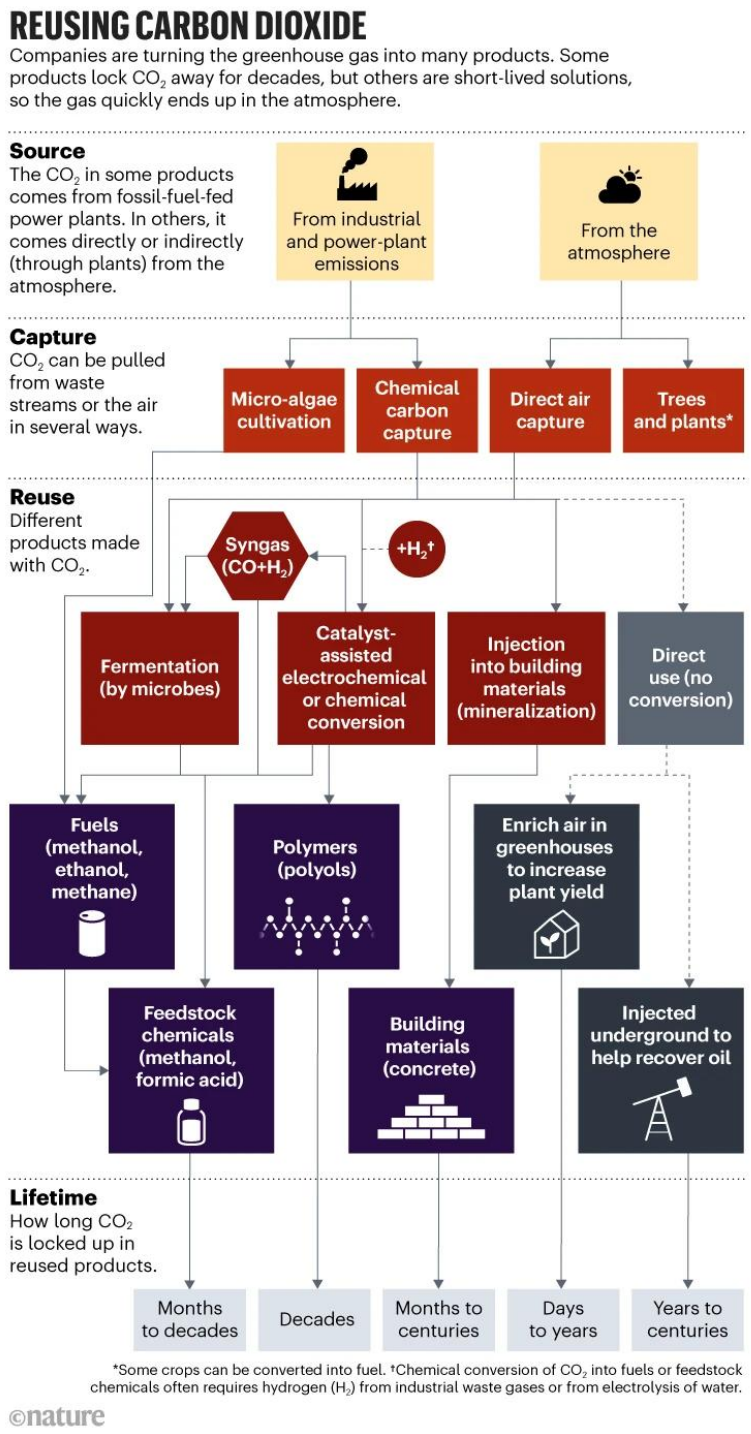
York, R., & and McGee, J. A. (2016). Understanding the Jevons paradox. *Environmental Sociology*, *2*(1), 77–87. https://doi.org/10.1080/23251042.2015.1106060

Zhao, Y. (2025). CCUS: A Panacea or a Placebo in the fight against climate change? *Green Energy & Environment*, *10*(2), 239–243. https://doi.org/10.1016/j.gee.2024.10.001

Appendices

Appendix A

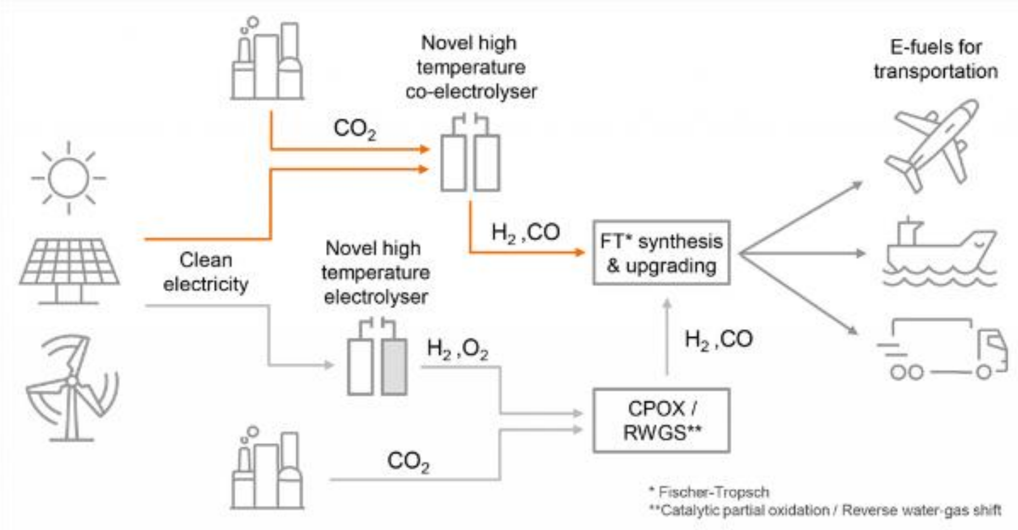
Illustration of ways to reuse carbon dioxide



(Peplow, 2022)

Appendix B

Illustration of possible E-fuel production process



(E-fuel, 2025)

Appendix C

Interview guides for all the interviews. As described in the methodology section, the interview guides were altered slightly from interview to interview to adjust to the position and job of each interviewee. They are all found under here in chronological order, so Interview 1 is the first interview conducted, Interview 2 the next and so forth. The number given the interviews correspond with the ones in the data table in appendix F.

Interview 1

- Setup and introduction (5min)
    - Consent form, information, etc.
    - Possibly a short introduction (position and daily work tasks)
- The Danish Energy Agency and CCS in Denmark (10min)
    - General status of the Danish CCS landscape?
    - How do you understand the different technologies (capture, utilisation, storage)? How is the work with them structured?
    - The general role of the Danish Energy Agency in the various related technologies (-CCS, CCUS, BECCS, DACCS) - right now? in the longer term for larger roll-outs?
- CCS pool and the tender round (15min)
    - *Following on from the different technologies etc...* Can you quickly explain the three pools (CCUS, NECCS, CCS) and their purpose in relation to each other?
    - *The CCS pool is ongoing with different deadlines throughout 2025 (Jan 2025, indicative offers in May 2025, best and available offer Nov 2025)*: How is the work with the application round structured - status right now?
    - Can you tell us about the applications you've received? (How many, what kind of projects, etc.)
        - If not: Can you provide a more general characterisation of the application material?
    - Can you say anything about the evaluation criteria for processing the applications?
    - *The funds are planned to be distributed over a long period of time and funded projects are planned to deliver full-scale capture and storage by 2030*: How is the work to ensure/control the delivery of that?
- CCS and the future (5min)
    - What do you imagine the future of CCS/CCUS in Denmark looks like?
    - i 2030? i 2050?
- Wrap-up (5-10min)

- Is there anything you would like to see added to any of the questions?
- Is there anything you think I should have asked that I didn't?
- Is there anyone else you can think of that I should also try talking to?
- Reminder about the consent form + possibility for follow-up if needed

Interview 2

Introduction (5min)

- Follow-up on consent form
- Background, education, previous work experience?
- A typical working day/week?

Greenhub Denmark (10min)

- Briefly tell me about Greenhub Denmark
- When, on what initiative, how is it organised, tasks
- Can you elaborate on what is meant by North Jutland being "Denmark's green Silicon Valley"?

Co2Vision (the foundation) (10min)

- Switch to talking about Co2Vision
- What is it, when did it start, on what initiative, how is it organised
- How is it positioned in relation to Greenhub Denmark (partnerships within a partnership? project within a project?)

The work of Co2Vision (15min)

- What does the practical work with Co2Vision consist of: typical tasks
- What is Co2Vision's role in relation to various other actors in the field: companies, stakeholder organisations, municipal actors, institutions
- What is the vision for the work - short term, long term?

Co2Vision and technologies (15min)

According to the website, Co2Vision works to "expand the overall value chain of CO2 capture, transport, utilisation and storage"...

- Can you briefly explain what CCUS is?
    - Is it different from CCS, BECCS, DACCS and similar technologies?
- Which technologies are part of the work of Co2Vision members?
    - Prioritising something? De-prioritising something else?
- What does the value chain cover?

Co2Vision and other stakeholders (15min)

As you probably know, there are many actors and processes etc. regarding the implementation of CCS, CCUS, BECCS and similar technologies in Denmark and internationally...

- How does Co2Vision relate to national initiatives and plans?
    - INNO-CCUS? Danish Energy Agency grant programmes? Energy Cluster Denmark? Other networks and collaborations?
- How do you see the area for CCS and CCUS in Denmark?

CCUS, green technology and transition

- How do you see CCUS in relation to the broader work with the green transition & the Danish climate goals (70% reduction 2030, 100% 2045/110% reduction 2050)?
- Are you familiar with various criticisms of CCUS such as "greenwashing", the postponement of emission reductions and similar
    - If so, what are your thoughts on this?
- How did CCUS become part of an overall regional business development strategy?

(Future (if time permits)

- Finally, very broadly: How do you envision the future (with CCS/CCUS**)**?

Wrap-up

- Consent form reminder
- Is there anything you would like to add to any of the questions?
- Is there anything you feel I should have asked that I didn't?
- Is there anyone else you can think of that I should talk to as well?
- Possibilities for email follow-ups, etc.

Interview 3

Introduction (5min)

- Follow-up on consent form
- Background - previous work experience?
- Typical working day/week?

CCS / CCUS in general

- What do you understand by CCS and CCUS?
- What does it cover? (collection technologies, storage technologies, utilisation technologies)

Working with CCUS / Ramboll

- How Ramboll works with CCS/CCUS
    - How much time?
    - Which projects
- Has it evolved/changed?
- Opportunities and challenges with it?

- How would you describe the current CCS/CCUS "landscape" from your perspective?

CCUS, green technology and transition

- How do you see CCUS in relation to transition & the Danish climate targets (70% reduction 2030, 100% 2045/110% reduction 2050) / international climate targets?
- Are you familiar with various criticisms of CCUS such as "greenwashing", delaying emission reductions or similar
    - If so, what are your thoughts on this?

The future (if time permits)

- Finally, very broadly: How do you envision the future (with CCS/CCUS**)**?
- In 10 years, 30 years, 50 years - - - - -

Wrap-up

- Is there anything you would like to add to any of the questions?
- Is there anything you feel I should have asked that I didn't?
- (Is there anyone else you can think of that I should talk to as well?)
- Consent form reminder + options for email follow-ups, etc.

Interview 4

Introduction

- Follow-up on consent form
- Background - work experience + daily tasks?

Working with CCS / CCUS

- How NIRAS works with CCS/CCUS
    - o How much time?
    - o Has it evolved/changed?

CCS / CCUS

- What do you understand by CCS and CCUS?
- How do the two relate to each other?

CCS/ CCUS in Denmark

- How would you describe the current CCS/CCUS "landscape" from your perspective?
    - o Orientation to other players? Industry, consultancies, innovation partnerships / missions, knowledge institutions
- Opportunities in the rollout?
- Challenges in the rollout?

CCS, CCUS - green technology - transition

- What is the role of CCS and CCUS in the transition & the Danish climate targets (70% reduction 2030, 100% 2045/110% reduction 2050)?
- Are you familiar with various criticisms of CCS and especially CCUS ("greenwashing", danger that it is a postponement of real emission reductions or similar)
    - o What are your thoughts on this?

The future

- Finally, very broadly: How do you envision the future (with CCS/CCUS**)**?
- In 10 years, 30 years, 50 years - - - - -

Wrap-up

- Is there anything you would like to add to any of the questions?
- Is there anything you feel I should have asked that I didn't?
- (Is there anyone else you can think of that I should talk to as well?)
- Consent form reminder + options for email follow-ups, etc.

Interview 5

Introduction

- Consent form
- Short introduction

Definition of CCS - CCUS

- How do you understand CCS and CCUS?

The work of INNO-CCUS

- Introduction to INNO-CCUS
- What does the work consist of?
- Deploying CCUS solutions: small and medium players vs large players
    - Considerations for finding the right solutions for different locations?

CCS / CCUS in DK

- The possibilities with CCUS in DK
- Challenges with CCUS in DK
- DK compared to international
    - (I saw in the roadmap, there was a lower TRL for liquid solvent capture technologies compared to global CCS institutes - how do you generally see Denmark in relation to the international landscape for CCS/CCUS - Nordic, EU, global - -

The role of transition and climate goals

- How do you see the role of CCS and CCUS in the green transition and climate goals?
- Short term? Long term?

Future scenarios (10 years, 30 years, 50 years?)

- How do you imagine the future in terms of CCS, CCUS, transition - 2035, 2055, 2075...)

Rounding off

- Anything you want to add to the questions?
- Something I should have asked?
- Consent form reminder

Interview 6

Introduction

- Consent form
- Short introduction

CCS - CCUS

- How do you understand CCS and CCUS? Carbon management technologies? Working definitions?
- How have you worked with it?
    - CARMA-green fuels cross mission carbon management
    - INNO-CCUS infrastructure
    - Large scale integration of carbon capture
- What is the "mood" around it? In academia? In industry?

CCS / CCUS in DK

- Biggest opportunities and challenges related to ongoing implementation of carbon management technologies in Denmark?
- How do you envision scaling up? (- the right technology solutions at the right scale?)
- DK vs international - what is DK's role/position?

The role of transition and climate goals

- How do you see the role of CCS and CCUS in the green transition and climate goals?
- How do you respond to the criticism of different CCS/CCUS technologies? (postponement of real emission reductions etc)

Future scenarios (10 years, 30 years, 50 years?)

- How do you imagine the future in terms of CCS, CCUS, transition - 2035, 2055, 2075...)

Rounding off

- Anything you want to add to the questions?
- Something I should have asked?
- Consent form reminder

Appendix D

Codebooks for the coding process of the qualitative material. First the codebook for the document analysis. Afterwards the codebook for the interviews.

Codebook for the document analysis

The categories from this codebook were subsequently used as a starting point for the coding / categorisation of the interview material

Name	Description
CCS - CCU Definition	Definitions of CCS or CCU (or CCUS), for example "CCS means xyz"
CCS ift CCU	Considerations for balancing CCS vs CCU in connection with deployment
EU	Covers plans and considerations related to CCUS deployment that relate to the relationship between Denmark and the EU / internationally
Expected emission reduction (in numbers)	Expected emission reduction in numbers that can be achieved from CCS and/or CCU
Green transition strategy	Descriptions of political ambitions and strategy for climate and green transition (related to CCUS)
Potential CCUS	Covers potentials seen in connection with scaling up CCUS (based in Denmark) - can be political, business and/or climate related. Made one for CCS and one for CCU and one overall to capture any differentiations between CCS and CCU. Everything coded to "potentials CCU" and "potentials CCS" is also coded in "Potentials CCUS"
Objectives CCUS rollout	Covers specific objectives related to the rollout of CCUS, for example "by 2030 we will have xyz"
CCS potentials	Covers potentials seen in connection with scaling up CCS (based on Denmark) - can be political, commercial and/or climate-related

Name	Description
CCU potentials	Covers potentials seen in connection with scaling up CCU (based on Denmark) - can be political, business and/or climate-related
Ref to external agencies	To capture when external agencies are referenced as guarantors of the necessity of CCUS
Challenges CCUS	Description of challenges in the rollout of CCUS, e.g. finances. Created one code for CCS and one for CCU to capture any differentiation. Overall CCUS code used to capture both CCU and CCS together.
Challenges CCS	Description of challenges related to CCS deployment, e.g. finances
Challenges CCU	Description of challenges in rolling out CCU, e.g. finances
Deployment CCUS Process	Descriptions of plans for how CCUS will be rolled out in Denmark. For example, mention of grant pools, setting up committees, commissioning reports or similar. Also covers various instruments to promote CCUS deployment in the long term, e.g. quotas and taxes. Also covers specific concerns that are expressed (e.g. ensuring that costs for CCS installations at waste facilities do not end up with heat and waste consumers). Covers the entire CCUS value chain.

Codebook for interviews

Codes from document analysis + some pre-made categories based on initial impressions from transcription of interviews + some codes added through the process of coding

Name	Description
Actors	To capture specific work to work together and connect actors around CCUS
CCS ift CCU	Considerations around CCS vs. CCU trade-offs (in the context of deployment). Also subcodes to capture considerations for different specific CCUS technologies, e.g. BECCS or DAC
BECCS	Covers the naming of BECCS
CCS - CCU - CCUS - Definition	Definitions of CCS or CCU (or CCUS), for example "CCS means xyz"
DAC	Covers the naming of the DAC
Pt-X	Everything about Pt-X
CCUS 'historical'	previous or other initiatives on CCUS - highlighted in relation to the "current" Danish political initiative
CO2 Export - Import	Consider the possibilities of exporting / importing CO2
EU + international	Covers plans and considerations related to CCUS deployment that relate to the relationship between Denmark and the EU / internationally
Expected emission reduction (in numbers)	Expected emission reduction in numbers that can be achieved from CCS and/or CCU
Green transition strategy	Descriptions of political ambitions and strategy for climate and green transition (related to CCUS and beyond)

Name	Description
Nation state - 'Leader in sustainable technologies'	Covers when people explicitly articulate nation-state interests, gains or potentials in relation to CCUS. E.g. Denmark as a leader in sustainable technologies and solutions
New industry - Immature industry	Covers articulations of CCUS as a new industry and/or an immature industry (to capture two sides of the same coin)
Personalised outlook on climate + transition	When interviewees talk about their personal views on the climate crisis and going green
Potential CCUS	Covers potentials seen in connection with scaling up CCUS (based in Denmark) - can be political, business and/or climate related. Made one for CCS and one for CCU and one overall to capture any differentiations between CCS and CCU. Everything coded to "potentials CCU" and "potentials CCS" is also coded in "Potentials CCUS"
CCUS in relation to climate	Direct mentions of the relationship between CCUS and climate transition
Objectives CCUS rollout	Covers specific objectives related to the rollout of CCUS, for example "by 2030 we will have xyz"
CCS potentials	Covers potentials seen in connection with scaling up CCS (based on Denmark) - can be political, commercial and/or climate-related
CCU potentials	Covers potentials seen in connection with scaling up CCU (based on Denmark) - can be political, business and/or climate-related
Ref to external agencies	To capture when external agencies are referenced - e.g. as guarantors of the necessity of CCUS, especially IPCC and/or IEA

Name	Description
Scale + local solutions	Considerations for scaling and customising CCUS solutions for different contexts
Time + Visions for the future	Imagining the future of CCUS (can be CCS, CCU and/or Pt-X related)
Challenges CCUS	Description of challenges in rolling out CCUS, e.g. finances. Created one code for CCS and one for CCU to capture any differentiation. Overall CCUS code used to capture both CCU and CCS together.
Challenges CCS	Description of challenges related to CCS deployment, e.g. finances
Challenges CCU	Description of challenges in rolling out CCU, e.g. finances
Deployment CCUS Process	Descriptions of plans for how CCUS will be rolled out in Denmark. For example, mention of grant pools, setting up committees, commissioning reports or similar. Also covers various instruments to promote CCUS deployment in the long term, e.g. quotas and taxes. Also covers specific concerns that are expressed (e.g. ensuring that costs for CCS installations at waste facilities do not end up with heat and waste consumers). Covers the entire CCUS value chain.
Administration according to CCUS	Covers practical or administrative elements related to CCUS - e.g. description of the Danish Energy Agency's responsibilities related to CCS
Working with CCUS	Descriptions of people's work involving CCUS (to gain insight into how CCUS impacts people's working lives)
CCUS + Business promotion	

Name	Description
The grant pools The Danish Energy Agency	

Appendix E

List of documents comprised for the document analysis

Name	Reference Name	Source
(1) Klimaaftale for energi og industri mv. jun2020	Doc1	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(2) En køreaftale for lagring af CO2 jun2021 (første del af en samlet CCS-strategi)	Doc2	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(3) En køreplan for fangst transport og lagring af CO2 dec2021 (anden del af en samlet CCS-strategi)	Doc3	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(4) Aftale om rammevilkår for CO2-lagring juni2022 (opfølgning på danmarks CCS-strategi)	Doc4	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(5) Aftale om styrkede rammevilkår for CCS i Danmark af 20. september 2023	Doc5	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(6) Aftale om langsigtede rammevilkår for CO2-fangst i forsyningssektoren feb2024	Doc6	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(7) 2021.website.KEFM.Ny	Doc7	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring

aftale skal sikre anlæg til CO_2-fangst og lagring i drift i 2025		
(8) 2024.website.KEFM.Fra fangst til lagring_ Nu er døren til nyt milliardudbud åbnet	Doc8	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(9) Faktaark_Den samlede strategiske indsats for udbredelse af fangst og lagring af CO_2_V02 2022	Doc9	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(10) Faktaark_Tilskudspuljer til fangst og lagring af CO_2_V02 2022	Doc10	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(11) KLIMALOVEN 2021	Doc11	https://www.retsinformation.dk/eli/lta/2021/2580
(12) Aalborg declaration nov2023	Doc12	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(13) Bilateral aftale om transport af CO2 DK-NL oct2023	Doc13	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(14) Bilateral aftale om transport af CO2 DK-BE dec2023	Doc14	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(15) Bilateral aftale om transport af CO2 DK-FR mar2024	Doc15	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring

(16) Bilateral aftale om transport af CO2 DK-NO apr2024	Doc16	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(17) Bilateral aftale om transport af CO2 DK-SE apr2024	Doc17	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(18) Samarbejdsaftale-MoU mellem DK og Østrig juli2024	Doc18	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(19) Joint statement DK_PAU_signed oct2024	Doc19	https://www.kefm.dk/klima/ccs-co2-fangst-og-lagring
(20) Udvikling af brint og grønne brændstoffer marts 2022	Doc20	https://www.kefm.dk/energi/power-to-x-og-groen-brint
(21) Aftaletekst - mulighed for etablering af brintinfrastruktur 1. delaftale 2023	Doc21	https://www.kefm.dk/energi/power-to-x-og-groen-brint
(22) Økonomiske rammevilkår for brintinfrastruktur -2. delaftale om rørbunden brintinfrastruktur_april 2024	Doc22	https://www.kefm.dk/energi/power-to-x-og-groen-brint

Appendix F

List of Interviews

Name	Reference Name	Position	Date of Interview	Length
Interview 1	Int1	State agency	25.03.2025	00.53.03
Interview 2	Int2	Intermediary	26.03.2025	01.11.42
Interview 3	Int3	Engineering consultant/project manager	31.03.2025	00.55.29
Interview 4	Int4	Engineering consultant/project manager	09.04.2025	00.58.40
Interview 5	Int5	Intermediary	10.04.2025	00.48.57
Interview 6	Int6	Researcher	11.04.2025	01.01.12

Appendix G

Timeline and mapping of CCUS in Denmark

The timeline showcases some of the key events and developments taken place since CCUS became an explicit part of Denmark's climate policies and planning. It covers political agreements, steps in the main public funding scheme administrated by the Danish Energy Agency, as well as events and developments related to the industry of CCUS, e.g. establishment of networks or highly publicised projects. The figure was constructed based on information gathered throughout working on the thesis through interviews, attendance at public events and general desktop research.